ASTRAL MODEL

VOLUME II:

SOFTWARE IMPLEMENTATION

SCIENCE APPLICATIONS, INC.

THE ASTRAL MODEL
VOLUME II:
SOFTWARE IMPLEMENTATION

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CONTENTS

		Page
1	INTRODUCTION	1-1
2	BASIC MODEL DESCRIPTION	2-1
2.1	Program DRIVER	2-6
2.1.1	Subroutine ENVIN	2-9
2.1.2	Subroutine PARIN	2-10
2.1.3	Subroutine RCVIN	2-11
2.1.4	Subroutine TRAKIN	2-12
2.1.5	Subroutine TLOUT	2-13
2.2	Subroutine ASEPTL	2-14
2.2.1	Subroutine INITAL	2-16
2.2.2	Subroutine RCVR	2-18
2.2.3	Subroutine COMPSI	2-20
2.2.3.1	Subroutine PSIRCY	2-22
2.2.3.2	Subroutine SURLOS	2-23
2.2.3.3	Subroutine EIGEN	2-24
2.2.3.3.1	Function HUP	2-26
2.2.3.3.2	Function HDN	2-30
2.2.3.3.3	Function AIRY	2-31
2.2.4	Subroutine SECTON	2-33
2.2.4.1	Subroutine TRACE	2-34
2.2.4.2	Subroutine PERIOD	2-36
2.2.4.3	Function BTMLOS	2-37
2.2.4.4	Subroutine NEWMOD	2-37
2.2.5	Subroutine SLOPE	2-38
2.2.6	Subroutine AMPDP	2-39
2.2.7	Subroutine MARCH	2-40
2.2.7.1	Subroutine COMPDW	2-42
2.2.7.1.1	Subroutine DELPSI	2-43
2.2.7.1.2	Subroutine COUPLE	2-44
2.2.7.2	Function NEWDW	2-44
2.2.7.3	Function NEWBC	2-45
2.2.7.4	Subroutine PHIBL	2-45
2.2.7.5	Subroutine RCOMP	2-46
2.2.7.6	Subroutine DBTOIN	2-47
2.2.7.7	Subroutine INTSUM	2-47
2.2.7.8	Function DONE	2-48

CONTENTS (Cont.)

	Page
2.2.8 Subroutine TLFINT	2-49
2.2.9 Subroutine SMOOTH	2-50
3 INPUT AND OUTPUT	3-1
3.1 Stand-Alone I/O	3-1
3.1.1 Input	3-1
3.1.2 Output	3-6
3.2 ASEPS I/O	3-16
3.3 Suspended Receiver Option	3-27
REFERENCES	R-1

Section 1
Introduction

This volume documents the computer code of the ASTRAL model whose physics and supporting mathematics are described in Volume I.* The purpose of this volume is to provide a bridge between the physics/mathematics of the model and the computer listing of the code. Section 2 describes the overall program flow and the functions of each of the routines. Section 3 describes the program input and output with examples.

This model was designed to be both a stand-alone model with its own driver controlling input and output as well as a callable subroutine whose input and output are handled entirely through common blocks. To avoid recomputing certain water-mass and near-field bathymetry information, some parameters, once computed, are saved for subsequent tracks in common blocks which must be made available in subsequent calls by users of the subroutine capability. Details of this dual approach are also contained in Section 3.

*Spofford (1978).

Section 2
Basic Model Description

The following subsections delineate the individual components of the ASTRAL model. The program can be conceptualized as a multi-leveled structure (Figure 2-1). The outer level, which is driven by routine DRIVER, consists of all parametric input routines (ENVIN, PARIN, TRAKIN, RCVIN), the basic control for the ASTRAL model (ASEPTL), a routine which smooths the transmission loss output (SMOOTH), and a routine for output of results (TLOUT).

The next level is composed of the major components of the ASTRAL model itself. The routines which comprise this second level are: INITAL, RCVR, SECTON, SLOPE, AMPDP, MARCH, TLFINT, and SMOOTH. The routines in this level, in turn, invoke other levels of execution (e.g., SECTON calls subroutine TRACE, which in turn calls subroutines PERIOD, BTMLOS, and NEWMOD).

A flow diagram (Figure 2-1) has been provided to facilitate conceptual understanding of the sequential nature of the execution of the model. Some license has been taken with the composition of the flow diagram: in the situations where a single subroutine is invoked by a number of other routines, the common module is depicted in all places where it is actually used (e.g., subroutine SMOOTH occurs in two places in the flow diagram).

Figure 2-2 shows the flow within the ASEPTL subroutine and between the subsequent levels of subroutines.

