(2)

TECHNICAL REPORT CR-RD-AS-90-3

EXTENSION AND UPDATING OF THE COMPUTER SIMULATION OF RANGE RELATIVE DOPPLER PROCESSING AND INVARIANT MAPPING FOR MM WAVE SEEKERS

VOLUME II

USER MANUAL OF THE RANGE RELATIVE DOPPLER PROCESSING SIMULATION FOR MM WAVE SEEKERS

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A computer simulation of Range Relative Doppler Processing (RRDP) and Invariant Mapping for MM Wave Seekers was developed in Volume I entitled "Extension and Upgrading of the Computer Simulation of Range Relative Doppler Processing and Invariant Mapping for MM Wave Seekers" [3]. Two programs were developed FRRDP and CRRDP. These programs use the same input files: CRRDPI.INP (system parameters) and CLUTINFI.INP (clutter map). Execution of FRRDP generates a file FRRDPG.GRD which stores the footprint reflectivity versus azimuth and range. Execution of CRRDP generates a file CRRDPG.GRD which stores the footprint reflectivity versus absolute x-y coordinates. Volume I contains all the theory, formulas, and listings.

This report, which is denoted as Volume II, is a user manual for the computer simulation documented in Volume I. With this manual MICOM personnel should be able to: (1) install the Fortran software on an IBM PC/compatible, (2) duplicate the results presented in this report, and (3) run the simulation for different clutter maps and targets. This report

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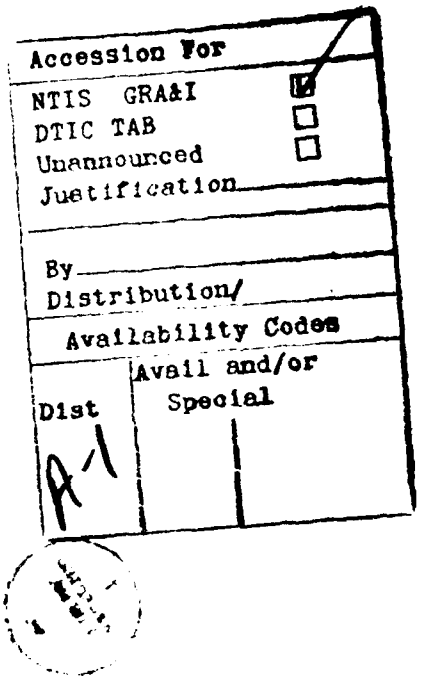
BLOCK 19 (Cont'd): contains: (1) hardware and software requirements, (2) user overview of the simulation, (3) demonstration diskettes, (4) installation procedure, (5) definition of inputs, (6) display information for FRRDP output, and (7) display information for CRRDP output.



PREFACE

The report for the work performed under Contract No. D.O. 0064, DAAH01–87–D–0021 consists of three volumes: (1) "Extension and Updating of the Computer Simulation of Range Relative Doppler Processing and Invariant Mapping for MM Wave Seekers", (2) "User Manual of the Range Relative Doppler Processing Simulation for MM Wave Seekers", and (3) "Computer Simulation of a Doppler Beam Sharpening Radar for MM Wave Seekers". The period of performance is April 12 to December 31, 1988.

The main objective of Volume I is to extend and update the MM wave computer simulation developed for Contract No. DAAH01–87–D–0021, D.O. 18, and documented in the final report dated February 1988 and entitled "Increasing Azimuth and Elevation Resolution of MM Wave Seeker Systems Using Coherent or Noncoherent Range Relative Doppler Processing (RRDP) with Constant or Linear Frequency Modulation and Invariant Mapping".

Volume II is a User Manual for the computer simulation documented in Volume I. With this manual, MICOM personnel should be able to: (1) install the Fortran software on an IBM PC/compatible, (2) duplicate the results presented in this report, and (3) run the simulation for different clutter maps and targets.

The main objective of Volume III is to develop Doppler Beam Sharpening for MM wave seekers. In this application the geometry is significantly different. That is, the seeker follows a straight horizontal trajectory while the antenna performs a forward near circular scan perpendicular to the trajectory.

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January 1989

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1. Introduction and Background

In previous reports [1,2,3] two new digital processing techniques were developed to extend the applications of SAR processing to nonlinear trajectories. They are called "Range Relative Doppler Processing" (RRDP), and "Invariant Mapping". In our application we increase the azimuth resolution of MM wave seeker systems by partitioning the range cells in up to 64 cells, on the basis of doppler. As explained in the preface the work covering the period from April 12 to December 31, 1988, is documented in three volumes. Volume I [3] extends and updates the RRDP computer simulation of [2]. Two main programs are developed: FRRDP and CRRDP. The first program generates the file FRRDPG.GRD which contains the footprint reflectivity versus azimuth and range. The second program applies the new invariant mapping technique to generate the file CRRDPG.GRD which contains the footprint reflectivity versus absolute x–y coordinates.

While Volume I contains all the necessary theory, formulas, and listings for the simulation, Volume II is a User Manual. With this manual MICOM personnel should be able to: (1) install the Fortran software on an IBM PC/compatible, (2) duplicate the results presented in this report, and (3) run the simulation for different clutter maps and targets. This report is delivered with three 5.25" DS/HD diskettes. The first two diskettes, entitled "DEMO DISKETTE #1" and "DEMO DISKETTE #2", contain demonstration programs on a directory "DEMOMMW". The third diskette, entitled "MM Wave Simulation", has the two main programs with the associated subprograms and input files on directory "MMWSIM".

The organization is as follows: (1) the hardware and software requirements are specified, (2) the user overviews of the FRRDP and CRRDP simulations are presented, (3) the software installation is discussed, (4) the operation of the DEMO diskettes is explained, (5) the input files for FRRDP and CRRDP are documented, (6) the operation of SURFER [4] on FRRDPG.GRD to produce 3–D and contour displays of reflectivity versus azimuth and range is addressed, (7) the operation of SURFER on CRRDPG.GRD for displays of reflectivity versus absolute x–y coordinates is also addressed, and (8) the report ends with conclusions.

2. Hardware and Software Requirements

The main programs FRRDP and CRRDP and the associated subroutines were developed on a Compaq Deskpro 386 equipped as follows: (1) a math co–processor Intel 80387, (2) two 40 MB hard disk drives, (3) a 10 MB core memory, (4) two high density floppy disk drives (5.25" and 3.5"), (5) a Compaq high resolution monitor with enhanced color graphics (EGA), (6) an IBM graphic proprinter XL–24, (7) an HP Laserjet Series II, and (8) an HP Paintjet printer. We have also access to an HP 7475A pen plotter but it was not utilized in this report.

The minimum recommended hardware is: (1) an IBM PC/compatible with a 386 CPU, (2) a 387 math coprocessor, (3) 2 MB of RAM, (4) a 20 MB hard disk drive, (5) a high resolution color graphics monitor,and (6) a laser printer or a pen plotter.

The simulations were developed using the following software: (1) Compaq DOS V3.31, (2) Microsoft Fortran V4.01, (3) graphics software SURFER from Golden Software, Inc. [4], and (4) Wordstar Professional release 4 as an ASCII editor.

The minimum software requirements are: (1) DOS V3.21 or above, (2) a Fortran–77 compiler, and (3) SURFER from Golden Software, Inc.

3. User Overview of FRRDP and CRRDP Simulations

Functional block diagrams for the FRRDP and CRRDP simulations can be found in Volume I, [3]. This section presents an overview of the two simulations from an user point of view, with emphasis on inputs and outputs.

An user overview of the FRRDP simulation is in Fig. 3.1. There are two input data files: (1) CRRDPI.INP which specifies all the system parameters, and (2) CLUTINFI.INP which defines the clutter map. Section 6 of this manual gives more details on the input files. The block diagram shows also two output files: (1) FRRDPG.GRD which stores the footprint reflectivity versus azimuth and range in the format specified by SURFER [4], and (2) FRRDPP.PRT which can store printouts at different places in the program, and which is only

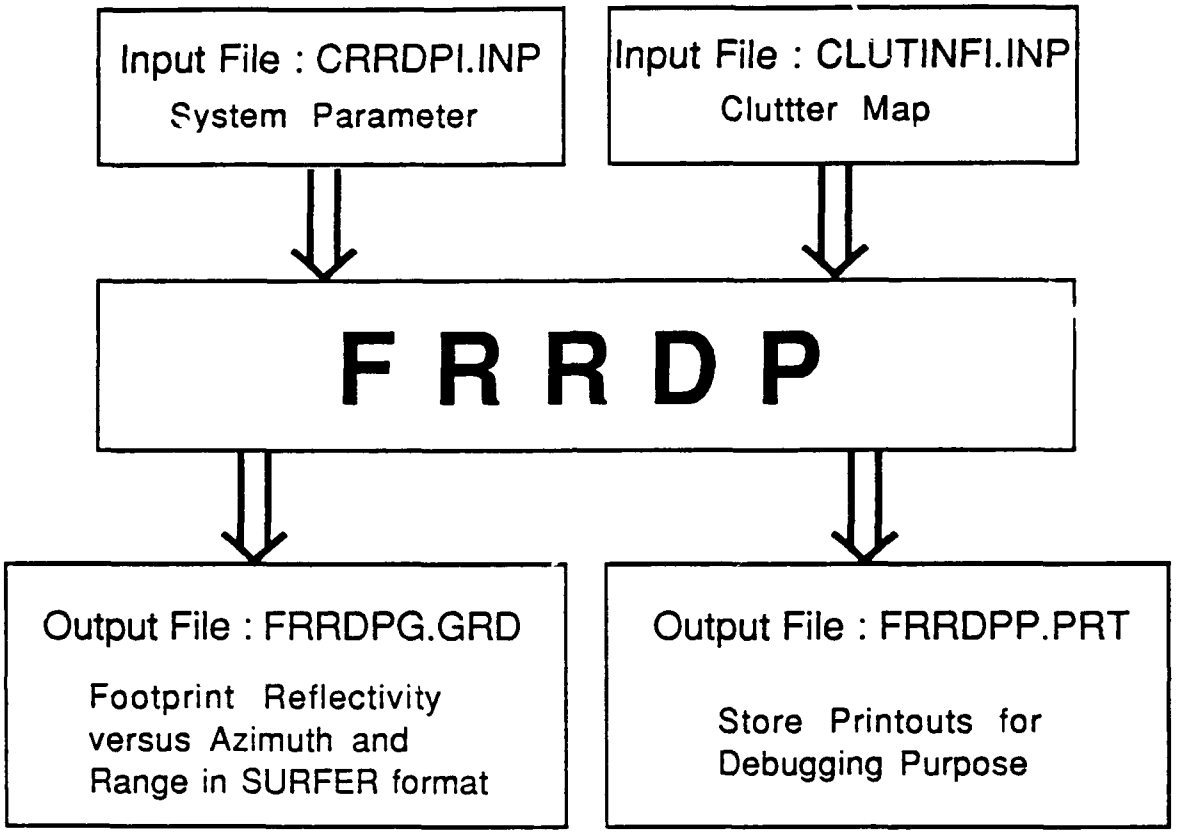

Figure 3.1 User overview of the FRRDP simulation.

needed for debugging purposes. Details on the format of FRRDPG.GRD and CRRPDG GRD are in Volume I, section 8.

An user overview of the CRRDP simulation is in Fig. 3.2. The program has the same two input data files as FRRDP: CRRDPI.INP and CLUTIFI.INP. There are two output files: (1) CRRDPG.GRD which contains the footprint reflectivity versus absolute x–y coordinates, and (2) CRRDPP.PRT which can store printouts for debugging purposes.

4. Demonstration Diskettes

Attached are two demonstration diskettes in a directory "DEMOMMW". Those diskettes contain two types of files: (1) files starting with (TAB) are ASCII files which can be displayed either using the DOS command "TYPE", or with any ASCII editor, and (2) files with name starting with (FIG) and ending with (.PLT) are graphic files which are displayed using the SURFER program "VIEW". A copy of "VIEW" is included in each diskette.

