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SAIC ACTIVATED BOTTOM SENSOR MODEL

Science Applications International Corporation

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SAIC-89/1059

June 30, 1989

Science Applications International Corporation

Prepared by

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Prepared for

AEAS Program Office

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SAIC ACTIVATED BOTTOM SENSOR MODEL

I INTRODUCTION

The SAIC Activated Bottom Sensor model is designed to provide quick response analysis of system concept performance. Its primary products are graphs showing detection coverage areas as a function of source-target-receiver geometry. These will allow the user to make trade-off studies regarding deployment configurations and to make general estimates of optimal system design parameters such as array length and orientation and waveform selection. Special features have been developed to address sensors near or on the ocean bottom. For general applications the model addresses active sonar performance under both monostatic and bistatic configuration in a range independent environment.

The programs are written in FORTRAN utilizing the VAX/VMS operating system. The plotting software is generated using DISSPLA. The plots may be displayed on either a 4010 Tektronix terminal or laser printer. To invoke the main menu type @MENU. For help in creating new executables type @HELPLFA.

II DESCRIPTION OF PHYSICS

Attributes of the Activated Bottom Sensor model are summarized in Figure 1. The underlying physics of the model is that it addresses fully bistatic geometries for a single source and receiver in a single-profile, flat-bottom environment. Propagation in this environment is described by FAME, an eigenray model with wave diffraction corrections.

SAIC ACTIVATED BOTTOM SENSOR MODEL

- VAX implementation - menu driven
- Bistatic geometry
- Single profile, eigenray propagation
- Semi-coherent bottom return
- Fast reverberation algorithm
- Peak echo with time-spread correction
- Direct transmission masking
- Omnidirectional noise
- Selectable array configuration
- Plan view detection coverage and A-scan outputs

Figure 1. Attributes of the Activated Bottom Sensor Model

Transmission loss, generally, is estimated by an incoherent (intensity) summation of all eigenray arrivals. That approach is followed here as well, with the exception that, for near-bottom receivers, eigenrays at the receiver are summed according to a semi-coherent technique: Eigenray pairs at the receiver whose histories differ only by an additional bottom reflection near the receiver are combined coherently, with phase. These pairs are then combined incoherently with other eigenrays or pair combinations. It is expected that this approach will provide better characterization of the field near the reflecting bottom.

The fast reverberation algorithm, developed by SAIC for use in its PC model, is used here also. This approach is substantially faster than the more elaborate approach taken by NISSM II and by the NUSC Generic Sonar Model, with no significant loss in accuracy, according to limited comparisons, at ranges of interest.

A fast peak echo estimation algorithm, that includes the effects of multipath time spread and mathed filter time compression, also has been included in the model. This algorithm identifies the peak level, obtained by convolving the eigenray arrival structure with the pulse envelope, separately for propagation from source-to-target and from target-to-receiver. The two-way loss needed for the echo calculation is the product of these two contributions. The result is to save computation time by reducing the amount of eigenray sorting performed.

The model also provides estimates of direct transmission masking, handles a user-input noise value as either three-dimensionally isotropic or two-dimensionally isotropic, and offers the user a selection of representative receiver array configurations.

Graphical output choices are (1) shaded plan-view coverage plots showing signal excess for detection as a function of target location, or (2) A-scan plots of reverberation vs time along a selectable radial direction from the receiver.

Some representative computed results are shown in the following figures. A plan view of detection coverage is illustrated in Figure 2 for a particular source and receiver configuration. The receiver is positioned at the center of the diagram, and the source is located 25 miles to the left.