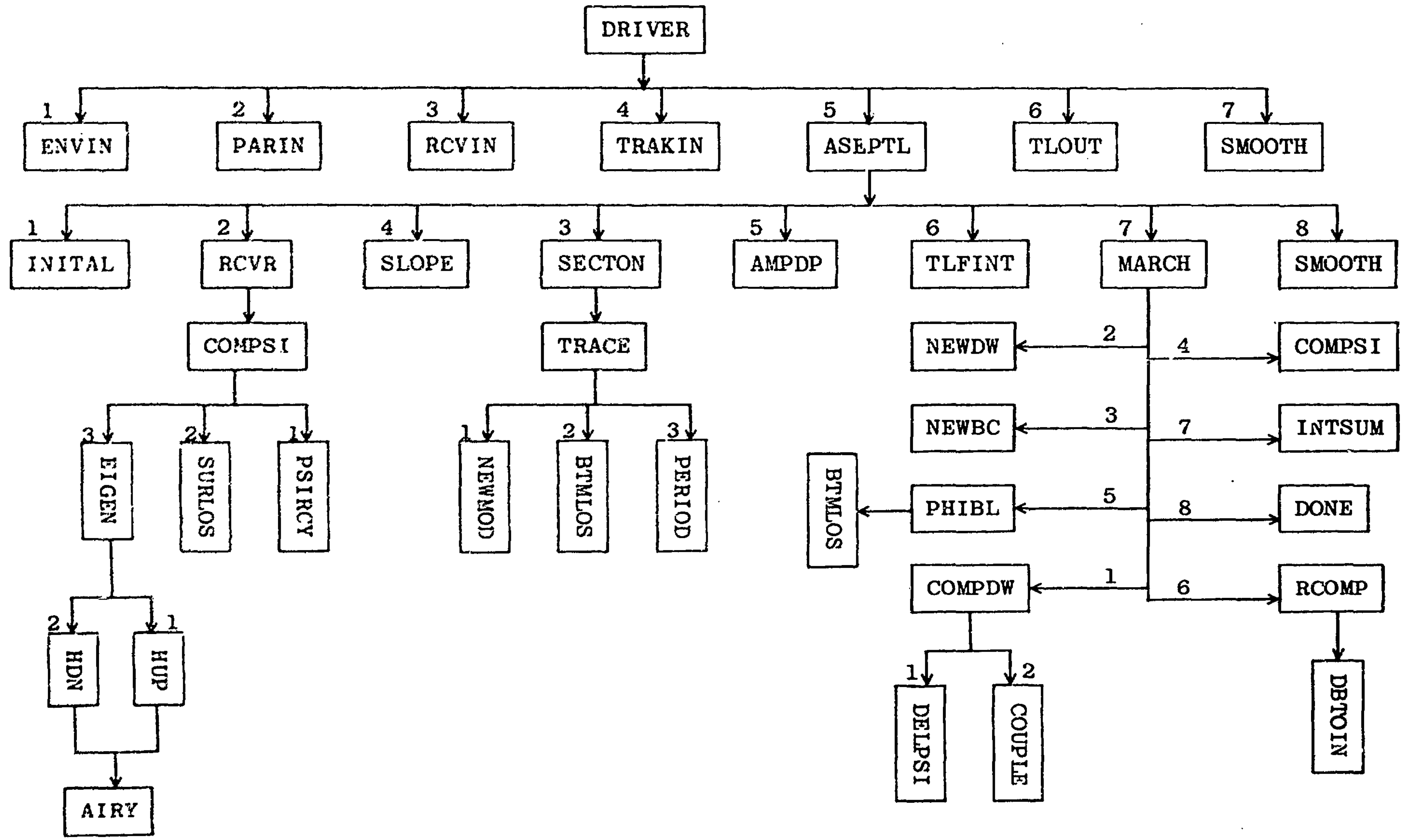

Figure 2-1. Overall Flow Diagram.

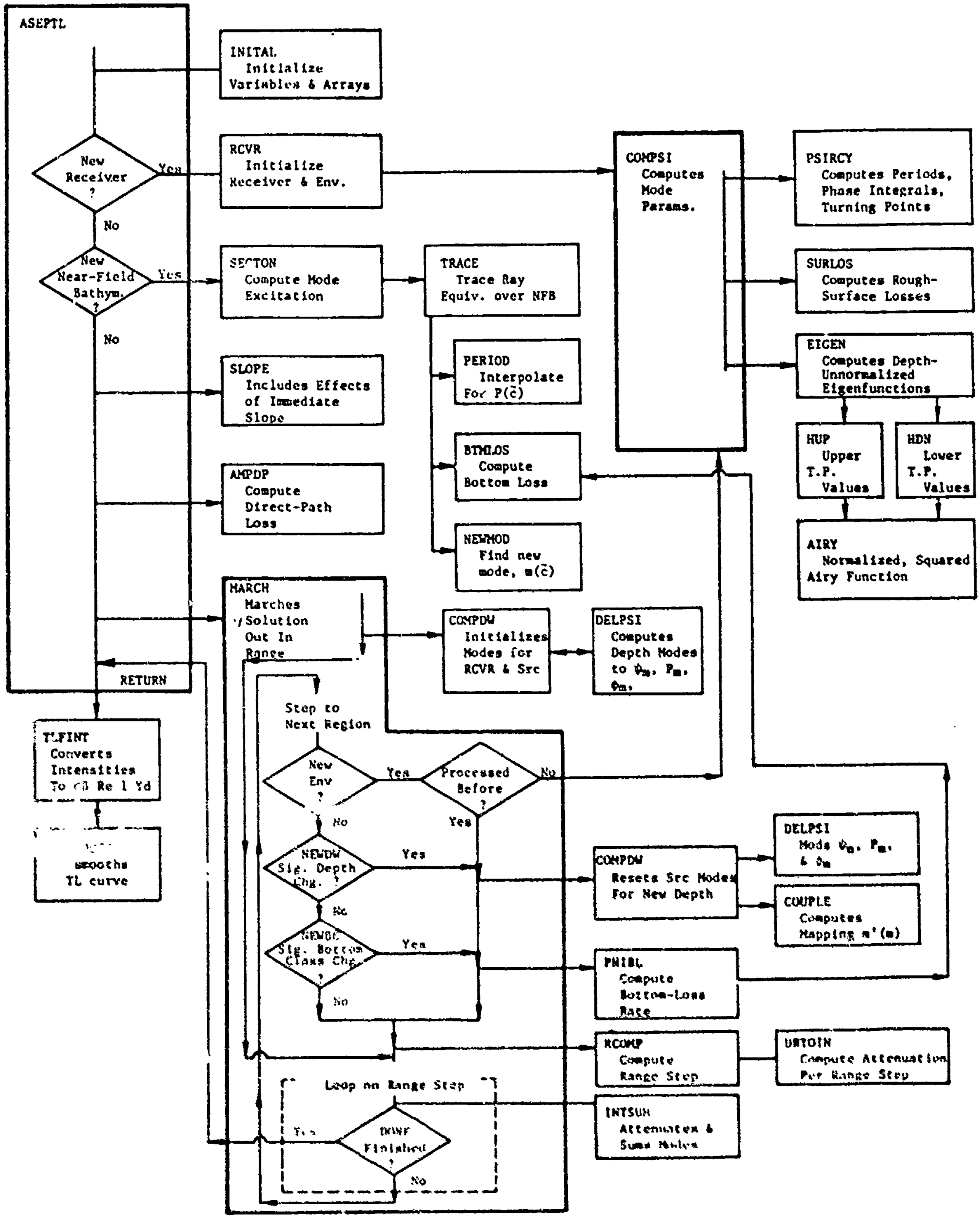

Figure 2-2. Basic Model (ASEPTL) Flow

Blocks are meant to denote routines whose names are indicated in capital letters. In a few more complicated routines some of the internal flow is indicated. Figure 2-3 identifies all subroutines and common blocks which they use.