The demonstration diskettes contains all the graphic displays and the associated input data sets which are used for the examples in Volume I. The names are very similar to those in Volume I. Table 4.1 shows the correspondence between the figures and tables in the DEMO diskettes and the figures and tables of the examples in Volume I [3]. From there on, the references in Volume II are only for figures and tables in Volume II (displays or text). The displays show 3–D or contour plots of reflectivity versus azimuth and range. DEMO DISKETTE #2 contains the plot files and the input data files of CRRDP for all the examples in section 13 of Volume I. The displays show 3–D or contour plots of reflectivity versus absolute x–y coordinates. Table 4.2a lists the plot files contained in DEMO DISKETTE #1 and the corresponding input files. Table 4.2b does the same for DEMO DISKETTE #2.

The demonstration diskettes can be used on any IBM PC/Compatible equipped with a high density floppy disk drive. A hard disk drive is not required. As an illustration, Table 4.3 explains how the user will display FIG121 (3–D reflectivity for 11 scatterers versus azimuth and range) and the corresponding input data sets (TABLE12.1 and TABLE12.2). It is assumed

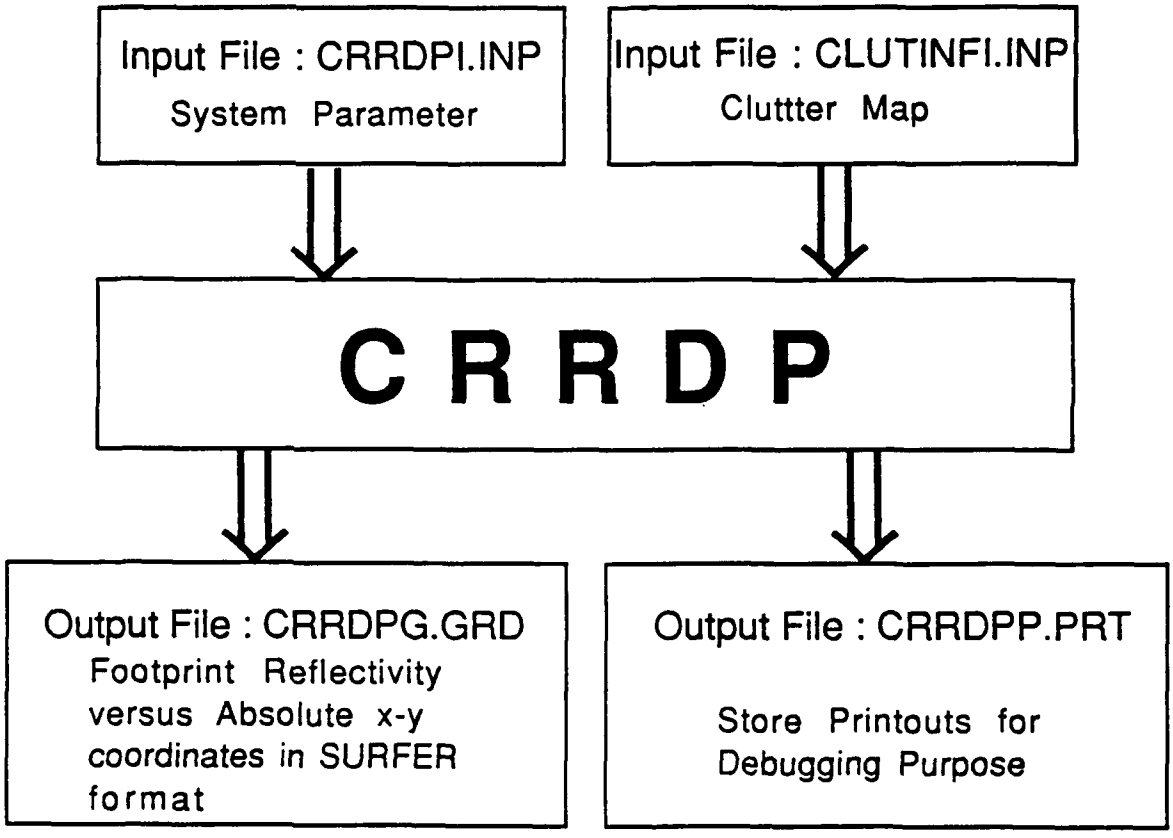

Figure 3.2 User overview of the CRRDP simulation.

Table 4.1. Correspondence between DEMO diskettes and examples of Volume I

FIG121.PLT	Fig. 12.1
FIG122.PLT	Fig. 12.2
FIG123.PLT	Fig. 12.3
FIG124.PLT	Fig. 12.4
FIG125A.PLT	Fig. 12.5A
FIG125B.PLT	Fig. 12.5B
FIG131A.PLT	Fig. 13.1A
FIG131B.PLT	Fig. 13.1B
FIG132.PLT	Fig. 13.2
FIG133.PLT	Fig. 13.3
FIG134.PLT	Fig. 13.4
TABLE12.1	Table 12.1
TABLE12.2A	Table 12.2A
TABLE12.2B	Table 12.2B
TABLE12.3	Table 12.3
TABLE12.4	Table 12.4
TABLE13.1	Table 13.1

Table 4.2a. Display files in DEMO DISKETTE #1 and corresponding input files

FIG121	PLT	(input files: TABLE12.1 and TABLE12.2A)
FIG122	PLT	(input files: TABLE12.1 and TABLE12.2A)
FIG123	PLT	(input files: TABLE12.1 and TABLE12.2A)
FIG124	PLT	(input files: TABLE12.3 and TABLE12.2A)
FIG125A	PLT	(input files: TABLE12.3 and TABLE12.4)
FIG125B	PLT	(input files: TABLE12.3 and TABLE12.4)

Table 4.2b. Display files in DEMO DISKETTE #2 and corresponding input files

FIG131A	PLT	(input files: TABLE12.1 and TABLE12.2A)
FIG131B	PLT	(input files: TABLE12.1 and TABLE12.2A)
FIG132	PLT	(input files: TABLE12.1 and TABLE12.2A)
FIG133	PLT	(input files: TABLE12.3 and TABLE12.2A)
FIG134	PLT	(input files: TABLE13.1 and TABLE12.2A)

that the floppy disk drive is A:. In the "Viewing" mode, one can move the display using the cursor arrow keys. Also one can change the size of the display (zooming) by using the (+, –) keys. Hitting ESC, then entering Q, will return to DOS. Figure 4.1 shows a hard copy of the screen obtained with the HP Paint Jet when viewing FIG121. This display can be shifted or zoomed as desired.

Table 4.3 Display of FIG121 using Demo Diskette #1

OPERATOR ACTION	COMPUTER RESPONSE
A:\>CD DEMMW	
	A:\DEMOMMW>
A:\DEMOMMW>TYPE TABLE12.1 ↵	
	display of system parameters
A:\DEMOMMW>TYPE TABLE12.1A ↵	
	display of clutter map, data set #1
A:\DEMOMMW>TYPE TABLE12.2B ↵	*display of screen printout when running FRRDP with data set #1*
A:\DEMOMMW>VIEW FIG.121.PLT ↵	*3-D display of footprint reflectivity versus azimuth and range for inputs given in Tables 12.1 and 12.2a.*
ESC ↵ Q ↵	
	A:\DEMOMMW>

5. Software Installation

A copy of the simulation software is in the 5.25" DS/HD diskette entitled "MM WAVE SIMULATION", the directory name is "MMWSIM". Table 5.1 lists the contents of the diskette. Assume that this software is to be installed in the directory MMWSIM of hard disk drive C: using floppy drive A:. The procedure is as follows:

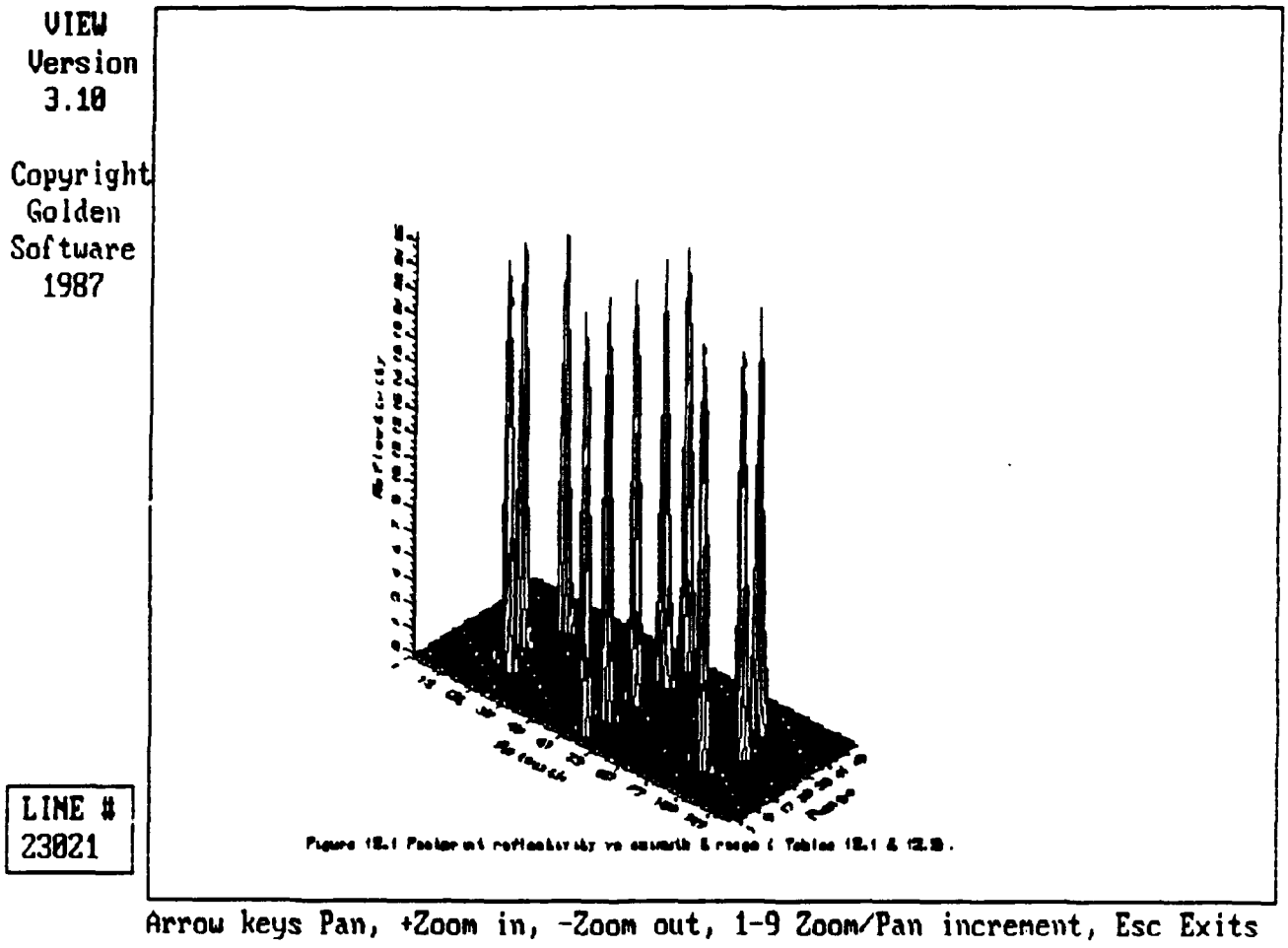

Figure 4.1. Hardcopy of screen when viewing FIG121.