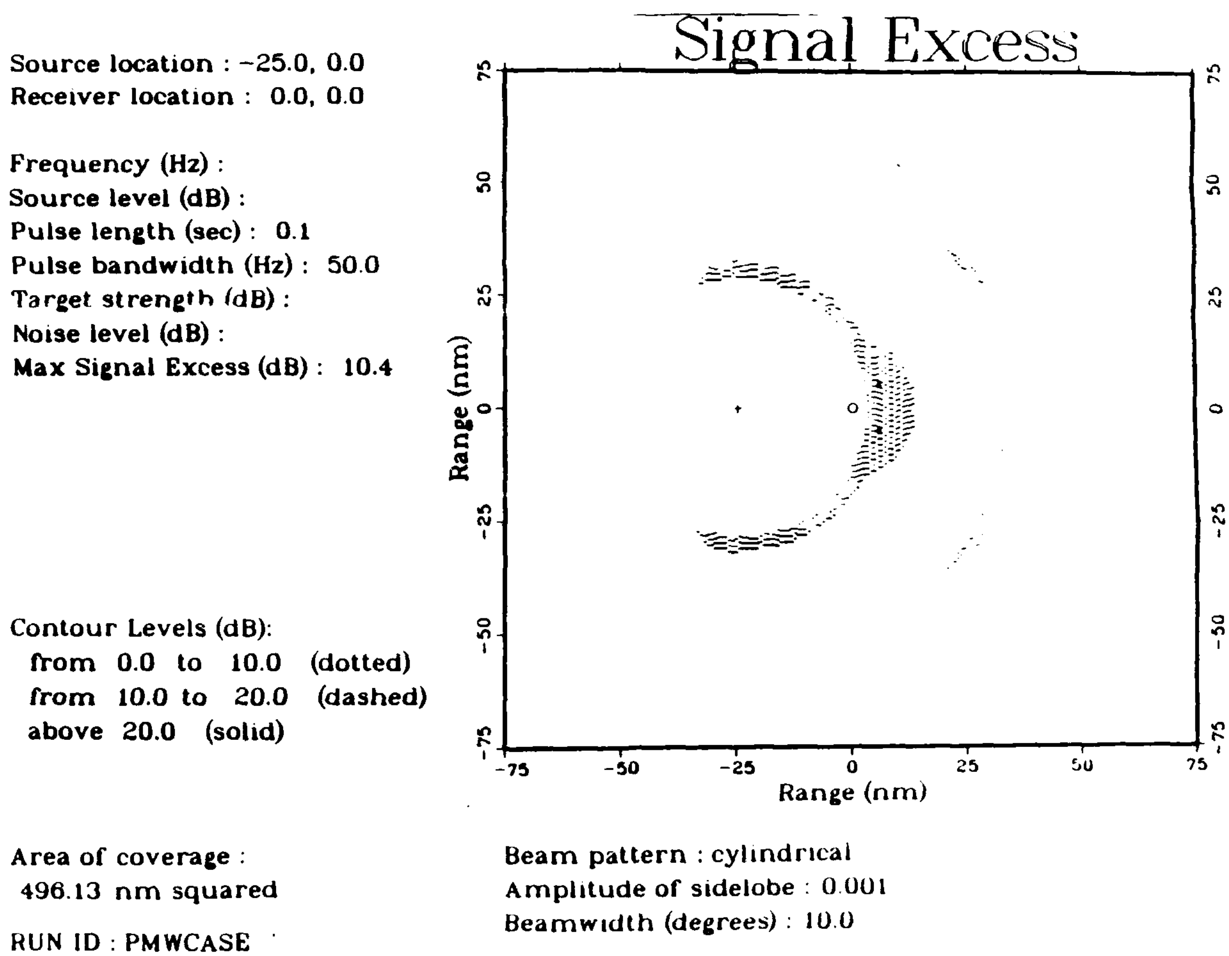


Figure 2.

Detection performance of the source-receiver combination was found to be highly sensitive to their separation. Examples of detection coverage for separations of 25, 35, and 45 miles are illustrated in Figure 3. Each case was generated in a separate model run, and each plot was aligned so that the source location was in line with zero range on the transmission loss plot at the top.

A useful measure of detection performance in this case is the total detection area. Detection area is plotted as a function of source-receiver separation in Figure 4, for a series of runs at separations in five-mile steps.

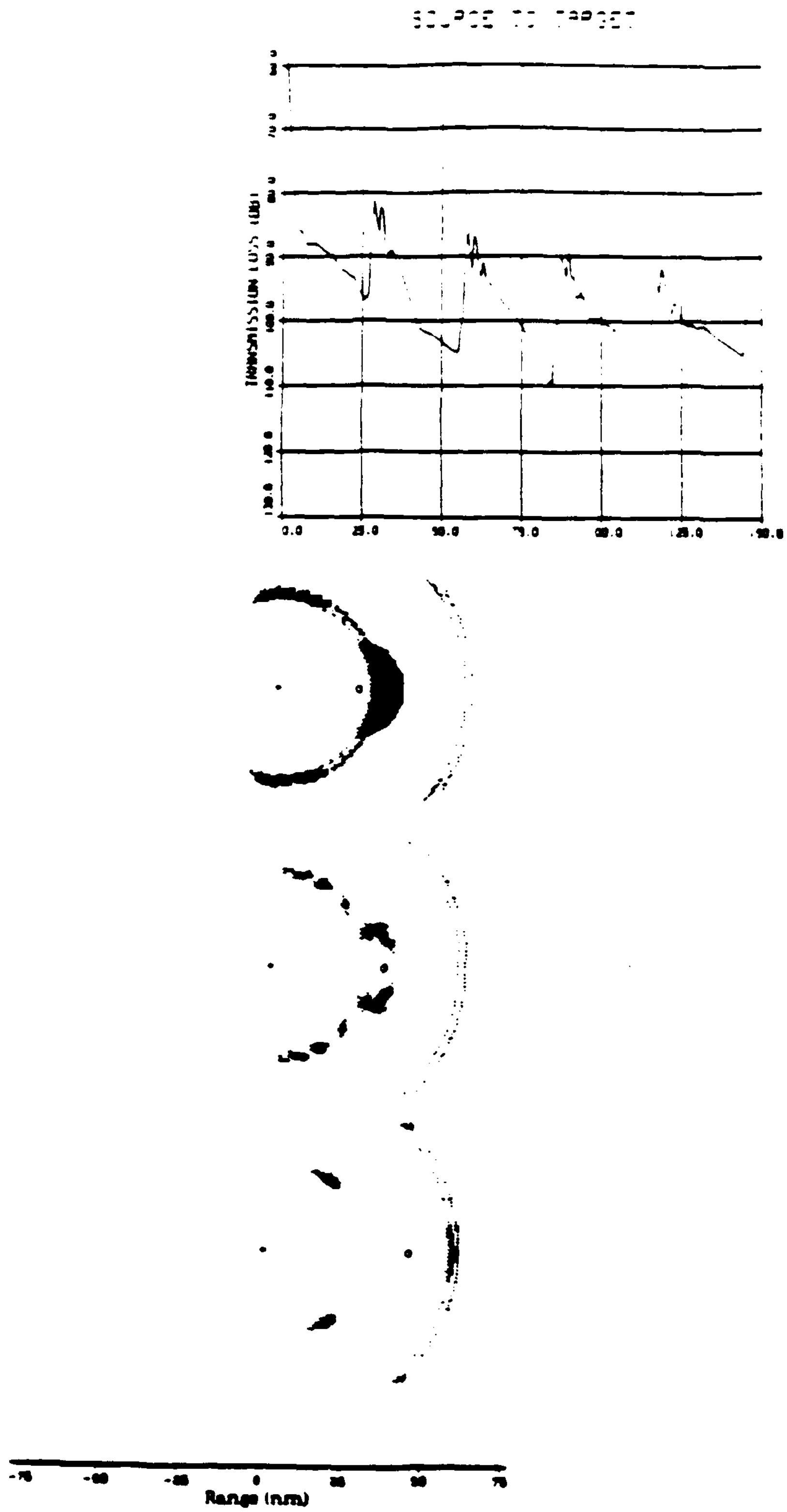


Figure 3.