COMMON BLOCK

SUBROUTINE	STATUS	RANGES	ENVS	ENVDET	NFB	RECVER	PRCENV	SRCFRQ	TLINT	RCVNFB	MODEMS	PHIRCV	FINISH	CONV	MODANG	BOTLOS	VOLOSS	ATTENS	SFLOSM	BOTTOM	DRDCM	TLSM
DRIVER	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
TLOUT	•	•						•	•													
ENVIN	•		•	•	•																	
PARIN	•	•			•	•	•	•														
RCVIN	•				•	•																
TRAKIN	•	•		•	•	•																
ASEPTL	•	•		•	•	•				•												
SMOOTH	•	•		•				•	•													•
INITAL	•	•					•	•	•			•	•	•	•		•	•		•		•
RCVR	•		•			•	•															
COMPSI	•		•				•	•							•							
PSIRCY																						
SURLOS																						
EIGEN	•							•														
HDN																						
HUP																						
AIRY																						
SECTON	•				•	•	•	•				•									•	
TRACE	•		•				•	•						•			•					
PERIOD							•														•	
NEWMOD							•															
SLOPE	•	•				•	•	•			•	•	•									
AMPDP		•				•		•	•													
MARCH	•	•	•	•			•				•											
COMPDW	•						•	•			•	•	•			•			•			
DELPSI																						
COUPLE											•		•									
NEWDW											•				•	•						
NEWBC											•											
PHIBL								•			•		•			•						
BTMLOS																				•		
RCOMP	•	•		•																		
DBTOIN	•							•			•		•	•		•	•	•	•			
INTSUM	•	•						•	•		•	•	•	•				•				
DONE		•											•	•								
TLFINT		•						•	•					•								

Figure 2-3. Common Block Utilization

2.1 PROGRAM DRIVER

Program DRIVER is, as its name implies, the driver for the program. DRIVER establishes the main common blocks used by the program. Additionally, it calls several subroutines which perform a variety of utility functions. The subroutines called by DRIVER are as follows:

Subroutine	Formal params.	Param. desc.	Sub. desc.
ENVIN	none	---------	reads and prints environmental input parameters
PARIN	none	--------	reads and prints other parametric input (e.g., ranges, source depth, etc.)
RCVIN	NTRACK	track number	reads and prints receiver input
TRAKIN	none	--------	reads and prints track input
ASEPTL	none	--------	driver for ASTRAL model
TLOUT	none	--------	prints results (viz., TL as a function of range, depth, and frequency)

Each of the aforementioned subroutines will be dealt with in greater detail in later sections of this volume.

The overall flow of the program through DRIVER is as follows:

1. Environmental parameters (e.g., number of profiles, number of points per profile, the sound speed profiles themselves, etc.) are read in. A summary of these inputs is then printed. (ENVIN)

2. Parametric inputs for the specific problem to be solved (viz., number of range points, maximum range step, source depths, frequencies, and the maximum number of modes) are read in. A summary of these inputs is then printed. (PARIN)

3. Data for each receiver (viz., number of tracks, receiver depth, and near-field bathymetry) are read in. A summary of the receiver input is then printed. (RCVIN)

4. For each track specified in part 3, track parameters (viz., number of environments, maximum range, immediate track slope, and near-field bathymetry index) are read in and printed. (TRAKIN)

5. Subroutine ASEPTL, the driver for the actual ASTRAL model, is invoked.

6. Transmission loss, as a function of depth, frequency, and range is printed in matrix form. (TLOUT)

7. Steps 4 through 6 are repeated for each track.

8. Steps 3 through 7 are repeated for each receiver.

The option exists for both raw and smoothed transmission loss curves to be printed. Use of the raw printout option is controlled by the value of the logical variable DEBUG(3). If DEBUG(3) is .TRUE., the transmission loss curve is first printed as raw data, then smoothed, and printed again. If the value of DEBUG(3) is .FALSE., the raw data is smoothed before printing, and then printed.

2.1.1 Subroutine ENVIN

Subroutine ENVIN is called from the main program driver (DRIVER). It is responsible for reading the environmental input parameters. Subroutine ENVIN calls no other subroutines; once it has been executed, control returns to the main program driver.

The following variables are established by subroutine ENVIN:

Variable	Description	Common
NPROFS	number of profiles or water masses	local var.
NZC(20)	number of points in each profile	/ENVS/
IFPRE(20)	logical variable which indicates whether an environment has been previously processed; initially set to .FALSE.	/ENVS/
ZE(25,20)	depth points for each profile (ft)	/ENVS/
CE(25,20)	sound speed points for each profile (ft/sec)	/ENVS/
WVHTE(20)	wave height (ft) corresponding to each water-mass area	/ENVS/

Subroutine ENVIN prints the environmental input parameters in summary form.

2.1.2 Subroutine PARIN

Subroutine PARIN is called by the main program driver. It reads the parametric inputs specific to the problem to be analyzed. No other subroutines are called by subroutine PARIN; once it has been executed, control is returned to the main program driver.

The following variables are established with a call to subroutine PARIN:

Variable	Description	Common
NRMAX	maximum number of range points (≤ 400)	/RANGES/
DRMAX	maximum range step (nmi)	/RANGES/
NZS	number of source depths (≤ 3)	/SRCFRQ/
NF	number of frequencies (≤ 6)	/SRCFRQ/
ZS(3)	source depths (ft)	/SRCFRQ/
F(6)	frequencies (Hz)	/SRCFRQ/
MMAX	maximum number of modes (≤ 25)	/PRCENV/
DEBUG(5)	logical variable controlling optional output	/STATUS/

Subroutine PARIN prints a summary of the parametric inputs before returning control to the main driver.

2.1.3 Subroutine RCVIN

Subroutine RCVIN is invoked by the main program driver. It establishes input data for each receiver to be analyzed. RCVIN calls no other subroutines; when execution of RCVIN is completed, control returns to the main program driver.

The following receiver variables are established with a call to subroutine RCVIN:

Variable	Description	Common
NTRACK	number of tracks	Formal Param.
ZR	receiver depth (ft)	/RECVER/
FRSRCV	logical variable; set to .TRUE.	/RECVER/
FRSNFB(8)	logical variable; set to .TRUE.	/NFB/
ZNFBZ(8)	zero-range depth (ft)	/NFB/
THNFB(8)	slope angle (radians, negative down): THNFB < -1.5 for suspended receiver	/NFB/
RNFB(8)	slope range (nmi)	/NFB/
IBCNFB(8)	slope bottom class	/NFB/

Subroutine RCVIN prints a summary of the receiver inputs before returning control to the main program driver.