Table 5.1. Directory of A:\MMWSIM

APEXTRAP	FOR	1920	1-16-89	12:08p
CLUTINFI	INP	2482	1-16-89	5:42p
CLUTINFI	ST1	2482	1-16-89	5:42p
CLUTINFO	FOR	3968	1-16-89	12:48p
CRRDP	EXE	199614	1-16-89	5:40p
CRRDP	FOR	9472	1-16-89	5:40p
CRRDPG	GRD	82494	1-16-89	5:42p
CRRDPI	INP	1971	1-16-89	5:42p
CRRDPI	ST1	1971	1-16-89	5:42p
CRRDPP	PRT	7860	1-16-89	5:42p
DERAMP	FOR	512	1-16-89	4:34p
DISH	FOR	1664	1-16-89	5:26p
DOTCOS	FOR	640	12-06-88	12:15p
FFT	FOR	2432	1-16-89	5:18p
FRRDP	EXE	116878	1-16-89	5:37p
FRRDP	FOR	9088	1-16-89	12:09p
FRRDPG	GRD	63820	1-16-89	5:41p
FRRDPP	PRT	90950	1-16-89	5:41p
KINPUT	FOR	128	7-24-87	3:48p
MAPAZM	FOR	896	1-11-89	2:36p
MAPRGM	FOR	512	1-11-89	1:59p
MMW01169	LIB	90624	1-16-89	5:33p
PAYOFX	FOR	384	1-16-89	4:40p
POLONFRA	FOR	13568	1-16-89	4:29p
PRTXY	FOR	384	1-16-89	4:41p
RANGSMOO	FOR	768	1-16-89	4:44p
SCAGAN	FOR	1280	12-06-88	12:29p
SORTI	FOR	512	1-16-89	4:48p
SORTII	FOR	640	1-16-89	4:49p
SORTRI	FOR	640	1-16-89	4:51p
TAYLOR	FOR	2432	12-02-88	4:10p
TSIGNAL	FOR	768	12-06-88	2:20p
WCHANGE	FOR	256	1-16-89	4:53p
WINDOWS	FOR	1536	1-16-89	5:09p
WINPUT	FOR	640	1-16-89	5:12p
XINPUT	FOR	128	8-10-88	1:39a

C:\>MD MMWSIM ↵ *(make directory in C:)*

C:\>CD MMWSIM ↵ *(change directory)*

C:\MMWSIM>XCOPY A:\MMWSIM*.* ↵ *(programs copied from A: to* C:\MMWSIM).

As a test for correct installation, the user can execute FRRDP using the input files CRRDPI.INP and CLUTINFI.INP which are included on the disk. CRRDPI.INP contains the system parameters for data set #1 (see DEMO DISKETTE #1, TABLE12.1). CLUTINFI.INP is the scatterer information for data set #1 (see DEMO DISKETTE #1, TABLE12.2A). The execution is as in Table 5.2a with comments in italics. Table 5.2b gives the actual screen listings.

Table 5.2a Execution of FRRDP

OPERATOR ACTION	COMPUTER RESPONSE
	C:\MMWSIM>
C:\MMWSIM>FRRDP ↵	
	computer displays the current system parameters
	C:\MMWSIM> K = ? *(enter index of parameter to change; 0 means no changes)*
C:\MMWSIM>K = ?0 ↵	*computer displays the current clutter map information*
	C:\MMWSIM> K=? *(enter index of scatterer to change; 0 means no change)*
C:\MMWSIM> K=?0 ↵	
	computer displays the $\{x_i, y_i, \mu_i, r_{gi}, \hbar_i\}$ *for each scatterer*
	C:\MMSIM>Stop–Program terminated

The user can now display the reflectivity versus azimuth and range contained in FRRDG.GRD *using* "VIEW" *from* SURFER *(see Section 7).*

Table 5.2b. Actual screen listings when executing FRRDP.

```
C:\MMWSIM>FRRDP
ARRAY W BEFORE UPDATE
TIMCNT=1; TIMDWL=2; VELOM=3; ALFM=4; BETM=5; WMPOSC=6-8; WQ9=9-10
DUMMY=11-14;DELRAN=15;FFNBIT=16;WPAR1=17=DELMAP;WPAR2=18=THRESH;WPAR3=19=XMN ;WP
AR4=20=YMN/ WPAR5=21=XMX; WPAR6=22=YMX; XIFXMT=23,SELWIN=24; BETKAI=25;SELDIS=26

         .0100000          .0200000       150.0000000          .0000000
        1.2217300          .0000000         7.0000000       900.0000000
      516.2463000       744.2216000          .0000000          .0000000
         .0000000          .0000000         1.0000000         6.0000000
         .7500000          .1000000       480.0000000       710.0000000
      550.0000000       780.0000000          .0000000         4.0000000
        3.1415900         2.0000000         1.0000000
ENTER INDEX OF W TO CHANGE; 0 MEANS NO CHANGE
K=?0
NXMAP=          94    NYMAP=          95
ARRAY W BEFORE UPDATE

 ENTERING SCAT-DATA, W(1)=3*NUMBER OF SCAT+1,(W(3i-1),W(3i),W(3i+1))=(Xi,Yi,Hbar
i) or (MUi,RGi,Hbari) for ith  SCATTERER

       -34.0000000          .0000000      1272.7910000          .0000000
         -.0304062      1272.7910000          .0000000          .0304062
      1272.7910000          .0000000          .0000000      1285.7910000
         .0000000         -.0267718      1285.7910000          .0000000
         .0267718      1285.7910000          .0000000          .0000000
      1260.7910000          .0000000         -.0273642      1260.7910000
         .0000000          .0273642      1260.7910000          .0000000
         .0000000      1295.7910000          .0000000          .0000000
      1250.7910000          .0000000
 ENTERING SCAT-DATA, W(1)=3*NUMBER OF SCAT+1,(W(3i-1),W(3i),W(3i+1))=(Xi,Yi,Hbar
i) or (MUi,RGi,Hbari) for ith  SCATTERER

       -34.0000000          .0000000      1272.7910000          .0000000
         -.0304062      1272.7910000          .0000000          .0304062
      1272.7910000          .0000000          .0000000      1285.7910000
         .0000000         -.0267718      1285.7910000          .0000000
         .0267718      1285.7910000          .0000000          .0000000
      1260.7910000          .0000000         -.0273642      1260.7910000
         .0000000          .0273642      1260.7910000          .0000000
         .0000000      1295.7910000          .0000000          .0000000
      1250.7910000          .0000000
ENTER INDEX OF W TO CHANGE; 0 MEANS NO CHANGE
K=?0
XI=.51624E+03 YI=.74422E+03 MUI=  .00000E+00 RGI=.12728E+04 HI=  .000
XI=.49359E+03 YI=.75957E+03 MUI= -.30406E-01 RGI=.12728E+04 HI=  .000
XI=.53842E+03 YI=.72818E+03 MUI=  .30406E-01 RGI=.12728E+04 HI=  .000
XI=.52674E+03 YI=.75920E+03 MUI=  .00000E+00 RGI=.12858E+04 HI=  .000
XI=.50641E+03 YI=.77303E+03 MUI= -.26772E-01 RGI=.12858E+04 HI=  .000
XI=.54668E+03 YI=.74483E+03 MUI=  .26772E-01 RGI=.12858E+04 HI=  .000
XI=.50646E+03 YI=.73025E+03 MUI=  .00000E+00 RGI=.12608E+04 HI=  .000
XI=.48648E+03 YI=.74384E+03 MUI= -.27364E-01 RGI=.12608E+04 HI=  .000
XI=.52606E+03 YI=.71612E+03 MUI=  .27364E-01 RGI=.12608E+04 HI=  .000
XI=.53474E+03 YI=.77063E+03 MUI=  .00000E+00 RGI=.12958E+04 HI=  .000
XI=.49824E+03 YI=.71850E+03 MUI=  .00000E+00 RGI=.12508E+04 HI=  .000
```

Similarly one can also execute CRRDP with the same input data files. From the user point of view the execution is identical to that of FRRDP. However, the output files are different: CRRDPG.GRD and CRRDPP.PRT. The file CRRDPG.GRD contains the reflectivity versus absolute x–y coordinates.

SURFER [4] is used to display FRRDPG.GRD or CRRDPG.GRD. Since SURFER is part of the required software the installation is briefly reviewed. SURFER is delivered on 3 diskettes: "GRID", "PLOTCALL", and "TOPO and SURF". Assume that: (1) A: is the floppy disk drive and (2) SURFER is installed in directory C:\SURFER>. The three diskettes are copied into the directory "SURFER":

C:\SURFER>XCOPY A:*.* ↵ (*diskette* GRID)

C:\SURFER>XCOPY A:*.* ↵ (*diskette* PLOTCALL)

C:\SURFER>XCOPY A:*.* ↵ (*diskette* TOPO & SURFER)

The only program that requires further installation is "PLOT". This is done by entering

C:\SURFER>PLOT/I ↵

As a response the computer displays the screen in Table 5.3. All that is needed is to select the proper printer. For example, enter #35 to specify the HP Laserjet Series II. The last steps are to hit ESC, and then to enter Y. To test that the installation is correct, one can view the demo plot supplied with SURFER by entering:

C:\SURFER>VIEW DEMO ↵.

The display can be shifted using cursor arrow keys and zoomed using the (+, –) keys. To return to DOS, hit ESC, and enter Q. It is recommended to include the lines:

PATH C:\SURFER

APPEND C:\SURFER

in the AUTOEXEC.BAT file. This makes SURFER available anywhere in the C: drive. Two options of SURFER (SURF and TOPO) can directly use the *.GRD file. SURF is for 3–D displays and TOPO is for contour plots.

Table 5.3. Installation of PLOT/I (screens 1 & 2).

```
                INSTALL Version 3.00
        Copyright(C) Golden Software Inc. 1987

 1. Amdek Amplot II Plotter          16. Epson LQ-1500 Printer
 2. Anadex DP-9620B Printer          17. Epson LQ-2500 Printer
 3. Autocad .DXF file                18. Epson MX-100 Printer
 4. C. Itoh 1550 Printer             19. Epson MX-80 Printer
 5. C. Itoh 8510 Printer             20. Epson RX-80 Printer
 6. Calcomp PlotMaster               21. Fujitsu DL-2400 Printer
 7. Datasouth DS-180 Printer         22. Houston Inst DMP-29 Lo-Res
 8. Enter Sweet-P 100 Plotter        23. Houston Inst DMP-40 Lo-Res
 9. Epson FX-100 Printer             24. Houston Inst DMP-42 Lo-Res
10. Epson FX-100 Printer - Draft     25. Houston Inst DMP-52 Lo-Res
11. Epson FX-80 Printer - Draft      26. Houston Instruments DMP-29
12. Epson FX-80 Printer - Hi Res     27. Houston Instruments DMP-40
13. Epson FX-80 Printer - Normal     28. Houston Instruments DMP-42
14. Epson GQ-3500                    29. Houston Instruments DMP-52
15. Epson HI-80 Plotter              30. HP 7470A Plotter

Esc  Return to previous menu
  N  Show next screen

Enter option (Esc,N, or 1 to 30): N
```

```
                INSTALL Version 3.00
        Copyright(C) Golden Software Inc. 1987

31. HP 7475A Plotter                 46. Leading Edge Prowriter II
32. HP 7550A Plotter                 47. Lotus .PIC file
33. HP 7586 Plotter                  48. Mannesman Tally MT-160
34. HP LaserJet 150 DPI              49. Mannesman Tally MT-180
35. HP LaserJet 300 DPI              50. Mannesman Tally Spirit-80
36. HP QuietJet +                    51. MPI 150 Printer
37. HP ThinkJet Printer              52. MPI 99 Printer
38. IBM Color Printer - Hi Res       53. NEC 8023A Printer
39. IBM Color Printer - Normal       54. NEC P5 Pinwriter Printer
40. IBM Parallel Printer             55. NEC ProII (6302) Printer
41. IBM Proprinter Printer           56. NEC ProII (6303) Printer
42. IDS 440 Printer                  57. NEC ProIII (6302) Printer
43. IDS 560 Printer                  58. NEC ProIII (6303) Printer
44. IDS Prism 132 Printer            59. Okidata 182 Printer
45. Leading Edge Prowriter I         60. Okidata 192 Printer

  P  Show previous screen
  N  Show next screen

Enter option (P,N, or 31 to 60): N
```

6. Inputs for FRRDP and CRRDP

Both FRRDP and CRRDP use the same input files: CRRDPI.INP and CLUTINFI.INP. The file CRRDPI.INP contains the system parameters, while the file CLUTINFI.INP contains the clutter map information. Tables 6.1 and 6.2 show, respectively, the contents of two of the input files included in the software delivered. In each table, a row contains the numerical value of the parameter followed by its definition.