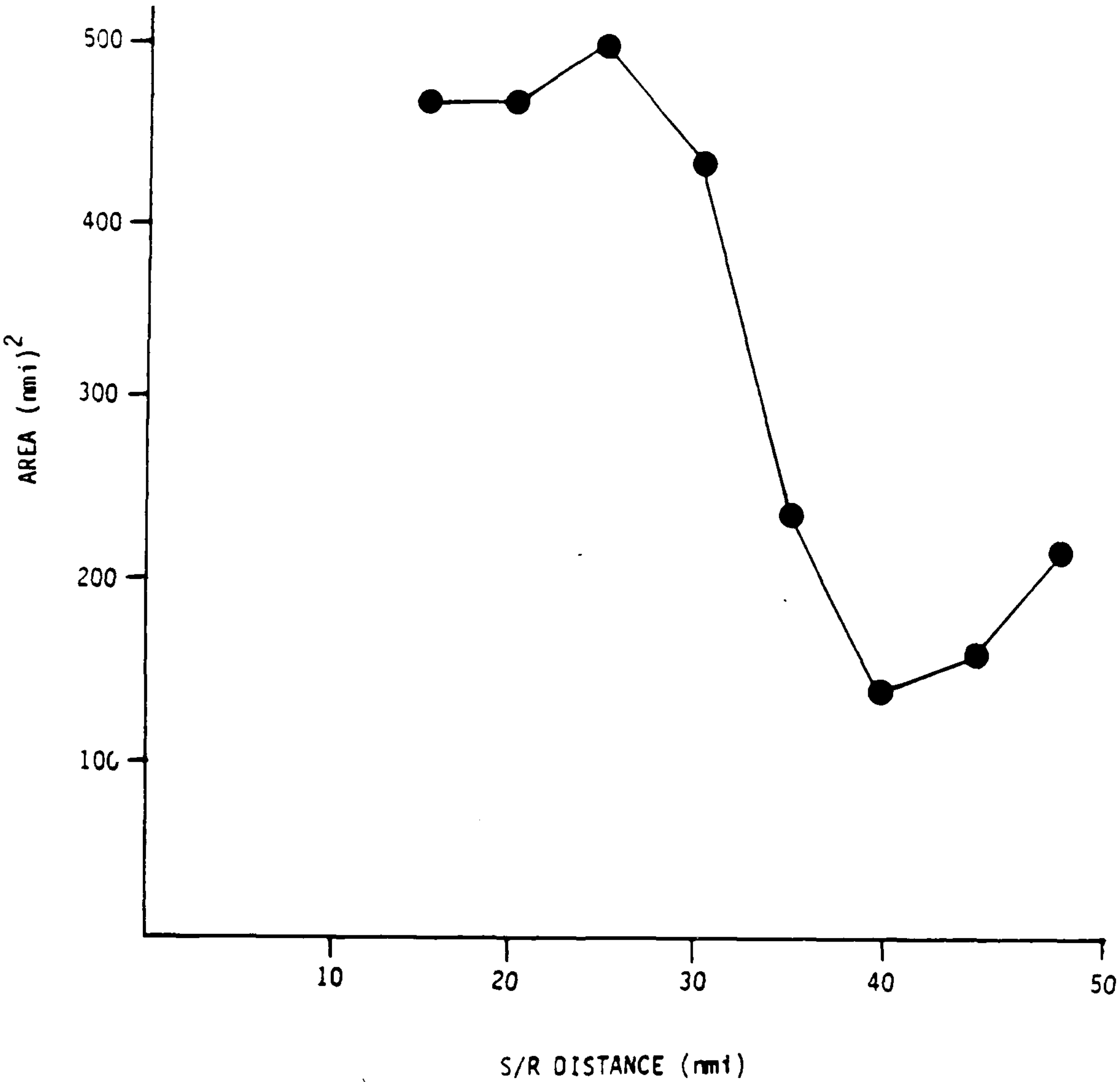


Figure 4. Detection Area as Function of Source Receiver Distance

III USER MANUAL

The following is a user guide for the SAIC ACTIVATED BOTTOM SENSOR MODEL. The program is completely menu-driven. To invoke the MAIN MENU type @MENU.

The MAIN MENU is shown in Figure 3-1. This menu is the first level and consists of five primary options. Each primary option consists of additional menus and options.

```
                    MAIN MENU

0)    EXIT
1)    SELECT RUN ID
2)    ENTER INPUT PARAMETERS
3)    PRINT/DISPLAY INPUT PARAMETERS
4)    RUN MODEL
5)    PLOT MODEL RESULTS

ENTER OPTION:
```

Figure 3-1. MAIN MENU

Option 0 is used to EXIT the program and return the user to the operating system level. The first primary option (option 1) allows the user to enter a new run ID or select an old one. The second option (option 2) allows the user to enter the desired input parameters. The third option (option 3) allows the user to print or display on the screen the input parameters associated with the selected run ID. The fourth option (option 4) allows the user to run the model. The fifth option (option 5) allows the user to plot the data generated by the model.

3.1 SELECTING OPTION 1 - SELECT RUN ID

Option 1 permits the user to enter a new run ID or select an old one. A new run ID will set all input parameters to default values. An old run ID will invoke a previously entered set of user input parameters. A run ID must be specified before any of the other options in the MAIN MENU can be selected. Figure 3-2 shows a sample RUN ID MENU.

```
                    RUN ID MENU

                 ENTER NEW RUN ID
                        or
                SELECT OLD RUN ID
                     PMW6
                     RTEST

            ENTER RUN ID (7 characters):
```