2.1.4 Subroutine TRAKIN

Subroutine TRAKIN is called by the main program driver. Its function is reading the data for each track. No other subroutines are called by subroutine TRAKIN; once its execution is completed, control is returned to the main program driver.

The following variables are established with a call to subroutine TRAKIN:

Variable	Description	Common
NENV	number of environment steps ($\leq$ 400)	/ENVDET/
RMAX	maximum range (nmi)	/RANGES/
THBRC	immediate track slope (rads)*	/RECVER/
INFB	near-field bathymetry index for this track	/NFB/
INDEX(400)	index for water mass in each step	/ENVDET/
IBC(400)	FNWC 1-5 (reset to 1,3,4) bottom class for each step	/ENVDET/
RENV(400)	beginning range (nmi) of new environment or step	/ENVDET/
DEP(400)	depth (ft) of this step	/ENVDET/

Subroutine TRAKIN prints a summary of the track inputs before returning control to the main program driver.

*THBRC $< -$ 1.5 rads for a suspended receiver

2.1.5 Subroutine TLOUT

Subroutine TLOUT is called by the main program driver to produce, in table form, the results of the ASTRAL model. Subroutine TLOUT is called after the data for each track have been processed. TLOUT is called with no formal parameters, and calls no other subroutines.

The following information is printed with a call to subroutine TLOUT. For a detailed description of output see Section 3.

Variable	Description
IEND	termination code
IR	number of range steps
ZS	array of source depths
F	array of frequencies

For each range step:

I	step number
RANGE(I)	range
AMPM(I,J,K)	TL for range step I (at range RANGE(I)) for K frequencies and J source depths

If the transmission loss profile is smoothed, subroutine TLOUT is called an additional time, after the smoothing process has been executed.

2.2 SUBROUTINE ASEPTL

The call to subroutine ASEPTL from the main program driver invokes the actual ASTRAL model. Subroutine ASEPTL serves as the driver for the subroutines which comprise the ASTRAL model and establishes the necessary common blocks. The flow of subroutine ASEPTL is indicated in Figure 2-2.

Calls are made from subroutine ASEPTL to the following subroutines:

Subroutine	Formal Parameters	Param. desc.	Description of subroutine
INITAL	none	----	initializes all internal variables
RCVR	INDEX(1)	sequential water mass index	initializes parameters for new receiver (including its profile) computes receiver angle and coupling for each mode
SECTON	INDEX(1) MUP(1,INFB) ATUP(1,INFB)	 mode index accumulated intensity loss	computes slope-conversion effects on each mode the receiver couples to
SLOPE	MUP(1,INFB) ATUP(1,INFB)		adjusts for effects of immediate slope
AMPDP	RNFB(INFB)	range to end of slope	computes direct path intensity using spherical spreading and two incoherent paths
MARCH	DPNFB	depth at range RNFB	march solution out in range
TLFINT	none	----	converts intensity to transmission loss
SMOOTH	none	----	smooths raw transmission loss curve

Additional information concerning the individual subroutines called by subroutine ASEPTL follows.

2.2.1 Subroutine INITAL

The call to subroutine INITAL from subroutine ASEPTL causes the initialization of all variables and arrays internal to the ASTRAL model. The following parameters are directly affected by a call to subroutine INITAL:

Variable	Description	Common block
Bottom loss parameters defined		
THCRIT(5,3)	critical angle (deg)	-----
BLZER(5,3)	loss at minimum grazing angle (dB)	-----
THXX(5,3)	angle at which loss becomes constant	-----
BLXX(5,3)	bottom loss at THXX (dB)	-----
FBRK(4)	break frequencies (Hz)	-----
Bottom loss angles and bottom loss by frequency class computed		
THC(6,5)	critical angle	/BOTTOM/
BLZ(6,5)	bottom loss at zero grazing angle	/BOTTOM/
THX(6,5)	first angle at maximum loss	/BOTTOM/
BLX(6,5)	loss at angle THX	/BOTTOM/
DBLDTH(6,5)	bottom loss slope (dB/rad)	/BOTTOM/
VLOSS(6)	volume loss (dB/nmi) at each frequency	/VOLOSS/
Logical variables for control of processing		
IFALL	indicates all modes attenuated below threshold; signals end of processing (.F.)	/FINISH/
IEND	values 0-5; termination code for run (0)	/RANGES/
IFMDN(25)	indicates end of mode processing (.T.)	/FINISH/
IFDONE(6,25)	indicates end of processing mode for each frequency (.T.)	/FINISH/

Variable	Description	Common Block
Mode variables zeroed		
PHIRC(6,25)	mode amplitude	/PHIRCV/
Tolerance levels		
DBCONV	conversion factor to dB re 1 yd	/CONV/
TLMAX	maximum transmission loss	/CONV/
AMPMIN	minimum amplitude (corresponding to TLMAX)	/CONV/
PHIMIN	minimum Eigenfunction amplitude	/CONV/
DZMIN1	minimum width for an eigenfunction	/CONV/
ATTMAX	maximum attenuation	/CONV/
Angle increments		
NA1	number of angles at DTH1	/MODANG/
NA2	number angles at DTH2	/MODANG/
DTH1	angle increment for first NA1 angles	/MODANG/
DTH2	angle increment for next NA2 angles	/MODANG/
TLTOL	maximum TL change (for smoothing)	/TLSM/
REPS	range tolerance (smoothing)	/TLSM/
DEPS	fractional depth tolerance (smoothing)	/TLSM/
RSMAX	maximum range window for smoothing	/TLSM/

Optional debug printout is available by setting the value of DEBUG(2) to .TRUE. Subroutine INITAL calls no other subroutines; once its execution is completed, control returns to subroutine ASEPTL.

2.2.2 Subroutine RCVR

For each new receiver (FRSRCV=.TRUE.), subroutine ASEPTL calls subroutine RCVR. RCVR is called with one formal parameter, INDEX(1), the index of the water masses at the receiver.

Subroutine RCVR performs any necessary parametric changes occasioned by the new receiver. The sound speed at the new receiver is determined by linear interpolation. Additional data, including the index of the first mode with which the receiver couples and the angle at the receiver for each mode are also computed.