Referring to Table 6.1, CRRDPI.INP contains 27 parameters. Normally the user should change only the parameters defining the seeker, footprint, and display window. The seeker parameters are:

W(3) ≡ VELOM ⇔ seeker velocity

W(4) ≡ ALFM ⇔ seeker azimuth angle

W(5) ≡ BETM ⇔ seeker elevation angle

W(6) ≡ WMPOSC(1) ⇔ seeker x–coordinate

W(7) ≡ WMPOSC(2) ⇔ seeker y–coordinate

W(8) ≡ WMPOSC(3) ⇔ seeker z–coordinate.

The footprint parameters are:

W(9) ≡ WQ9(1) ⇔ footprint center x–coordinate

W(10) ≡ WQ9(2) ⇔ footprint center y–coordinate.

The display window parameters are:

W(19) ≡ WPAR(3) ⇔ x–min display window

W(20) ≡ WPAR(4) ⇔ y–min display window

W(21) ≡ WPAR(5) ⇔ x–max display window

W(22) ≡ WPAR(6) ⇔ y–max display window

The absolute coordinates (x–min, y–min) and (x–max, y–max) define respectively, the upper left and lower right corner of the display window (scatterers outside the specified display window will be ignored by the simulation).

Table 6.1. Data set #1 for file CRRDPI.INP (see TABLE12.1)

.0100000	TIMCNT=central time
.0200000	TIMDWL=observation interval
150.0000000	VELOM=seeker velocity
.0000000	ALFM=seeker azimuth angle
1.2217300	BETM=seeker elevation angle
.0000000	WMPOSC(1)=seeker x-coordinate
7.0000000	WMPOSC(2)=seeker y-coordinate
900.0000000	WMPOSC(3)=seeker z-coordinate
516.2463000	WQ9(1)=footprint center x-coordinate
744.2216000	WQ9(2)=footprint center y-coordinate
.0000000	DUMMY=future use
.0000000	DUMMY=future use
.0000000	DUMMY=future use
.0000000	DUMMY=future use
1.0000000	DELRAN=range bin
6.0000000	FFNBIT=# FFT bits
.7500000	WPAR(1)=rectangular grid increment
.1000000	WPAR(2)=mapping threshold
480.0000000	WPAR(3)=x-min display window
710.0000000	WPAR(4)=y-min display window
550.0000000	WPAR(5)=x-max display window
780.0000000	WPAR(6)=y-max display window
.0000000	XIFXMT=transmitter phase
4.0000000	SELWIN=define FFT window
3.1415900	BETKAI=Kaiser window parameter
2.0000000	SELDIS=define dish simulation
1.0000000	BITINT=define FFT interpolation

Table 6.2. Data set #1 for input file CLUTINFI.INP (see TABLE12.2a)

-34.00000000	W1=3* #scatt.+1,pos. if (xi,yi),neg. if (mui,rgi)
.0000000	X1=x(1st scat), or mu1
1272.7910000	Y1=y(1st scat), or rg1
.0000000	Z1=z(1st scat) = hbar1
-.0304062	X1=x(2nd scat), or mu2
1272.7910000	Y1=y(2nd scat), or rg2
.0000000	Z1=z(2nd scat) = hbar2
.0304062	X1=x(3rd scat), or mu3
1272.7910000	Y1=y(3rd scat), or rg3
.0000000	Z1=z(3rd scat) = hbar3
.0000000	X1=x(4th scat), or mu4
1285.7910000	Y1=y(4th scat), or rg4
.0000000	Z1=z(4th scat) = hbar4
-.0267718	X1=x(5th scat), or mu5
1285.7910000	Y1=y(5th scat), or rg5
.0000000	Z1=z(5th scat) =hbar5
.0267718	X1=x(6th scat), or mu6
1285.7910000	Y1=y(6th scat), or rg6
.0000000	Z1=z(6th scat) = hbar6
.0000000	X1=x(7th scat), or mu7
1260.7910000	Y1=y(7th scat), or rg7
.0000000	Z1=z(7th scat) = hbar7
-.0273642	X1=x(8th scat), or mu8
1260.7910000	Y1=y(8th scat), or rg8
.0000000	Z1=z(8th scat) = hbar8
.0273642	X1=x(9th scat), or mu9
1260.7910000	Y1=y(9th scat), or rg9
.0000000	Z1=z(9th scat) = hbar9
.0000000	X1=x(10th scat), or mu10
1295.7910000	Y1=y(10th scat), or rg10
.0000000	Z1=z(10th scat) = hbar10
.0000000	X1=x(11th scat), or mu11
1250.7910000	Y1=y(11th scat), or rg11
.0000000	Z1=z(11th scat) = hbar11

The antenna beam elevation and azimuth angles are calculated at central time from the seeker and footprint parameters. They remain constant during the entire dwell interval.

The files CRRDPI.INP and CLUTINFI.INP contain the first data sets (TABLE12.1 and TABLE12.2A). They have been copied onto CRRDPI.ST1 and CLUTINFI.ST1, respectively, as backups. It is a good practice to backup each important data set, in a similar fashion. For example, if the size of the display window is reduced (as in TABLE12.3 in DEMO DISKETTE #1), then a backup file called CRRDPI.ST2 should be created.

Referring to Table 6.2, CLUTINFI.INP contains the clutter map information. The number of rows is equal to {3 × (# scatter) + 1}. The first row indicates the number of rows in the file, where the sign is positive or negative depending whether the scatterer information is $(x_i,y_i,\hbar_i)$ or $(\mu_i,r_{gi},\hbar_i)$. The correspondence between $(x_i,y_i,\hbar_i)$ and $(\mu_i,r_{gi},\hbar_i)$ is explained in Appendix A. The height of the ith scatterer is $z_i = \hbar_i$ = hbari. In our examples CLUTINFI.INP defines 11 scatterers: in data set #1 all the scatterers are on the ground, and in data set #2 the central scatterer is 3m above ground.

For both input files, there are two ways to modify the input data: (1) editing the file using any ASCII editor, and (2) changing parameters online as needed. As an example of online change, assume that the seeker velocity varies from 150 m/sec to 200 m/sec. The change is performed during the execution of FRRDP or CRRDP as follows. The computer displays the current parameters in CRRDPI.INP and stops with a prompt "K=?". The user should enter 3 to indicate that the third parameter is to be modified. The computer responds with another prompt "X = ?". Now the user enters the new value (200.) for the third parameter. If this is the only change, the user should enter 0 at the next prompt "K=?". Note that the file CRRDPI.INP is rewritten with the updated values. The same procedure applies to modify CLUTINFI.INP online.

7. Display of FRRDPG.GRD: Footprint Reflectivity versus Azimuth and Range

This section explains how to use SURFER on the output file FRRDPG.GRD (generated by FRRDP) to display 3–D or contour plots of the reflectivity versus azimuth and range. The

use of SURFER will be demonstrated on the FRRDPG.GRD obtained by running FRRDP with the CRRDPI.INP and CLUTINFI.INP input files given in Tables 6.1 and 6.2 (data set #1 for both files).

The command to go from DOS to SURFER is

C:\MMWSIM>SURFER ↵.

The computer responds with the menu in Table 7.1, the hard copy was printed on the HP Paint Jet. The options are: GRID, TOPO, SURF, VIEW, PLOT, and Quit. The option GRID creates a grid file starting from an input file with one 3–D data set {x,y,z} per row. This option is not needed in our application because FRRDP and CRRDP directly generate the grid files. The TOPO program displays a contour map starting from a grid file. The SURF program produces a 3–D display from a grid file. As explained in section 4, the program VIEW allows direct viewing of a plot file. The program PLOT is used to generate a plot file (*.PLT) which can be stored on a diskette for the purpose of producing a hard copy on a printer or a plotter. Another application is to store the plot files on a diskette for later demonstration since they can be viewed directly using "VIEW". The command Quit is used to return to DOS.

Select SURF on the SURFER menu for a 3–D display. The first step in SURF is to enter the grid file name. Table 7.2 shows a screen printout of the "SURF" menu for the input file FIG71.GRD≡FRRDPG.GRD with input data sets {#1 and #1}.

SURF options are discussed below in the same order as they appear on the screen. "INPUT" allows the user to define the current grid file and it also computes the grid bounds. All our 3–D displays use the following settings for the six selectable parameters in "VIEW": {Orthographic, 312, 30, automatic, yes, upper}. In "LINETYPE" we recommend the default parameters except for the color option (1–15). In "BASE" we keep the default parameters. The purpose of option "TITLE" is to enter a title for the display. The option "AXES" are to specify the x, y and z coordinates, one axis after the other. In option "SIZE", we change the

Table 7.1. Screen printout for SURFER menu

```
[Main Menu]  GRID TOPO SURF VIEW PLOT Quit
Run the GRID program to create a grid file for SURF or TOPO
```

```
SURFER Access System  Version 3.00
Copyright (C) Golden Software Inc. 1987
```

```
F1=Help     Esc=Backup     Arrows keys move pointer
```

Table 7.2. Screen printout for SURF menu

```
[SURF]  Input View LineTyp Base Title Axes Size XYLine Post Output Equip
Specify an input grid file to plot

Input grid file: FIG71.GRD
Input grid size: 54 x 128

     GRID MINIMUM   GRID MAXIMUM   SCALE FACTOR
X               1            128
Y               1             54
Z               0          25.82          4.918

F1=Help F2=View F3=Main F4=Store F5=Directory Esc=Backup Arrows=Move pointer
```

length from the default value 4" to 6", for a bigger display which still fits within a standard size hardcopy. In "XYLINE", "POST", and "EQUIP" we retain the default settings. The option 'OUTPUT" is used to create a binary or an ASCII plot file. This plot file can then be viewed on any IBM PC/Compatible using the executable file "VIEW" which is part of SURFER. Hard copies of the plot can be obtained with an IBM PC/Compatible which contains "PLOT" from SURFER and which is attached to a printer or a plotter. In our applications we recommend the following settings: {*.PLT, 1, 1, 1, ASCII, Overwrite, 3, NO} where * denotes the file name (no longer than 8 characters).

Select TOPO on the SURFER menu to display contour maps from a grid file. Again the first step in TOPO is to enter the grid file name. Table 7.3 shows a screen printout of the "TOPO" menu for the same grid file, i.e., FIG71.GRD. The "INPUT" option was discussed earlier. Only three options will be explained: LEVEL, TITLE, and GRID. For all the remaining options we recommend the default settings. In option "LEVEL" one specifies the minimum and maximum contours and the contour interval. Recommended settings are: {minimum contour = 15, maximum contour = as computed by SURFER, contour interval = 12, level file = as computed by SURFER}. Option "TITLE" was reviewed earlier. Option "GRID" is to define a display grid: {color, dash length, and x and y spacing}. In all our examples the choices are {color = 1, length = 0.08", x and y spacing = automatic}.

As a short cut one can use SURF or TOPO directly on a grid file:

C:\MMWSIM>SURF FRRDPG ↵

or

C:\MMWSIM>TOPO FRRDPG ↵ .