Figure 3-2. SAMPLE RUN ID MENU

3.2 SELECTING OPTION 2 - ENTER INPUT PARAMETERS

Option 2 enables the user to enter all the required input parameters via menu. A sample INPUT PARAMETERS MENU is shown in Figure 3-3. A detailed explanation of each of the options in the menu is contained in Table 3-1. There are internal checks on several of the input parameters.

```
                     INPUT PARAMETERS MENU

 0) EXIT to MAIN MENU
 1) SOURCE LOCATION (X,Y):  -X.X  X.X N MI
           DEPTH:  X.XX FT             LEVEL:  X.X dB
           VERTICAL BEAM PATTERN FILENAME - XXXX.DAT
 2) RECEIVER LOCATION (X,Y):  X.X  X.X N MI
             DEPTH:  X.XX FT
             INCOHERENT SUMMATION OF ALL EIGENRAY ARRIVALS
             NO VERTICAL BEAM PATTERN
 3) TARGET DEPTH:  X.XX FT     STRENGTH:  X.X dB
           SPEED:  X.XX KTS    HEADING:  X.X DEG
 4) BOTTOM DEPTH:  X.XX FT     SCATTERING STRENGTH:  -X.X dB
 5) BOTTOM CLASS:  X           FREQUENCY:  X HZ
 6) SOUND VELOCITY PROFILE FILENAME - XXXX.DAT
 7) VOLUME SCATTERING STRENGTH:  -X.X dB
 8) BEAM PATTERN:  CYLINDRICAL ARRAY
                   AMPLITUDE OF SIDELOBE RESPONSE:  X.XXXX
                   CYLINDRICAL BEAMWIDTH:  X.X DEG
 9) PULSE DURATION:  X.XXX SEC    PULSE BANDWIDTH:  X.XX HZ
10) NOISE:  X.X dB   DIRECTIVITY INDEX AGAINST NOISE: X.X dB
    WIND:   X.X KTS  SHIPPING LEVEL:  NOT USED TO CALCULATE
                                 NOISE
11) AREA OF INTEREST:  X-AXIS (-X.X X.X) N MI
                       Y-AXIS (-X.X X.X) N MI

ENTER OPTION:
```

Figure 3-3. SAMPLE INPUT PARAMETERS MENU

Table 3-1. INPUT PARAMETERS

0) EXIT to store input parameters and return to MAIN MENU.

1) Source

   A. Location (N MI) in (X,Y) plane. To simulate a monostatic situation, set to (0,0).

   B. Depth (FT).

   C. Level (dB) - intensity of the radiated sound in decibels relative to the intensity of a plane wave of rms pressure 1 microPascal referred to a point 1 yard from the center of the projector.

   D. Vertical Beam Pattern Filename (max. 7 characters) - power level of source beam as a function of the elevation angle. See Appendix A for sample file.

2) Receiver

   A. Location (N MI) in (X,Y) plane - preset to (0,0) N MI.

   B. Depth (FT).

   C. Eigenray Summation

      1. Semi-coherent summation for near-bottom receivers. Eigenray pairs which differ only by an additional bottom reflection are combined coherently with phase. These pairs are then combined incoherently with eigenrays or pair combinations.
      2. Incoherent summation of all eigenray arrivals.

   D. Vertical Beam Pattern Filename (max. 7 characters). See Appendix A for sample file.

3) Target

   A. Depth (FT)

   B. Strength (dB)

   C. Speed (KTS)

   D. Heading (DEG) - positive counter-clockwise from source-receiver axis.

Table 3-1. INPUT PARAMETERS (Continued)

4) Bottom

   A. Depth (FT)

   B. Scattering strength (dB) - coefficient for Mackenzie model.

5) Bottom class - enter bottom class (1-9) to access BLUG parameters in consolidated BLUG data base.

6) Ocean sound speed table filename (max. 6 characters). See Appendix A for sample file.

7) Volume scattering strength (dB).

8) Beam pattern

   A. Not applied

   B. Horizontal line array steered broadside

      1. Amplitude of sidelobe response.
      2. Array length (M) - omnidirectional array can be modeled with array length of 0.

   C. Horizontal line array steered at fixed orientation

      1. Steer direction of towed array relative to source-receiver axis (DEG).
      2. Amplitude of sidelobe response.
      3. Array length (M) - omnidirectional array can be modeled with array length of 0.

   D. Cylindrical array

      1. Amplitude of sidelobe response.
      2. Cylindrical beamwidth (DEG).

9) Source Pulse

   A. Pulse duration (SEC) - power is assumed constant over this interval. Reverberation levels are affected by 10 log pulse length, but noise levels are not.

   B. Pulse bandwidth (HZ) - increases ambient noise by 10 log bandwidth.

Table 3-1. INPUT PARAMETERS (Continued)

10) Noise

A. Ambient omnidirectional noise level (dB)

B. Directivity index against noise (dB)

C. Wind speed (KTS)

D. Shipping level - if specified used with wind to calculate ambient noise.

11) Area of interest - (X,Y) space for contour and planned view plots. Used to determine maximum range and time for model calculations.

3.3 SELECTING OPTION 3 - PRINT/DISPLAY INPUT PARAMETERS

Option 3 allows the user to print or display the user input parameters associated with the current run ID. From a menu as shown in Figure 3-4, the user can select to print the parameters on the Printronix line printer or the laser printer. The user can also select to display the input parameters on the terminal screen. The system will display 1 page of inputs and STOP. To display the second page, press RETURN. This page will remain on the screen for 30 seconds. The user will then be returned to the calling menu. A sample printout of input parameters is shown in Table 3-2.

```
PRINT/DISPLAY INPUT PARAMETERS MENU

 0)  EXIT
 1)  PRINT ON LINE PRINTER
 2)  PRINT ON LASER PRINTER
 3)  DISPLAY ON TEKTRONIX 4010 TERMINAL

ENTER OPTION:
```