The following variables are affected by a call to subroutine RCVR:

Variable	Description	Common
THR(25)	angle of each mode at receiver (+ radians)	/RECVER/
DSTHR(25)	solid angle of each mode at receiver	/RECVER/
MMIN	index of first mode receiver couples to	/RECVER/
FRSRCV	logical variable indicating presence of new receiver; set to .FALSE. at end of subroutine RCVR	/RECVER/

Subroutine RCVR calls subroutine COMPSI, which determines the new mode parameters. The call to subroutine COMPSI is of the form:

```
CALL COMPSI (IX,PHINF(1,IX))
```

where

IX = INDEX(1)	See above
PHINF(1,IX)	array of Eigenfunction values within COMPSI the mode/frequency/ source-depth dependencies are included in a three-dimensional array equivalenced to PHINF(1,IX)

Additional information concerning subroutine COMPSI follows.

Once execution of subroutine RCVR is completed, control is returned to subroutine ASEPTL.

2.2.3 Subroutine COMPSI

Subroutine COMPSI computes the mode parameters for each new environment. COMPSI may be called either by subroutine RCVR or by subroutine MARCH. It is called with two formal parameters, as follows:

CALL COMPSI (IX, PHINF(1,IX))

where

IX	index of water mass of interest
PHINF(1,IX)	array of Eigenfunction values

Initially, the sound-speed minimum is determined. From that, the phase velocities are computed (see Volume I, Section 2.3.4). A call to subroutine PSIRCY generates, for each mode, the phase integral, range period, upper and lower turning point depths, and upper and lower turning point gradients (subroutine PSIRCY will be discussed in detail in the next subsection). The call to subroutine PSIRCY is as follows:

```
CALL PSIRCY(NC,ZE(1,IX),CE(1,IX),CM(M,IX),PSIZ(M,IX),RCYCZ(M,IX),
          ZUP(M,IX),ZDN(M,IX),GUP,GDN)
```

where

NC	no. of points in current sound-speed profile
ZE(1,IX)	depth of first point on profile (ft)
CE(1,IX)	sound speed of first point on profile
CM(M,IX)	phase velocity (ft/sec) of mode M for environment IX

PSIZ(M,IX)	phase integral (sec)
RCYCZ(M,IX)	range period (nmi)
ZUP(M,IX)	upper turning point depth
ZDN(M,IX)	lower turning point depth
GUP	upper turning point gradient
GDN	lower turning point gradient

Surface loss is the next parameter to be established. At present, zero loss is assumed for all angles, frequencies, and waveheights. This is currently done within subroutine COMPSI; however, once an expression for surface loss is available, it can readily be implemented in subroutine SURLOS, which is currently inactive.

In the event that subroutine SURLOS is utilized, the calling sequence is as follows:

```
CALL SURLOS (STHSRF,WVHTE(IX),NF,F,SURFLS(1,M,IX))
```

where

STHSRF	sin(surface grazing angle)
WVHTE	waveheight (ft)
NF	number of frequencies
F	frequency array (Hz)
SURFLS(1,M,IX)	surface loss returned (dB/bounce)
M	mode number
IX	environment number

Subroutine COMPSI next calls subroutine EIGEN, which computes depth-unnormalized eigenfunctions for the source. The call to subroutine EIGEN is as follows:

```
CALL EIGEN(CM(M,IX),CS,STHSRF,ZUP(M,IX),ZDN(M,IX),GUP,GDN,CZS,
        XPHINF(1,1,M)
```

where

CS = CE(1,IX)	sound-speed at surface
CZS	sound-speed at source depths
XPHINF(1,1,M)	array of Eigenfunction values (treated by EIGEN as 2-dimensional array on frequency/source-depth)

Subroutines EIGEN, SURLOS, and PSIRCY will be discussed subsequently.

Subroutine COMPSI returns control to subroutine ASEPTL upon completion of execution.

2.2.3.1 Subroutine PSIRCY

Subroutine PSIRCY computes mode parameters for each new environment. PSIRCY is invoked by a call from subroutine COMPSI. Computations are made for each layer in the sound speed profile, and are dependent on the computed value of the gradient at each point. The gradient value specifies whether or not the point in question is a turning point. For a non-zero gradient, the range period and the phase integral of each mode in the new environment are adjusted.

The following variables are affected by a call to PSIRCY:

Variable	Description
PSIZ(M,IX)	phase integral (sec) of mode M for environment IX
RCYCZ(M,IX)	range period (nmi)
ZUP(M,IX)	upper turning point depth

Variable	Description
ZDN(M,IX)	lower turning point depth
GUP	upper turning point gradient
GDN	lower turning point gradient

For a complete treatment of the methodology involved in the computations, see Volume 1, Section 3.2.2.

Subroutine PSIRCY calls no other subroutines; once its execution is complete control is returned to subroutine COMPSI.

2.2.3.2 Subroutine SURLOS

Subroutine SURLOS computes surface losses in dB per bounce for each specified frequency. At present, subroutine SURLOS returns a value of zero for all surface losses. This can easily be modified with placement of an appropriate expression for surface loss in the subroutine.

The following variables are affected by a call to subroutine SURLOS:

Variable	Description
STHSRF	sin(surface grazing angle)
WVHTE	waveheight (ft)
NF	no. of frequencies
F	frequencies (Hz)
SURFLS(1,M,IX)	surface loss (dB/bounce) mode M environment IX

Subroutine SURLOS calls no other subroutines; once execution is completed, control returns to subroutine COMPSI.

2.2.3.3 Subroutine EIGEN

Subroutine EIGEN is called by subroutine COMPSI to compute depth un-normalized source eignfunctions. These eigenfunctions are functions of the upper and lower turning point depths, upper and lower turning point gradients, source depth, and frequency.

Geometric limits on intensity and the corresponding diffraction-limit angle are initially set. Then, for each frequency, the lower turning point scale factors and limits of diffraction (e.g., minimum angle before diffraction limits intensity, caustic limit on intensity, and depth scale factor) are determined. A check is made to determine whether the mode is totally internally refracted (RR) or refracted at depth and surface reflected (RSR). Based on this information, appropriate calculations of the upper turning point scale factors and diffraction limits are made.

It is then determined whether the upper and lower turning point regions overlap. If overlap exists, the region of overlap is defined, and a linear interpolation between the upper and lower caustic limits on intensity is performed.