The 3–D display of Fig. 7.1 was obtained by using SURF on FRRDPG for inputs in TABLE12.1 and TABLE12.2A. This is the same display as viewing FIG121 from DEMO DISKETTE #1. Figure 7.2 is the side view of Fig. 7.1 and corresponds to viewing FIG122. Figure 7.3 has the same input files as Figs. 7.1 and 7.2, and corresponds to viewing FIG123. It is the reflectivity contour map for the 11 scatterers in data set #1. Figure 7.4 corresponds to

Table 7.3. Screen printout for TOPO menu

```
[TOPO]  Input Level Scale ConLine Title Border XYLine Grid Post Output Equip
Specify an input grid file to contour

Input grid file: FIG71.GRD
Input grid size: 54 x 128

     GRID MINIMUM   GRID MAXIMUM
X               1            128
Y               1             54
Z               0          25.82

 Minimum contour: 2
 Maximum contour: 24
Contour interval: 2

F1=Help F2=View F3=Main F4=Store F5=Directory Esc=Backup Arrows=Move pointer
```

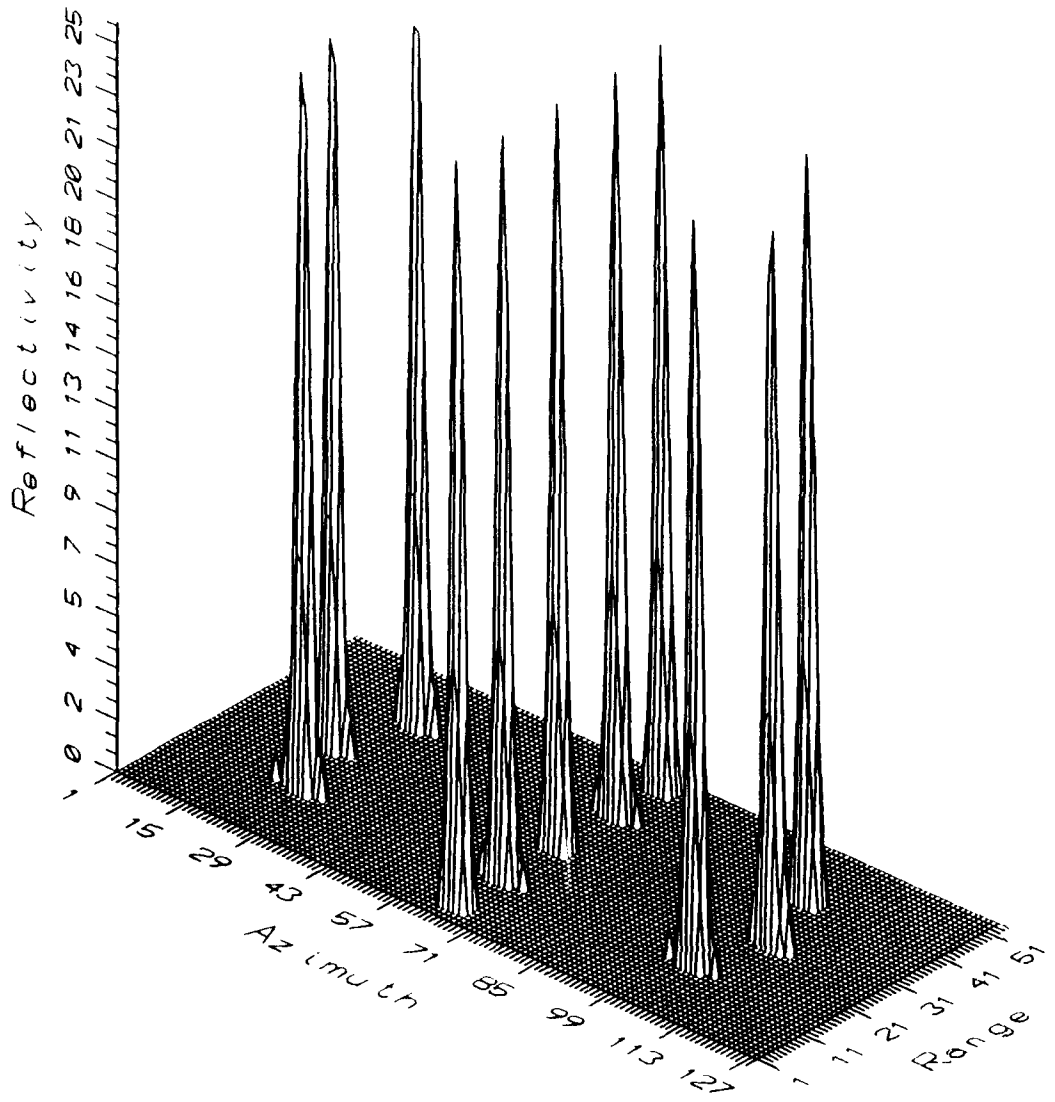

Figure 7.1 3-D display using SURF on FRRDPG (Input data sets: #1 & #1).

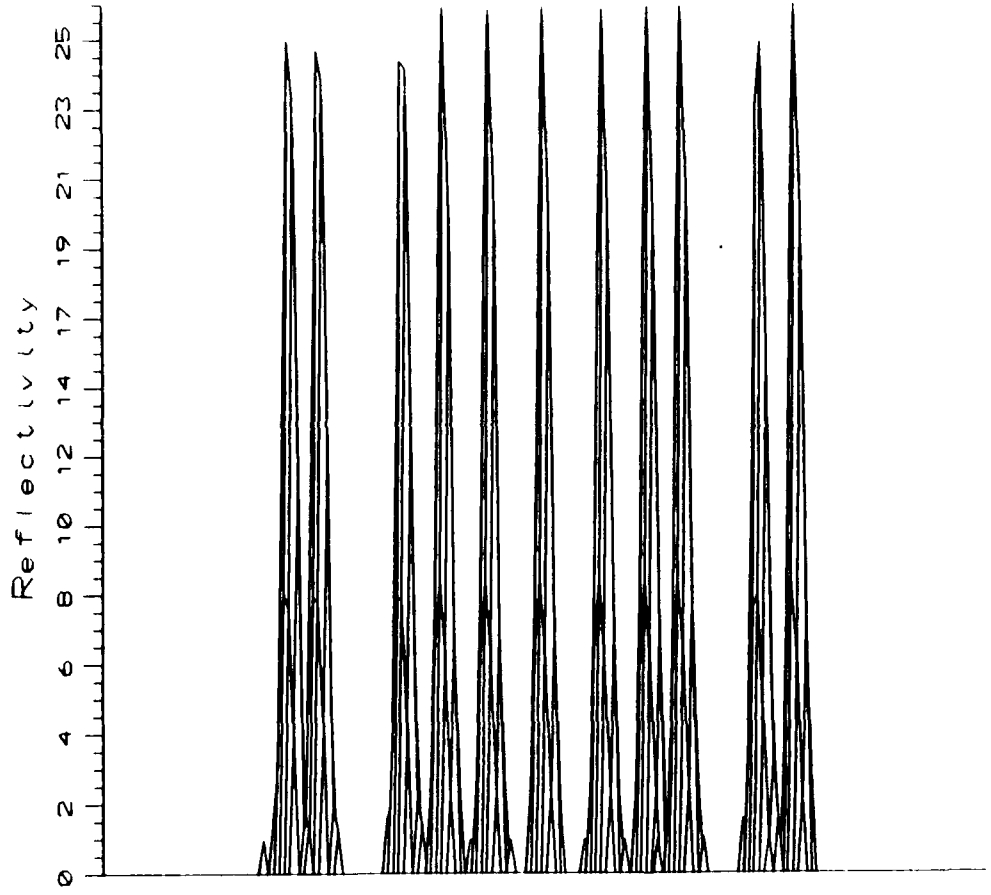

Figure 7.2 Side view corresponding to Fig. 7.1 .

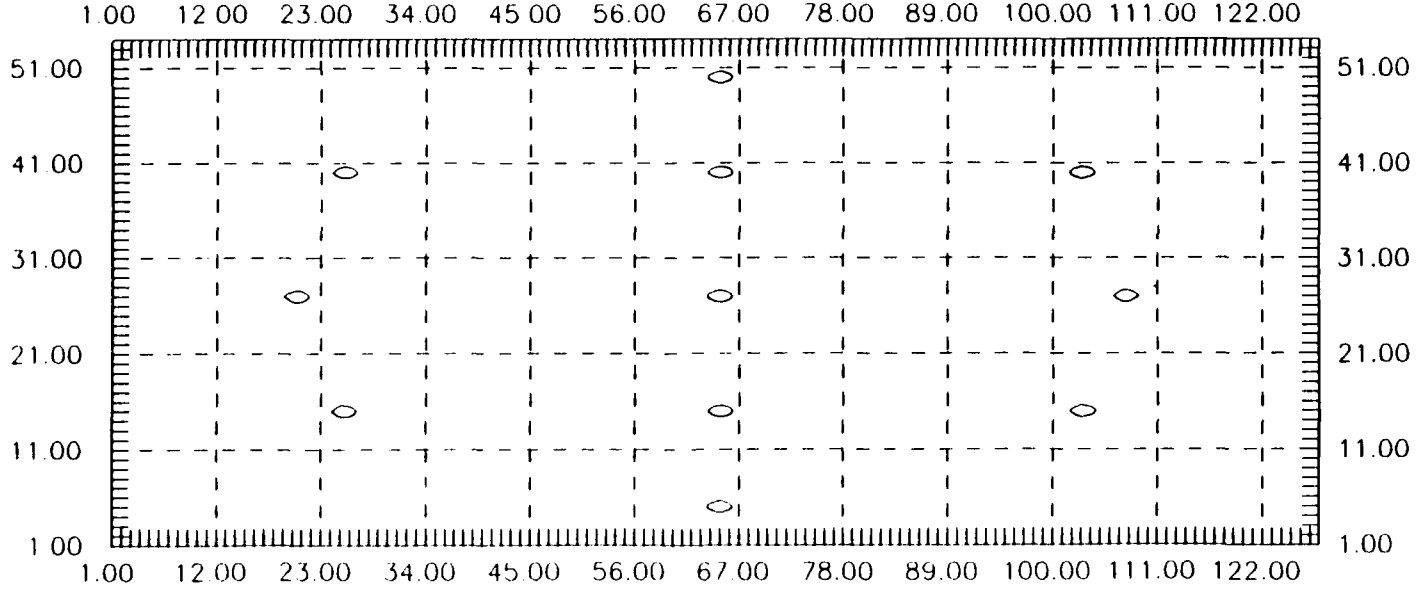

Figure 7.3 Contour map using TOPO on FRRDPG (input data sets:#1 & #1).

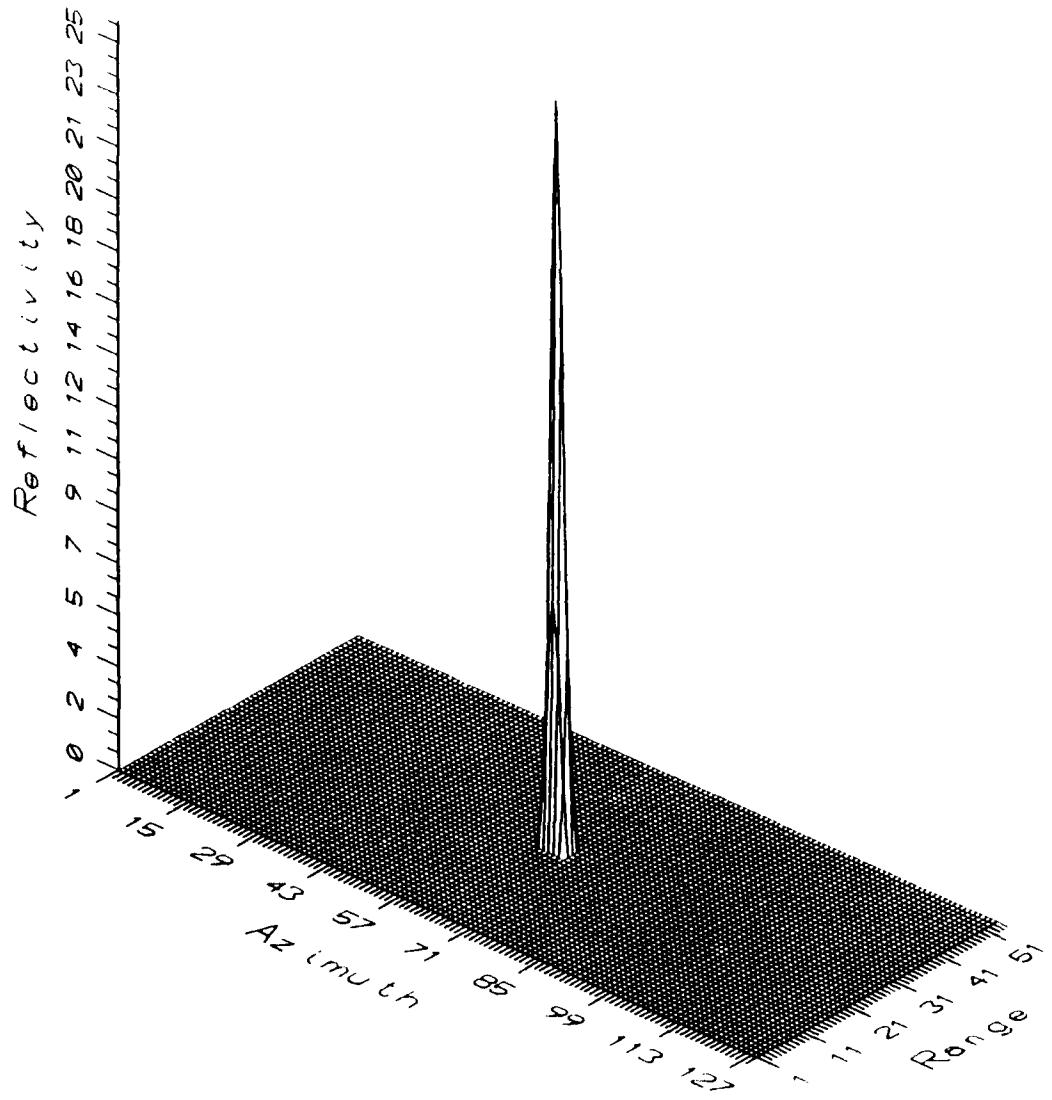

Figure 7.4 3-D display using SURF on FRRDPG (input data sets: #2 & #1).