Figure 3-4. PRINT/DISPLAY INPUT PARAMETERS MENU

Table 3-2. SAMPLE PRINTOUT OF INPUT PARAMETERS

```
RUNID   XXX

SOURCE (X,Y) LOCATION:   (X.XX X.XX) N MI
       DEPTH:  X.XX FT         LEVEL:  X dB
       VERTICAL BEAM PATTERN FILENAME  XXXX.DAT

RECEIVER (X,Y) LOCATION:  (0.00  0.00) N MI
          DEPTH:  X.XX FT
          EIGENRAYS AT RECEIVER ADDED COHERENTLY
          NO VERTICAL BEAM PATTERN

DISTANCE BETWEEN SOURCE AND RECEIVER  X.XX N MI
ANGLE FROM SOURCE TO RECEIVER  X.XX DEG

TARGET  DEPTH:  X.XX FT       STRENGTH:  X.XX dB
        SPEED:  X.XX KTS      HEADING:   X.XX DEG

PULSE DURATION:  X.XX SEC     PULSE BANDWIDTH:  X.XX HZ

FREQUENCY:  X.XX HZ

WIND:   X.XX KTS    SHIPPING LEVEL:  NOT USED
NOISE:  X.XX dB     DIRECTIVITY INDEX AGAINST NOISE:  X.XX dB

BOTTOM DEPTH:  X.XX FT        BOTTOM CLASS:  X

BOTTOM SCATTERING STRENGTH:  -X.XX dB
VOLUME SCATTERING STRENGTH:  -X.XX dB

SOUND VELOCITY PROFILE FILENAME  XXXX.DAT

BEAM PATTERN - CYLINDRICAL ARRAY
               CYLINDRICAL BEAMWIDTH  X.X DEG
               AMPLITUDE OF SIDELOBE RESPONSE  X.XXXX

AREA OF INTEREST: X-AXIS (X.X  X.X) N MI   Y-AXIS (X.X  X.X) N MI
                  MAX TIME:  X.XX SECS     MAX RANGE:  X.XX N MI
```

3.4 SELECTING OPTION 4 - RUN MODEL

Option 4 allows the user to execute the model. In fact several programs are automatically run in sequence. Table 3-3 shows the run sequence that will appear on the screen in order to keep the user informed on the status of the run. Note that the user must type a "Y" or "N" when queried by the system model on whether to include the direct blast. There is no direct blast for the monostatic and quasi-monostatic case.

Table 3-3. SAMPLE SCREEN RUN SEQUENCE

```
..... GENERATE EIGENRAYS
     X1 EIGENRAYS STORED (source-surface   SRCSUR.DAT)
     X2 EIGENRAYS STORED (source-target    SRCTAR.DAT)
     X2 EIGENRAYS SORTED
     X3 EIGENRAYS STORED (source-bottom    SRCBOT.DAT)
     X4 EIGENRAYS STORED (receiver-surface RCVSUR.DAT)
     X4 EIGENRAYS SORTED
     X5 EIGENRAYS STORED (receiver-target  RCVTAR.DAT)
     X6 EIGENRAYS STORED (receiver-bottom  RCVBOT.DAT)
     X6 EIGENRAYS SORTED
     X7 EIGENRAYS STORED (source-receiver SRCRCV.DAT)
         only bistatic case
..... COMPUTE RECEIVER-SURFACE TL' FILE (RUNID.RS)
..... COMPUTE SOURCE-SURFACE TL' FILE   (RUNID.SS)
..... COMPUTE SOURCE-BOTTOM TL' FILE    (RUNID.SB)
..... COMPUTE RECEIVER-BOTTOM TL' FILE  (RUNID.RB)
..... COMPUTE SOURCE-TARGET TL FILE     (RUNID.ST)
..... COMPUTE RECEIVER-TARGET TL FILE   (RUNID.RT)
..... COMPUTE DIRECT BLAST FILE         (RUNID.DIR)
         only bistatic case
..... COMPUTE REVERBERATION, ECHO, AND NOISE

Do you want to include direct blast?  (Y/N)
```

3.5 SELECTING OPTION 5 - PLOT MODEL RESULTS

Option 5 allows the user to plot the model results. Figure 3-5 shows a sample PLOT MENU. Table 3-4 provides a list of the options available for PLOT TYPE (OPTION 1) and PLOT OUTPUT DEVICE (OPTION 2). Sample plots are shown in Figures 3-6 through 3-10.

```
                    PLOT MENU

0)   EXIT to MAIN MENU
1)   SELECT PLOT TYPE
     - TRANSMISSION LOSS -
 SOURCE-SURFACE     RECEIVER-SURFACE
 SOURCE-BOTTOM      RECEIVER-BOTTOM
 SOURCE-TARGET      RECEIVER-TARGET
2)   SELECT PLOT OUTPUT DEVICE
     - TEKTRONIX 4010 GRAPHICS TERMINAL
3)   GENERATE PLOT

ENTER OPTION:
```

Figure 3-5. SAMPLE PLOT MENU

Table 3-4. PLOT OPTIONS

0) EXIT to MAIN MENU

1) Select plot type

   A. Plan view
      - Signal excess - constant recognition differential
      - Signal excess - coherent processing
      - Signal excess - incoherent processing
      - Output signal to noise ratio