Subroutine EIGEN utilizes functions HUP and HDN to compute the values of the eigenfunctions associated with the upper and lower turning points, respectively. Functions HUP and HDN use Airy functions to compute the eigenfunctions of the upper and lower turning points in the following manner:

$$h_{up} = h_{c_{up}} \left\{ \left[\frac{Ai^2(-\alpha_{up}(Z - Z_{up}))}{Ai^2(0)} \right]^{1/2} - (\text{If } Z \neq 0) \left[\frac{Ai^2(-\alpha_{up}(-Z - Z_{up}))}{Ai^2(0)} \right]^{1/2} \right\}^2$$

$$h_{dn} = h_{c_{dn}} \frac{Ai^2(\alpha_{dn}(Z - Z_{dn}))}{Ai^2(0)}$$

where h_c = caustic limit of intensity

Ai = Airy function

α = depth scale factor

$Z_{up/dn}$ = upper/lower turning point depths

Z = source depth

Functions HUP and HDN are discussed in more detail subsequently. For an in-depth treatment of the methodology involved in the development of the source eigenfunctions, see Volume I, Section 3.2.2.

Function HUP is invoked by subroutine EIGEN in the following manner:

```
H(J) = HUP(ZS(J),ALUP,HCUP,ZUP,HG(J),TH3(J),THUP3)
```

where ZS(J) = source depth

ALUP = depth scale factor = α_{up} = $1.77/\Delta Z_{up}$

HCUP = caustic limit of intensity = $1/\theta_{up}$

ZUP = upper turning point depth

HG(J) = geometric intensity limit = $1/\tan(\theta_{up})$

TH3(J) = θ^3; θ = angle at source depth Z_s of the ray equivalent

THUP3 = $\theta_{up}{}^3$; θ_{up} = minimum angle permitted before diffraction limits intensity

A flow diagram of subroutine EIGEN is shown in Figure 2-4.

2.2.3.3.1 Function HUP

Function HUP computes the eigenfunction value associated with the upper turning point. The parameters necessary for upper turning point eigenfunction computation are:

HUP(ZS,ALUP,HCUP,ZUP,HG,TH3,THUP3)

where
ZS = source depth

ALUP = depth scale factor

HCUP = upper caustic limit for intensity = $1/\theta_{up}$

ZUP = upper turning point depth

HG = geometric intensity limit

TH3 = cube of angle θ at source depth ZS of the ray equivalent

THUP3 = $\theta_{up}{}^3 = (3/4)g_{up}/f$

The upper turning point eigenfunction H(J), is computed as follows:

Subroutine EIGEN

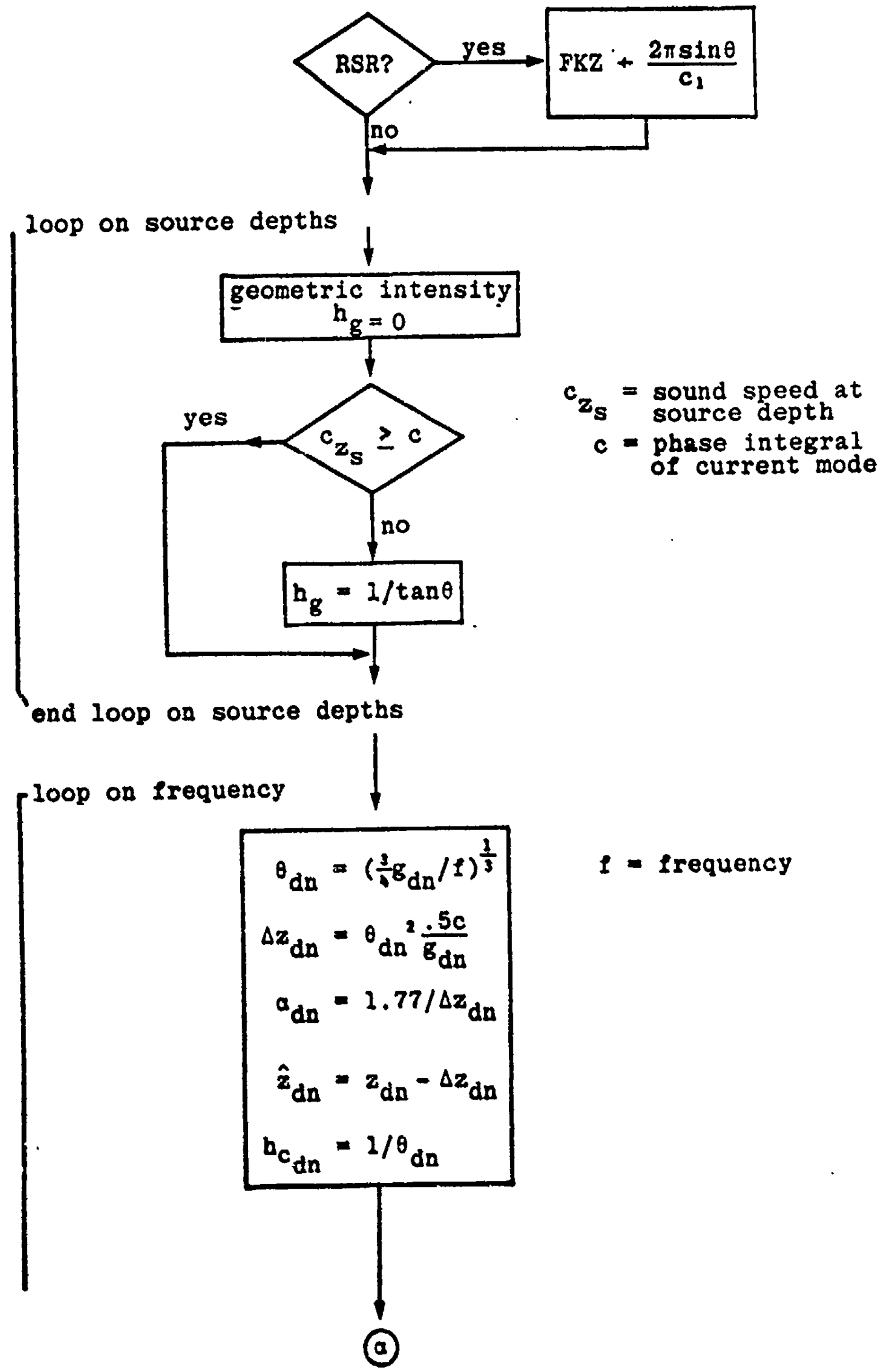

Figure 2-4a. EIGEN Flow

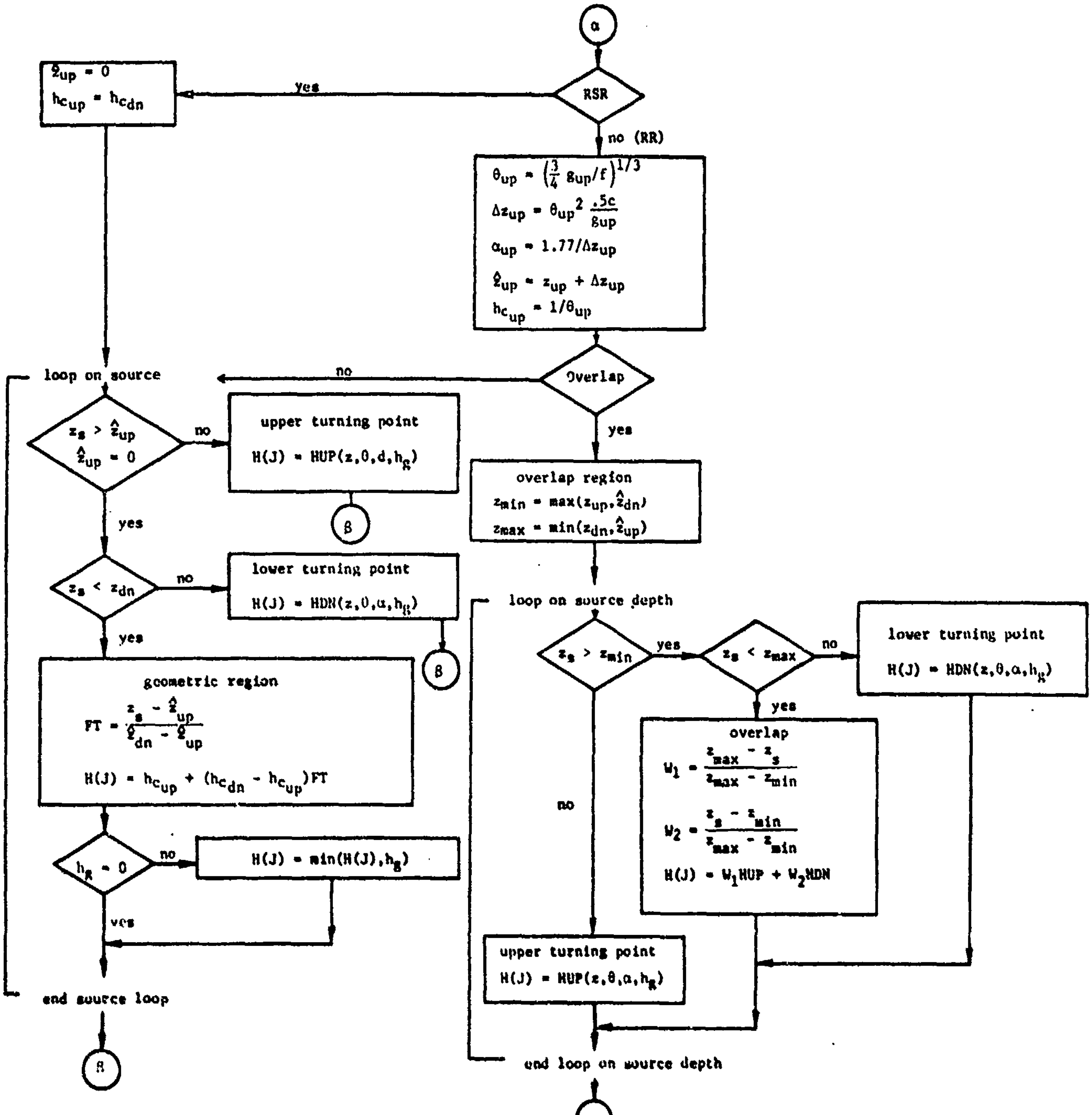

Figure 2-4b. EIGEN Flow (Cont.)