FIG124 and the inputs are in TABLE12.3 and TABLE12.2A. This 3–D display shows only one scatterer because of a smaller window. Figures 7.5a and 7.5b correspond to FIG125A and FIG125B in DEMO #1. The inputs are in TABLE12.3 and TABLE12.4. These figures demonstrate how the scatterer height shifts the 3–D and contour displays.

8. **Display of CRRDPG.GRD: Footprint Reflectivity Versus Absolute x–y Coordinates**

In section 7 we have explained how to use SURFER on the output file FRRDPG.GRD. Here, SURFER operates on the output file CRRDPG.GRD and the 3–D and contour displays are for the reflectivity versus absolute x–y coordinates.

Figures 8.1, 8.2 and 8.3 use the same input files: CRRDPI.INP = CRRDPI.ST2, and CLUTINFI.INP = CLUTINFI.ST1 (see TABLE12.1 and TABLE12.2A). Figure 8.1 shows the 3–D reflectivity display. Figure 8.2 gives the corresponding contour map. Figure 8.3 is the corresponding side view. It demonstrates that the simulation is nearly impulse invariant.

Both figures 8.4 and 8.5 use the clutter map CLUTINFI.ST1. Figure 8.4 shows the 3–D reflectivity display with system parameters in CRRDPI.INP ≡ TABLE12.2. Only one of the eleven scatterers appears in the display, because of a smaller display window. Figure 8.5 shows the 3–D display for a smaller absolute grid increment (WPAR(1) = 0.6m, instead of 0.75m; see TABLE13.1). The size of the display was also reduced slightly (due to SURFER limitation) so that only 8 scatterers can be seen.

9. Summary and Conclusions

This User Manual is delivered with two demonstration diskettes and one simulation diskette. The demonstration diskettes allow viewing typical inputs and outputs of the simulation on any IBM PC/Compatible equipped with one DS/HD 5.25" floppy disk drive and a high resolution monitor. The simulation diskette "MM Wave Simulation" contains two executable files FRRDP and CRRDP. FRRDP generates an output file FRRDPG.GRD which SURFER uses to display reflectivity versus azimuth and range. CRRDP uses Invariant Mapping to generate an output file CRRDPG.GRD which SURFER uses to display reflectivity versus absolute x–y coordinates. Both 3–D displays and contour plots are presented.

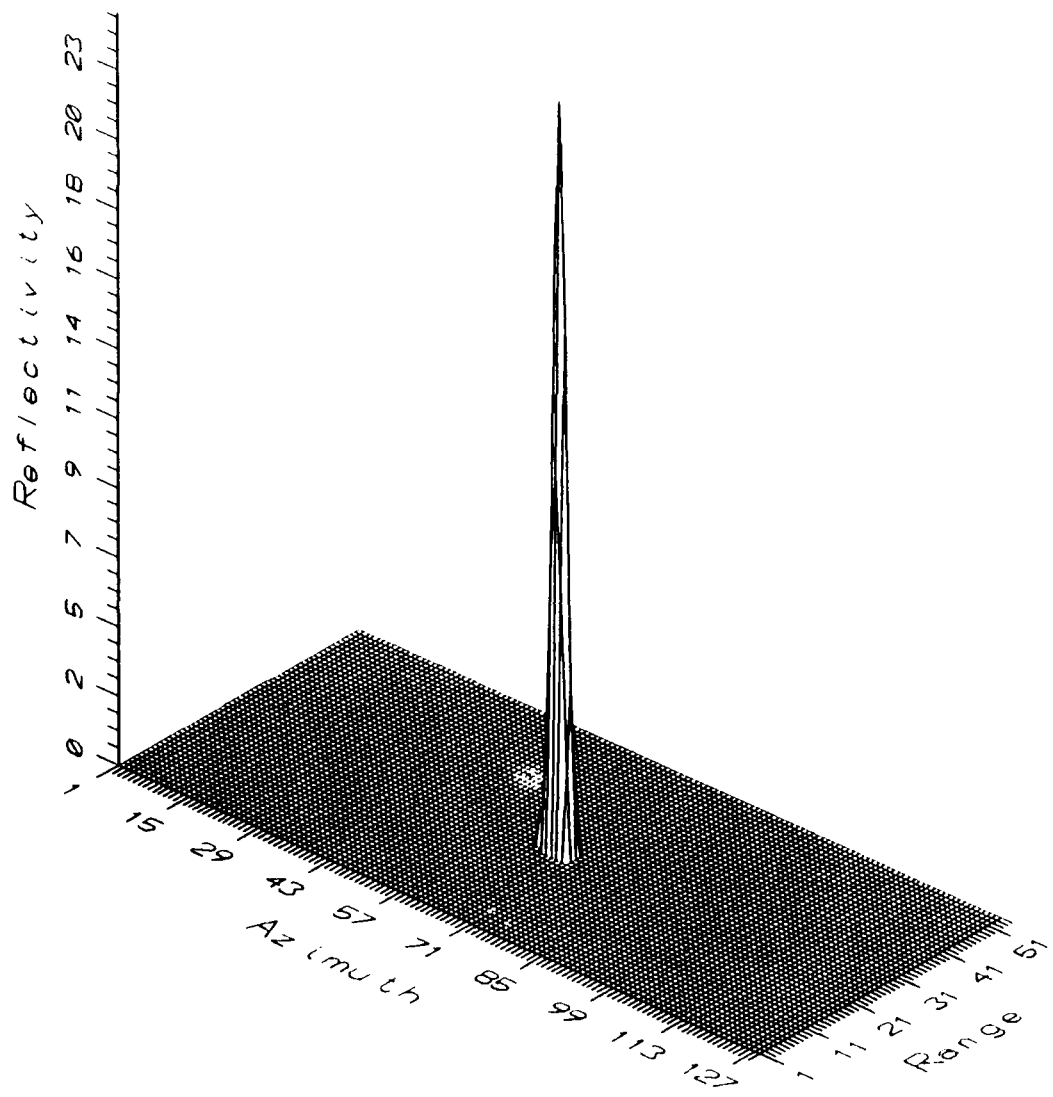

Figure 7.5a 3-D display using SURF on FRRDPG (input data sets: #2 & #2).

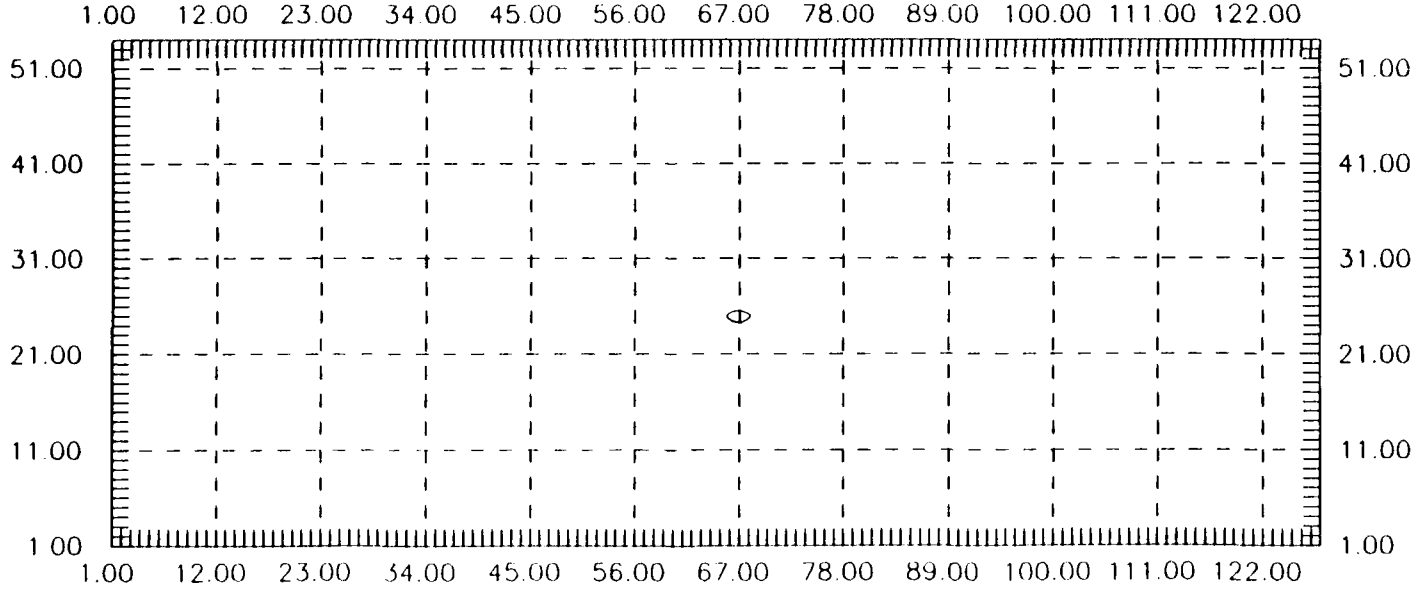

Figure 7.5b Contour map using TOPO on FRRDPG (input data sets:#2 & #2).

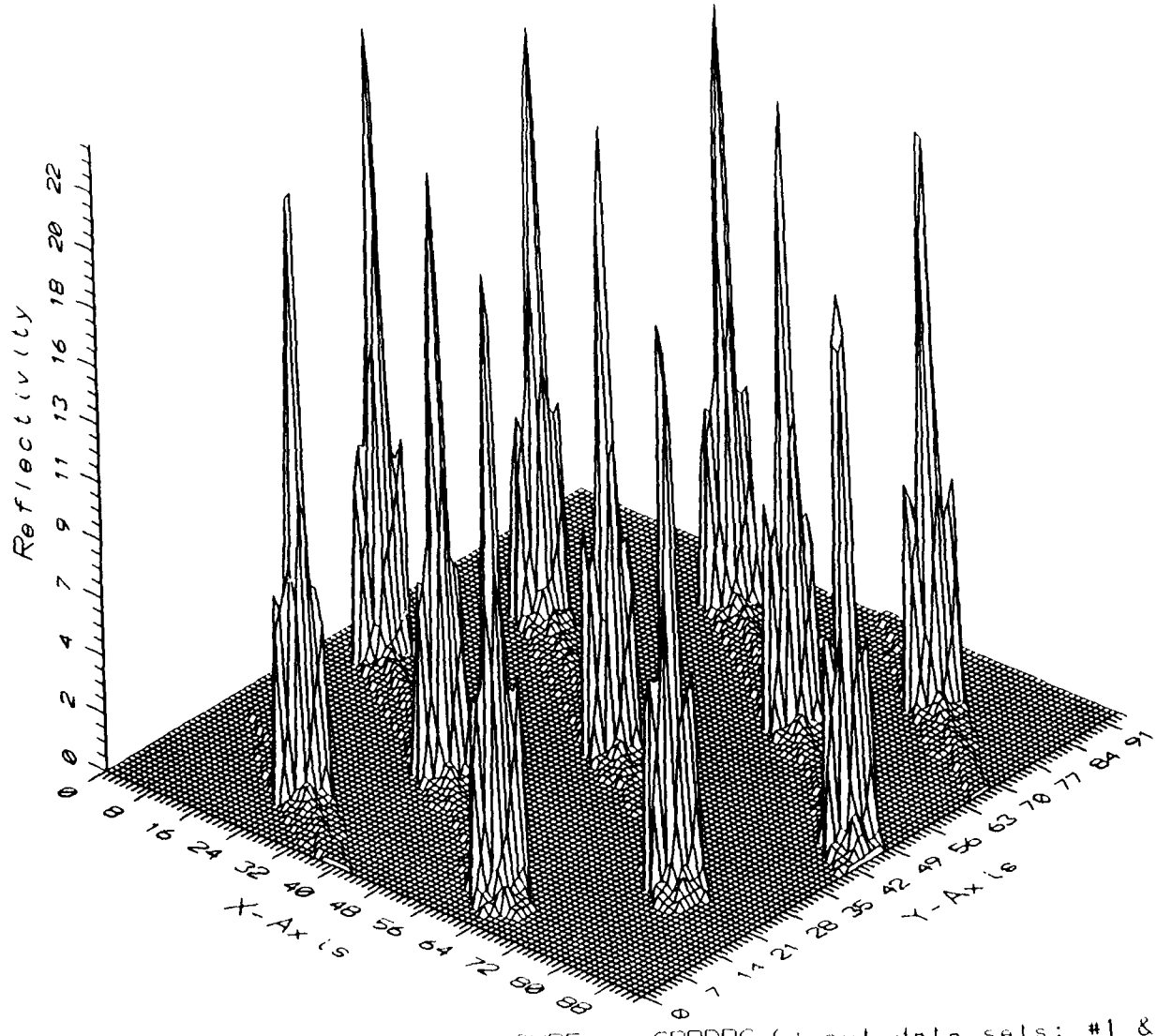

Figure 8.1 3-D display using SURF on CRRDPG (input data sets: #1 & #1)