   B. Contour - Beam reverberation

   C. Contour - Reverberation density

   D. Bearing scan - Reverberation, echo, noise

   E. Transmission loss

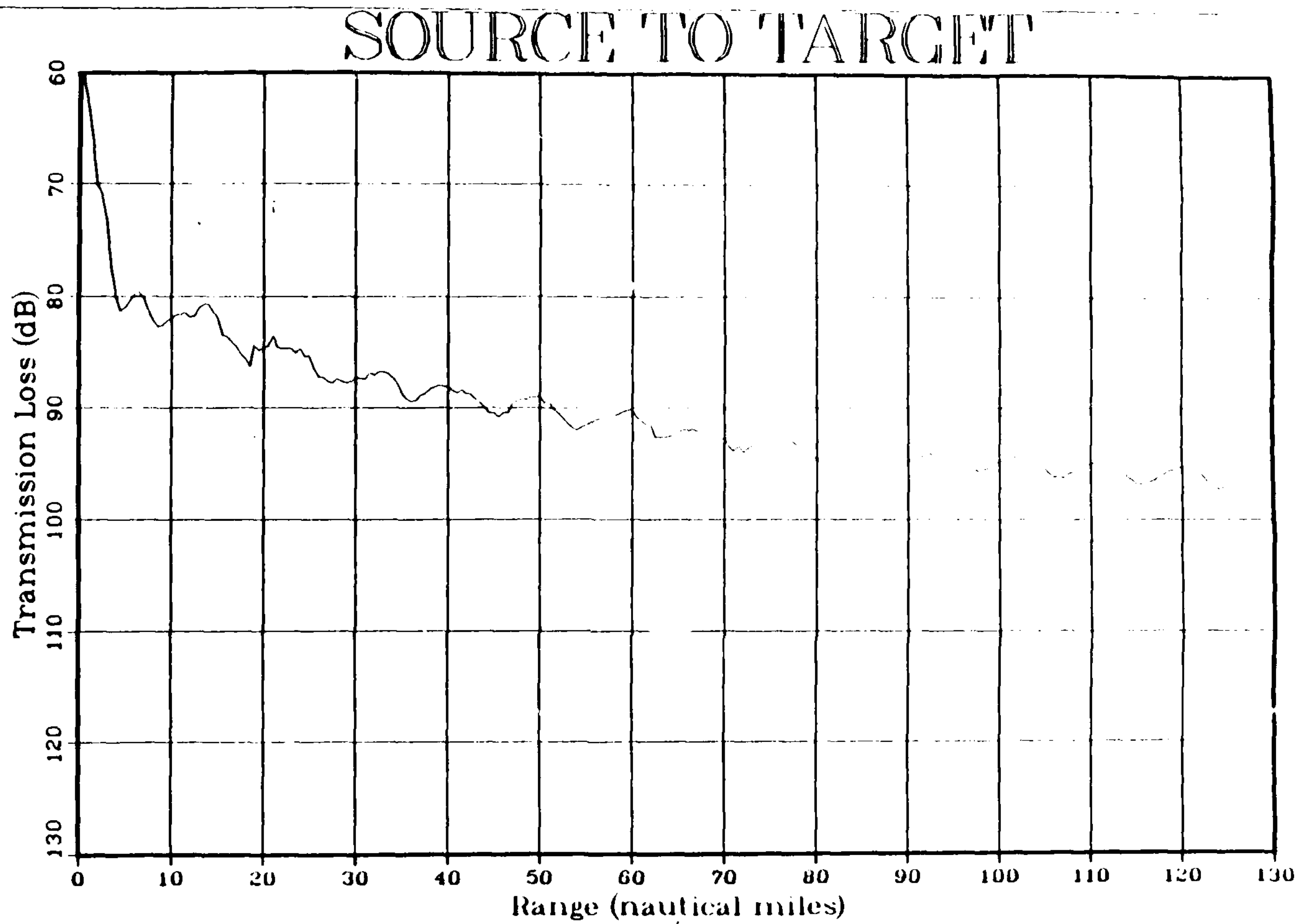
Source-Surface	Receiver-Surface
Source-Bottom	Receiver-Bottom
Source-Target	Receiver-Target

2) Select plot output device

   A. Tektronix 4010 Terminal

   B. Laser printer

3) Generate plot



RUNID : NOP2

Source depth (ft) :
Target depth (ft) :

Bottom class :
Frequency (Hz) :

Figure 3-6. SAMPLE TRANSMISSION LOSS PLOT

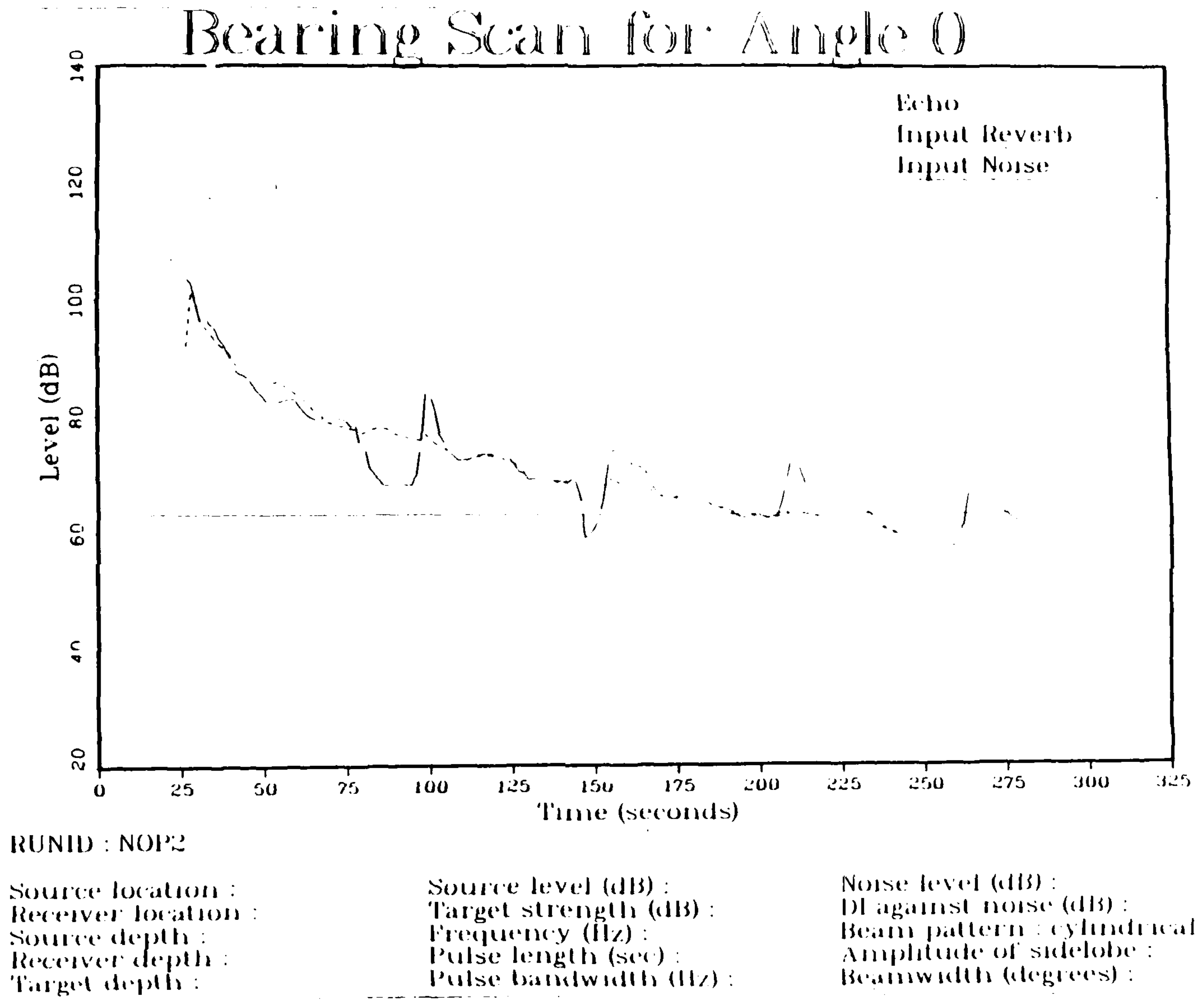


Figure 3-7. SAMPLE BEARING SCAN PLOT

Source location :
Receiver location :