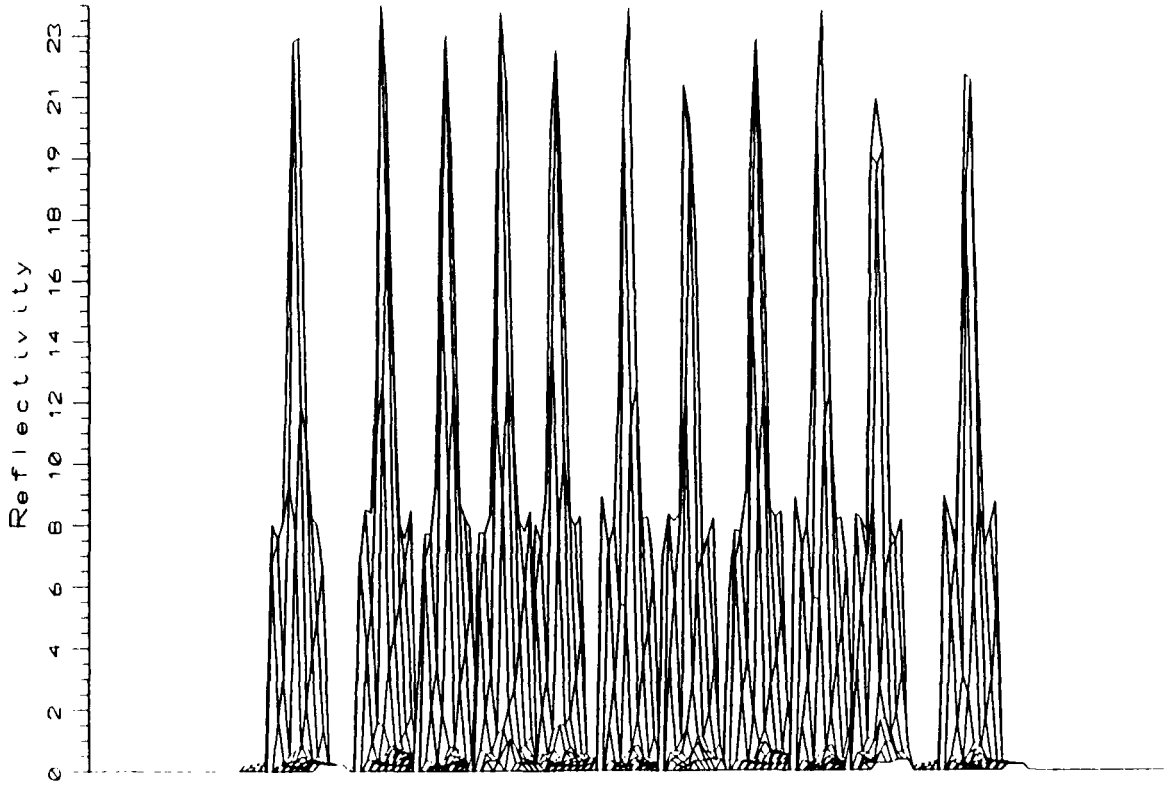

Figure 8.2 Side view corresponding to Fig. 8.1 .

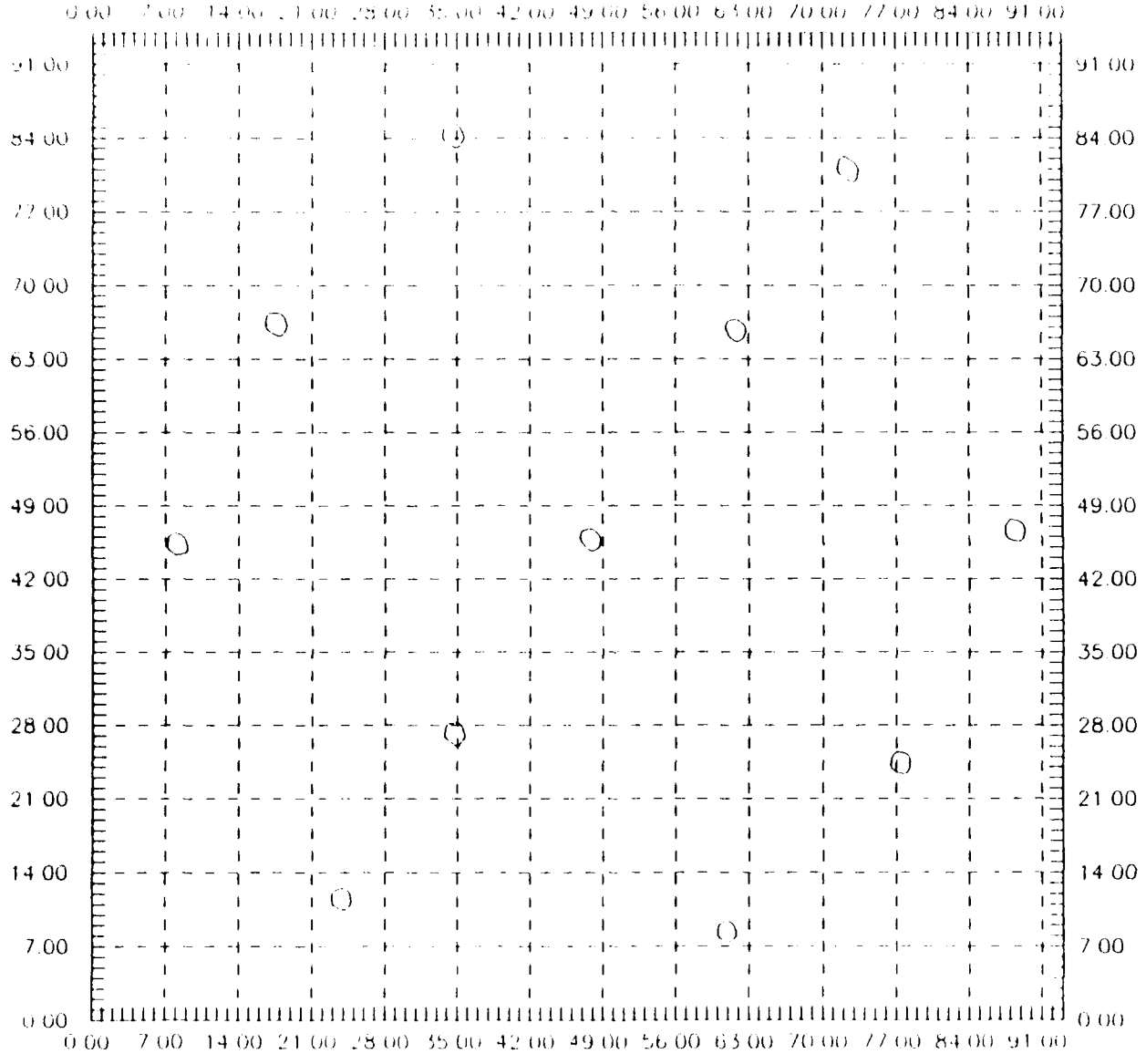

Figure 8.3 Contour map using IOPO on Grid0PG (input data sets #1 & #1).

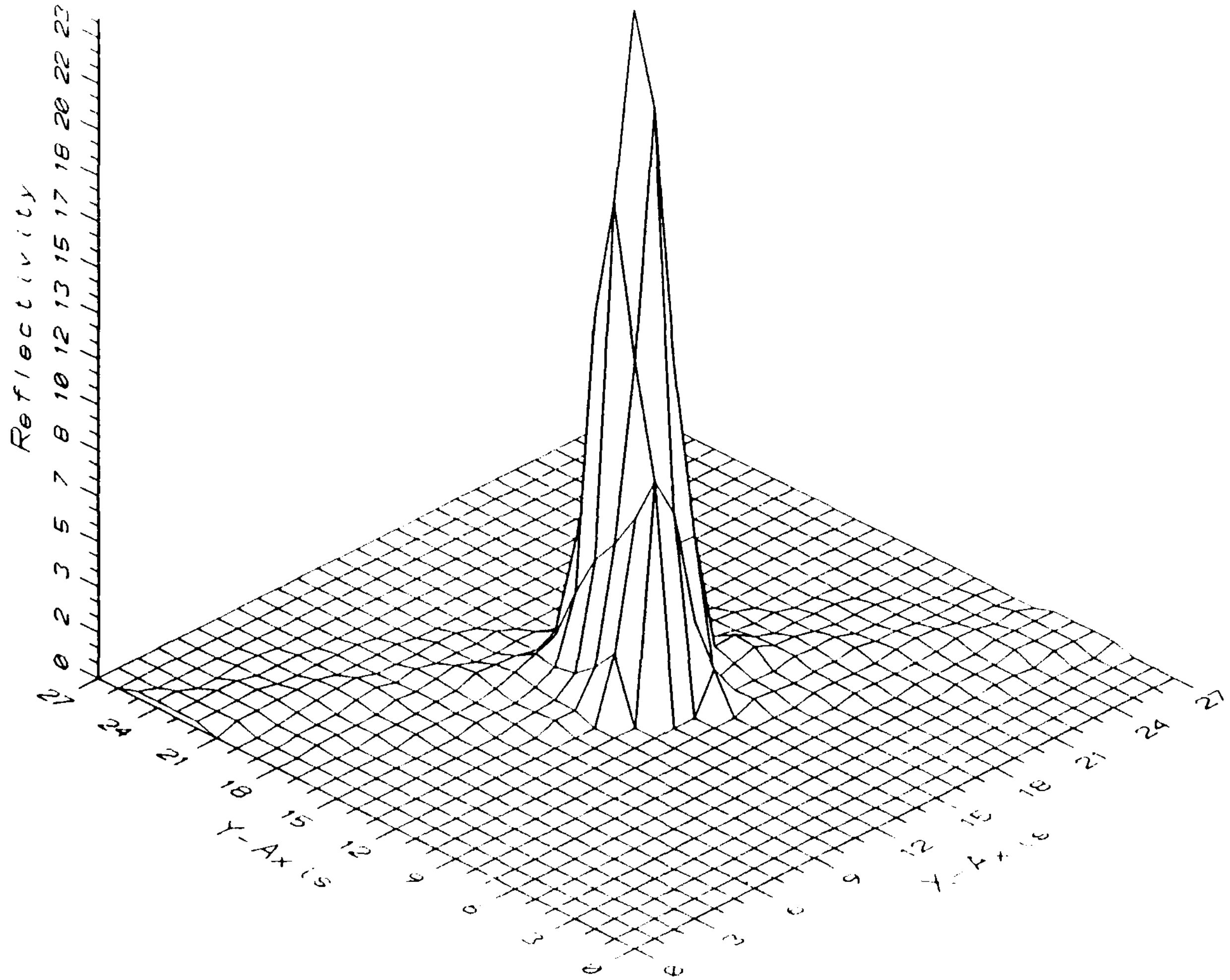

Figure 8.4 3 D display using SURF on CRRDPG (input data sets: #2 & #1).