Frequency (Hz) :
Pulse length (sec) :
Pulse bandwidth (Hz) :
Source level (dB) :
Source depth (ft) :
Receiver depth (ft) :
Target depth (ft) :
Target strength (dB) :
Noise level (dB) :
DI against noise (dB) :
Beam pattern : cylindrical
Amplitude of sidelobe :
Beamwidth (degrees) :

SVP filename : NOPAC
Source beam pattern : VKRBP

RUN ID : NOP2

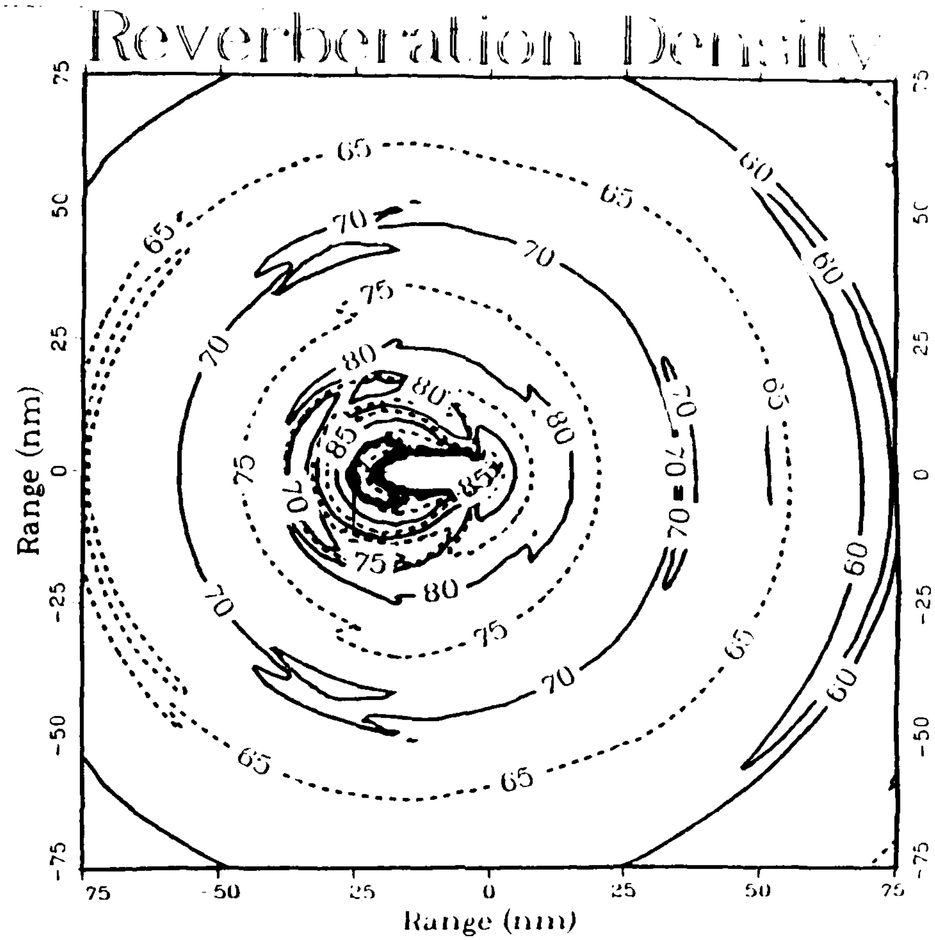


Figure 3-8. SAMPLE REVERBERATION DENSITY CONTOUR PLOT

Source location :
Receiver location :

Frequency (Hz) :
Pulse length (sec) :
Pulse bandwidth (Hz) :
Source level (dB) :
Source depth (ft) :
Receiver depth (ft) :
Target depth (ft) :
Target strength (dB) :
Noise level (dB) :
DI against noise (dB) :
Beam pattern : cylindrical
Amplitude of sidelobe :
Beamwidth (degrees) :