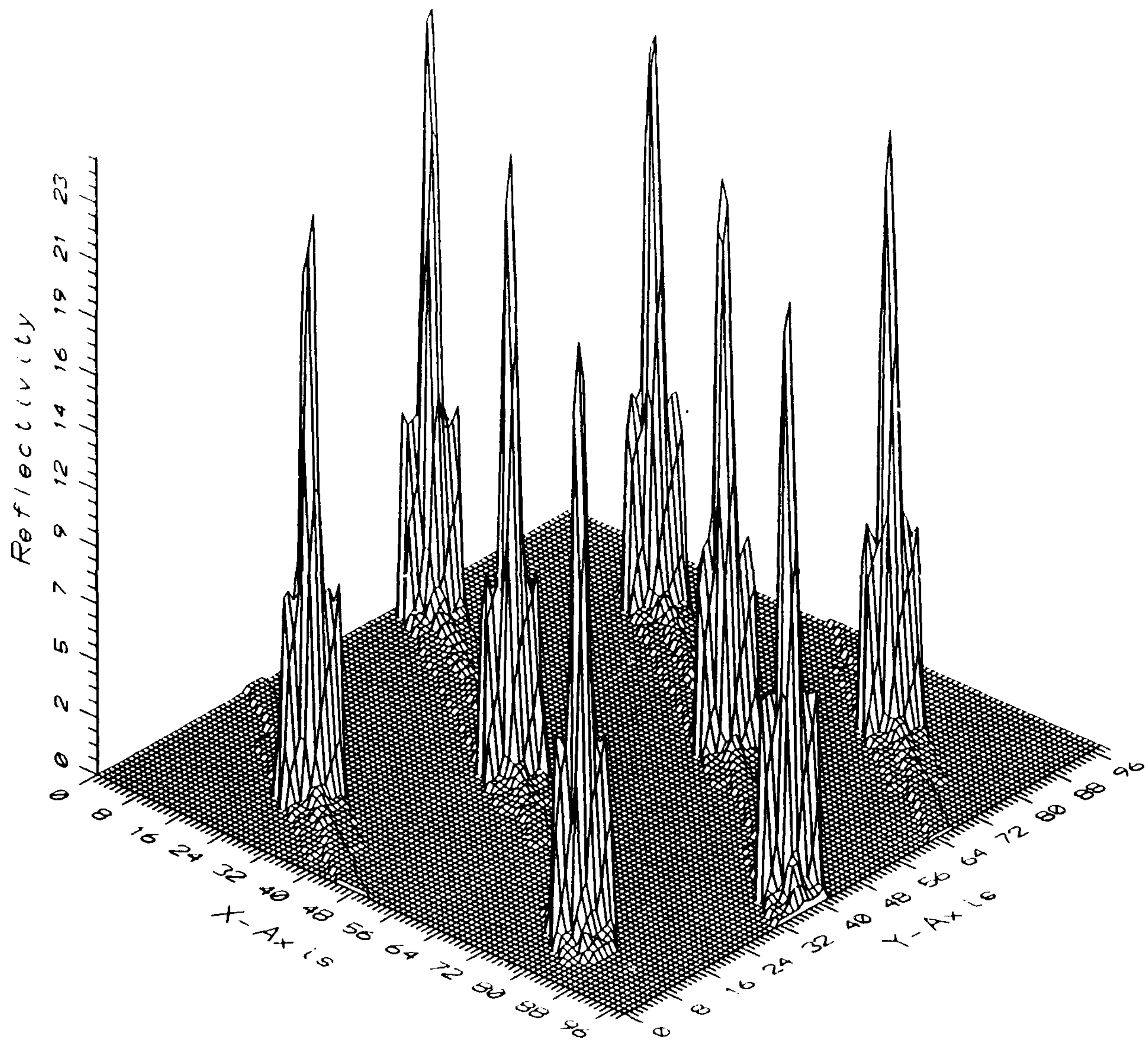

Figure 8.5 3-D display using SURF on CRRDPG (input data sets: #2 & #3).

The hardware requirements for the simulation are:

386 CPU with a 387 math coprocessor

20 Mbyte Hard disk

2 Mbyte Core memory

1 DS/HD 5.25" floppy disk drive.

In order to execute FRRDP or CRRDP, the user needs to install both "SURFER" [4] and the Simulation diskette "MM Wave Simulation". A Fortran 77 compiler is required if any modification is contemplated.

The content is as follows: (1) Overview of FRRDP and CRRDP Simulations, (2) instructions for the DEMO diskettes, (3) guidance for software installation, (4) details on the input files, (5) display of reflectivity versus azimuth and range using SURFER on FRRDPG.GRD, and (6) display of reflectivity versus absolute x–y coordinates using SURFER on CRRDPG.GRD.

This user manual is self contained, and it can be utilized without reading Volume I [3] or any other reference. Similarly Volume I is also complete. Of course, Volume II is a natural complement to Volume I. Therefore, we have used, as much as possible, the same notation in both Volumes to facilitate understanding.

References

[1] Polge, R. J., Mahafza, B. R., and Kim, J. G.," Computer Simulation for a MM Wave Seeker Including SAR Processing and Invariant Maping", prepared for Georgia Institute of Technology under subcontract # A–4521–S1 in support of U. S. Army Missile Command Prime Contract # DAAH01–84–DA029, D.O. 0088 UAH Technical Report, May 1987. SECRET.

[2] Polge, R. J., Mahafza, B. R., and Kim, J. G., "Increasing Azimuth and Elevation Resolution of MM Wave Seeker Systems Using Coherent or Noncoherent Range Relative Doppler Processing (RRDP) with Constant or Linear Frequency Modulation and Invariant Mapping", prepared by the University of Alabama in Huntsville for the U. S. Army Missile Command under Contract DAAH01–87–D–0021, D.O., 18 February 1988.

[3] Polge, R. J., Mahafza, B. R., and Kim, J. G., "Extention and Updating of the Computer Simulation of Range Relative Doppler Processing for MM Wave Seekers", prepared by the University of Alabama in Huntsville for the U. S. Army Missile Command under Contract DAAH01–87–D–0021, D.O., January 1989.

[4] SURFER Reference Manual, by Golden Software Inc, 807 14th Street, P. O. Box 281, Golden, Colorado, 80402, (Tel: 1–800–972–1021).

APPENDIX A

Entering scatterer data as $\{x_i, y_i, h_i\}$ or $\{\mu_i, r_{gi}, h_i\}$

A.1 Introduction

The transformation from absolute x–y coordinates to spherical coordinates is explained using data set #1 in a file CRRDPI.INP (see Table 6.1). Figure A.1 shows the geometry involved in the computation of the ith scatterer information. Note that the user does not need to worry about this transformation since it is done automatically in the program. More precisely, the screen shows complete information for each scatterer:

$$\{x_i, y_i, \mu_i, r_{gi}, h_i\} \quad , \tag{A.1}$$

regardless of how the information is entered. As explained earlier $\{\mu_i, r_{gi}\}$ refer to $\vec{C}_{gi}$, the ground projection of the ith scatterer $\vec{C}_i$.

A.2 Reading relevant system parameters from file CRRDPI.INP.

d_x=WPMOSC(1)=seeker x–coordinate=0.0

d_y=WMPOSC(2)=seeker y–coordinate=7.0

h=WMPOSC(3)=seeker z–coordinate=900.0 (A.2)

x_q=WQ9(1)=footprint center x–coordinate=516.2463

y_q=WQ9(2)=footprint center y–coordinate=744.2210

A.3 Computation of α^*

$$\alpha^* = \text{ATAN2}(x_q - d_x \, , \, y_q - d_y) \tag{A.3}$$

(or use rectangular to polar transformation (→POL) on a calculator.)

A.4 Computation of (μ_i, r_{gi}) from (x_i, y_i)

$$\mu_i = \text{ATAN2}\,(x_i - d_x, \, y_i - d_y) - \alpha^* \tag{A.4}$$

$$r_{gi} = \text{SQRT}[(x_i - d_x)^2 + (y_i - d_y)^2 + h^2]$$

A.5 Computation of (x_i, y_i) from (μ_i, r_{gi})

$$x_i = [\text{SQRT}(r_{gi}^{\,2} - h^2)]*\text{SIN}(\mu_i + \alpha^*) + d_x$$

$$y_i = [\text{SQRT}(r_{gi}^{\,2} - h^2)]*\text{COS}(\mu_i + \alpha^*) + d_y \tag{A.5}$$

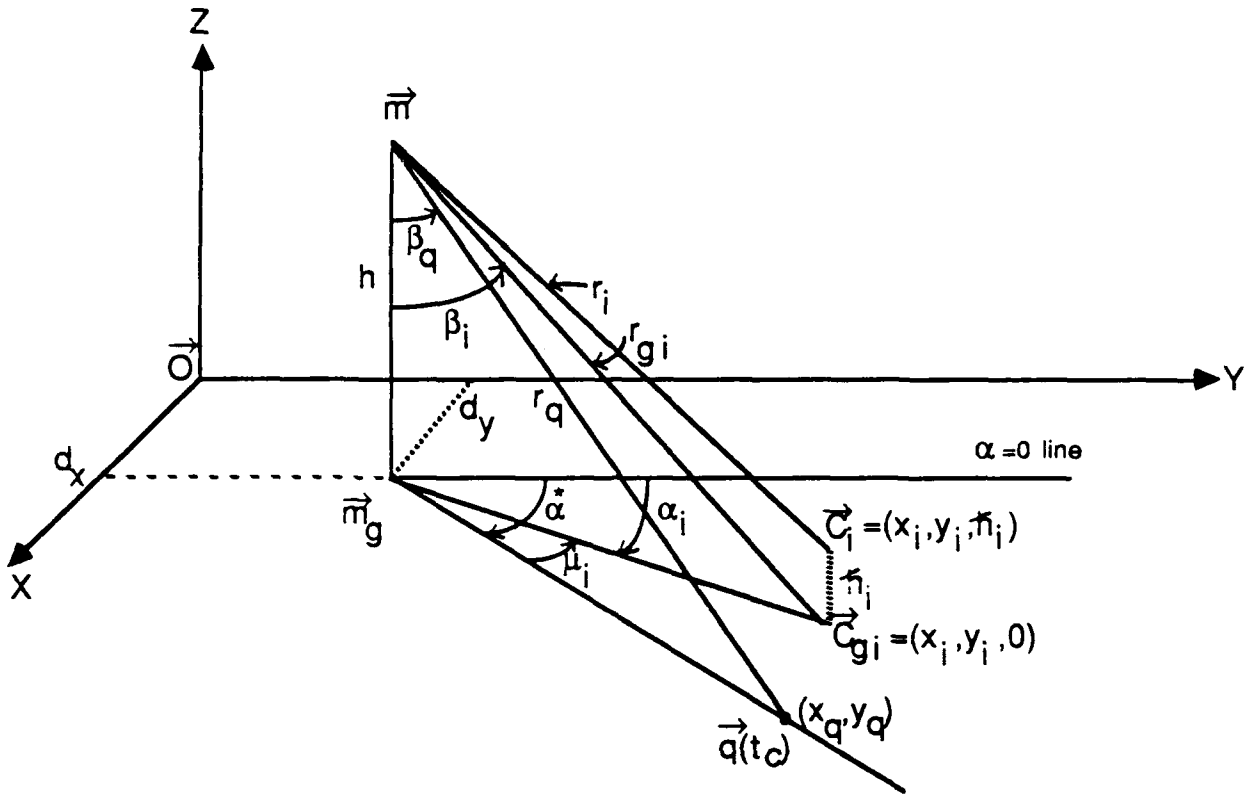

Figure A.1 Geometry for the ith scatterer.

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