SVP filename : NOPAC
Source beam pattern : VKRBP

RUN ID : NOP2

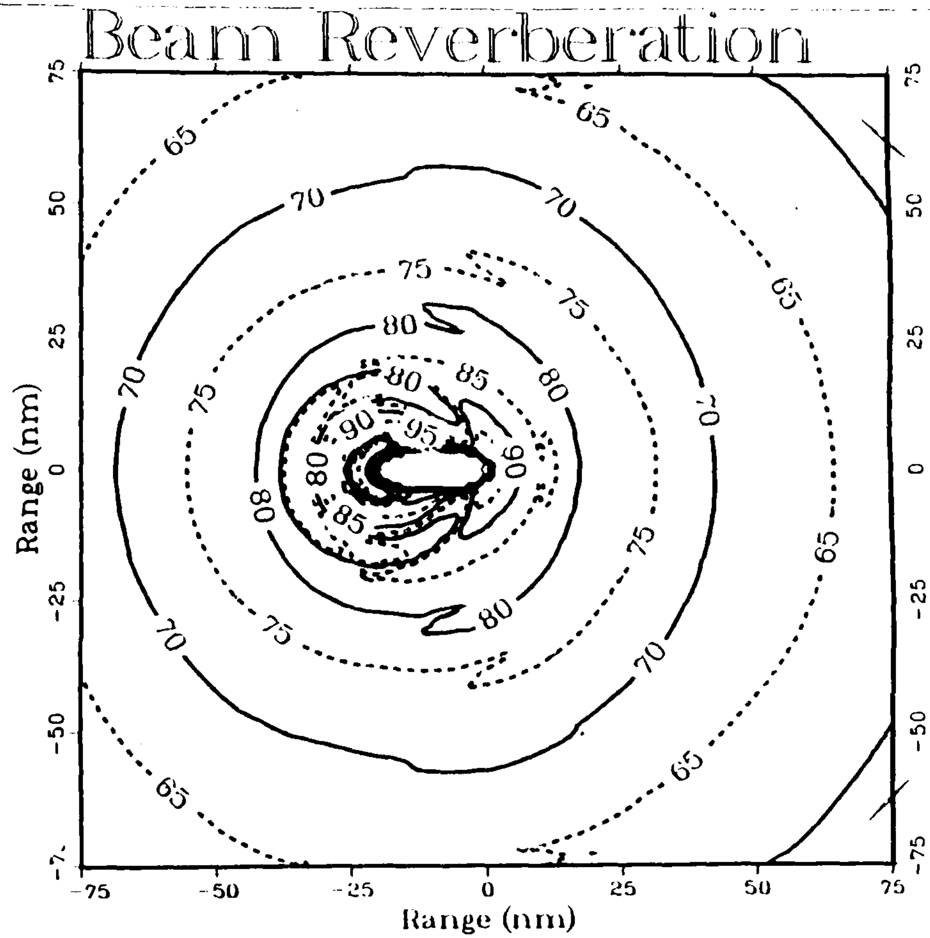
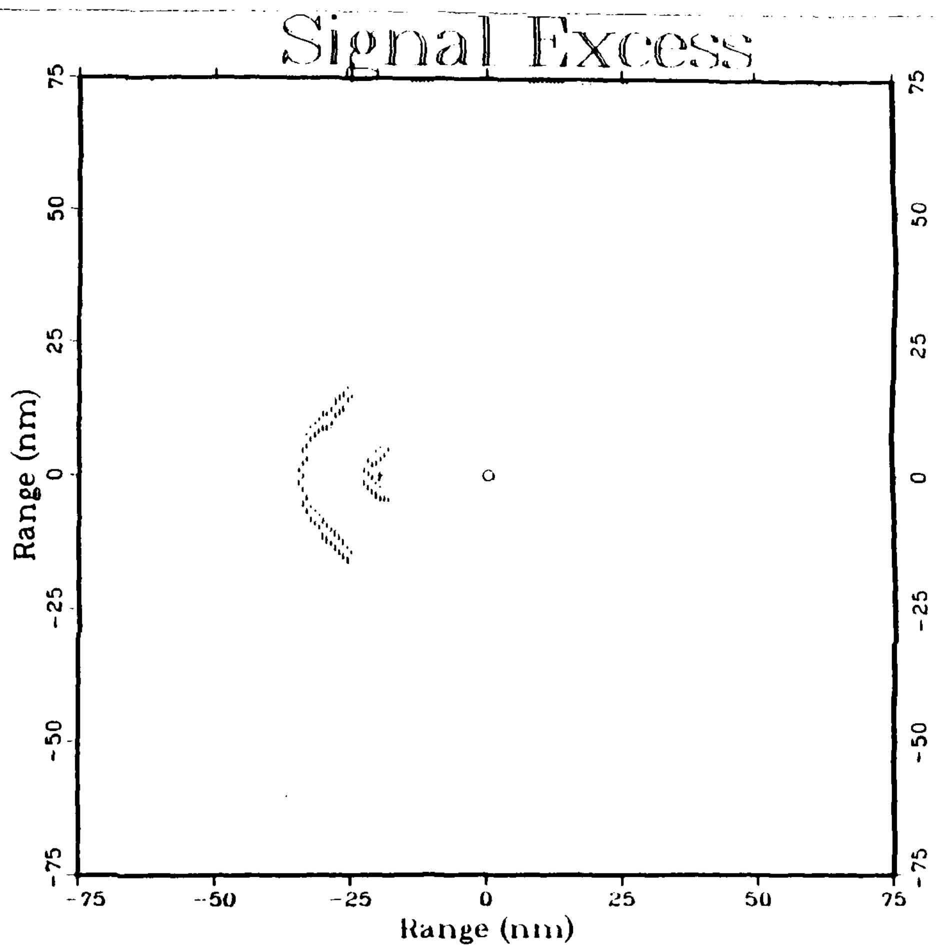


Figure 3-9. **BEAM REVERBERATION CONTOUR PLOT**

Source location :
Receiver location :

Frequency (Hz) :
Pulse length (sec) :
Pulse bandwidth (Hz) :
Source level (dB) :
Source depth (ft) :
Receiver depth (ft) :
Target depth (ft) :
Target strength (dB) :
Noise level (dB) :
DI against noise (dB) :
Beam pattern : cylindrical
Amplitude of sidelobe :
Beamwidth (degrees) :

SVP filename : NOPAC
Source beam pattern : VKRBP



Constant RD :
Max signal excess (dB) :
Area of coverage (nm sqrd) :

RUN ID : NOP2

Contour Levels (dB):
from 0.0 to 10.0 (dotted)
from 10.0 to 20.0 (dashed)
above 20.0 (solid)

Figure 3-10. SIGNAL EXCESS PLAN-VIEW COVERAGE PLOT

Appendix A
SAMPLE INPUT FILES

Sample Sound Speed Profile Input File

```
OCEAN SOUND SPEED TABLE

M          M/S
    X.XX       XXXX.XX
    XX.XX      XXXX.XX
    XXX.XX     XXXX.XX
    XXXX.XX    XXXX.XX

EOF
```

Format:

```
Title
Unit Label (A3, 7X, A5, 5X)
Depth, Ocean Sound speed (2F10.2)
....
....
EOF        (A3)
```

Sample Vertical Beam Pattern Input File
(Source and/or Receiver)

```
X
-XX.XX      -XX.XX
-XX.XX      -XX.XX
- X.XX      - X.X
0.00          0.0
X.XX        - X.X
XX.XX       -XX.XX
```

Format:

Number of elements in beam pattern table (I5)
Incident angle, Power level (dB) (2F10.2)

Positive angles are measured downward from the horizontal plane.
Beam pattern values are non-positive.