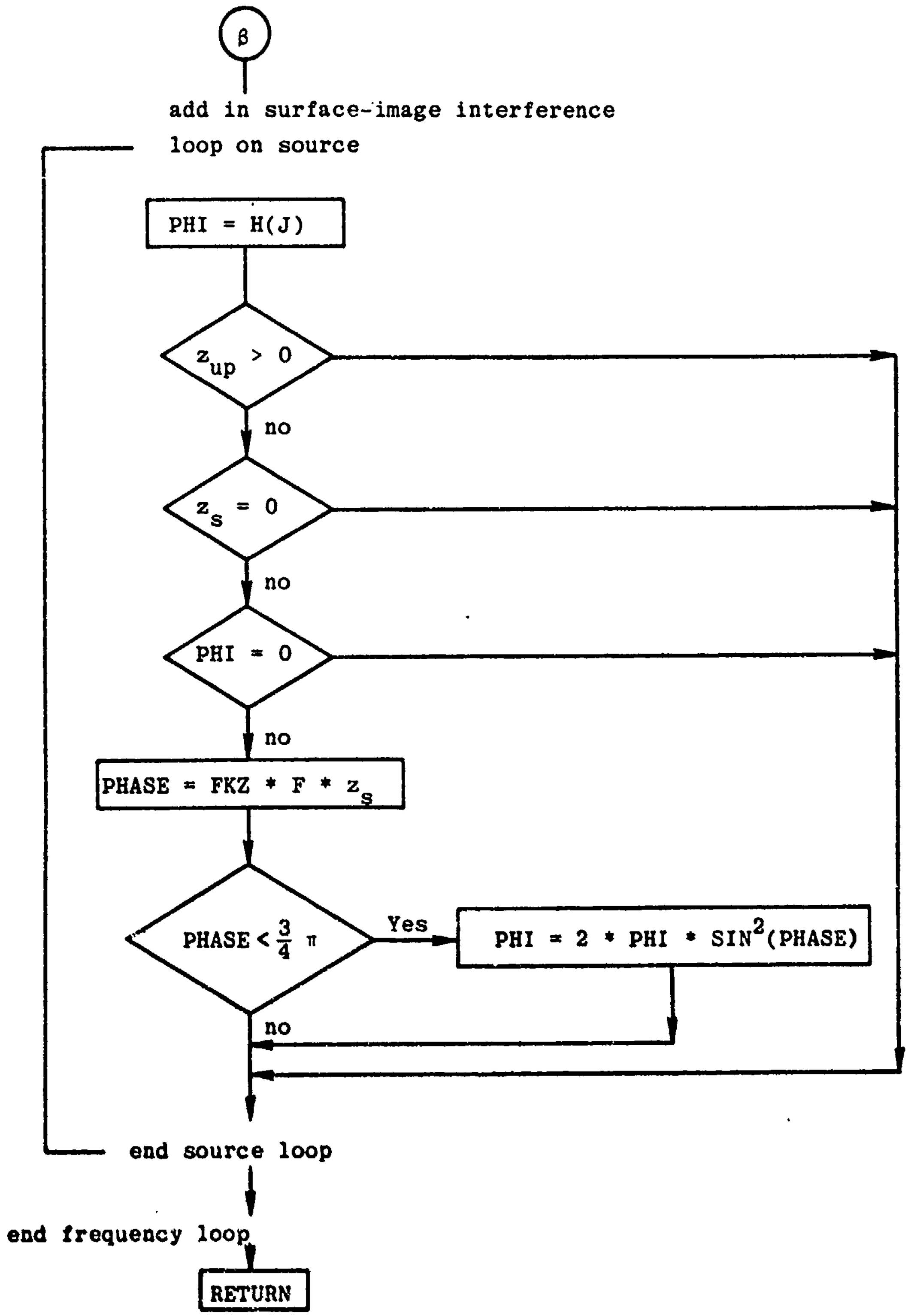

Figure 2-4c. EIGEN Flow (Cont.)

$$H(J) = h_{up} = h_{c_{up}} \left\{ \left[\frac{Ai^2(-\alpha_{up}(Z - Z_{up}))}{Ai^2(0)} \right]^{1/2} - _{(\text{if } z \neq 0)} \left[\frac{Ai^2(-\alpha_{up}(-Z - Z_{up}))}{Ai^2(0)} \right]^{1/2} \right\}$$

where Ai = the Airy function

For a more detailed treatment of the methodology involved, see Volume I, Section 3.2.2.

2.2.3.3.2 Function HDN

Function HDN computes the eigenfunction of the lower turning point. HDN is called from subroutine EIGEN in the following manner:

H(J) = HDN(ZS,ALDN,HCDN,ZDN,HG,TH3,THDN3)

where ZS = source depth

ALDN = depth scale factor

HCDN = caustic limit of intensity = $1/\theta_{dn}$

ZDN = lower turning point depth

HG = geometric intensity limit

TH3 = cube of angle θ at source depth ZS of ray equivalent

THDN3 = $\theta_{dn}{}^3 = (3/4)g_{dn}/f$

The value of the eigenfunction of the lower turning point H(J), is computed as follows:

$$H(J) = h_{dn} = h_{c_{dn}} \frac{Ai^2(\alpha_{dn}(Z - Z_{dn}))}{Ai^2(0)}$$

where Ai = the Airy function.

For a more detailed treatment of the related methodology, see Volume I, Section 3.2.2.

2.2.3.3.3 Function AIRY

Function AIRY produces normalized, squared Airy functions. AIRY is called from functions HUP and HDN.

$$\mathrm{AIRY}(X) = \begin{cases} \dfrac{Ai^2(-X)}{Ai^2(0)} & -4.0 \leq X \leq 1.77 \\ 0 & X < -4.0 \\ \dfrac{1}{.792(X)^{\frac{1}{2}}} & X > 1.77 \end{cases}$$

For $-4.0 \leq X \leq 1.77$, Ai(X) is approximated by 10^{-CX}, where CX is interpolated from tabulated values of C(I) and

$$C(I) = 2\log_{10}\left(\frac{Ai(0)}{Ai\left(\frac{I-11}{5}\right)}\right) \qquad I=1,31$$

The range of I corresponds to a range of -X from -2.0 to 4.0 at intervals of 0.2. This function (or more properly 1/AIRY) was originally used and documented in FACT (Baker and Spofford, 1974).

Function AIRY is called in the following manner:

From Function HUP:

```
AIRY(A*(Z-ZT))
```

where A = depth scale factor = α_{up}

Z = source depth

ZT = upper turning point depth

From function HDN:

AIRY(A*(ZT-Z))

where A = depth scale factor = α_{dn}

Z = Source depth

ZT = lower turning point depth = Z_{dn}

2.2.4 Subroutine SECTON

SECTON treats the near-field bathymetry (NFB) (if it has not been treated before) by tracing (in TRACE) all ray equivalents which reach the receiver, over the near-field bathymetry. It sets up certain parameters for TRACE and cycles through the angles (both up- and down-going). The following variables are affected by a call to TRACE:

Variable	Description	Common
FRSNFB	Logical flag indicating first time this sector is seen (set = .FALSE.)	/NFB/
DRDCMY DZPDCM DZNDCM	Derivatives of period, z_{up}, z_{dn} with respect to phase velocity for routine PERIOD	/DRDCM/
MUPDN(2,25)	Mode number after NFB for each mode MP(J) for up (first index = 2) and down (first index = 1) ray at angle THR(M)	Formal Parameter
ATUPDN(2,25)	Accumulated attenuations (intensity reductions) per mode and angle after NFB	Formal Parameter

The call to TRACE is

```
CALL TRACE(IX,M,ZR,TH,ZNFBZ,THNFB,RNFB,
           IBCNFB,MUPDN(I,M),ATUPDN(I,M),TANBET
           SINBET,COSBET)
```

where

IX = water-mass index

M = mode number

TH = initial ray angle at receiver

ZNFBZ = extrapolated NFB depth at range zero

THNFB = NFB slope angle

RNFB = max range of NFB

IBCNFB = NFB bottom class

MUPDN = new index

ATUPDN = accumulated (intensity) losses

TANBET = tan(THNFB)

SINBET = sin(THNFB)

COSBET = cos(THNFB)

SECTON calls TRACE (which calls PERIOD, BTMLOS and NEWMOD) and returns control to ASEPTL.

2.2.4.1 Subroutine TRACE

TRACE traces rays from the receiver to the end of the near-field bathymetry. The flow of TRACE is shown in Figure 2-5. Numbers in parentheses correspond to FORTRAN statement numbers. The following variables are defined by a call to TRACE:

Variable	Description	Common
MC	Zero mode number, = 0 if ray terminated	Formal Parameter
AT(6)	Accumulated losses at each frequency (in Intensity)	Formal Parameter

TRACE calls BTMLOS, PERIOD and NEWMOD as follows and returns control to SECTON.

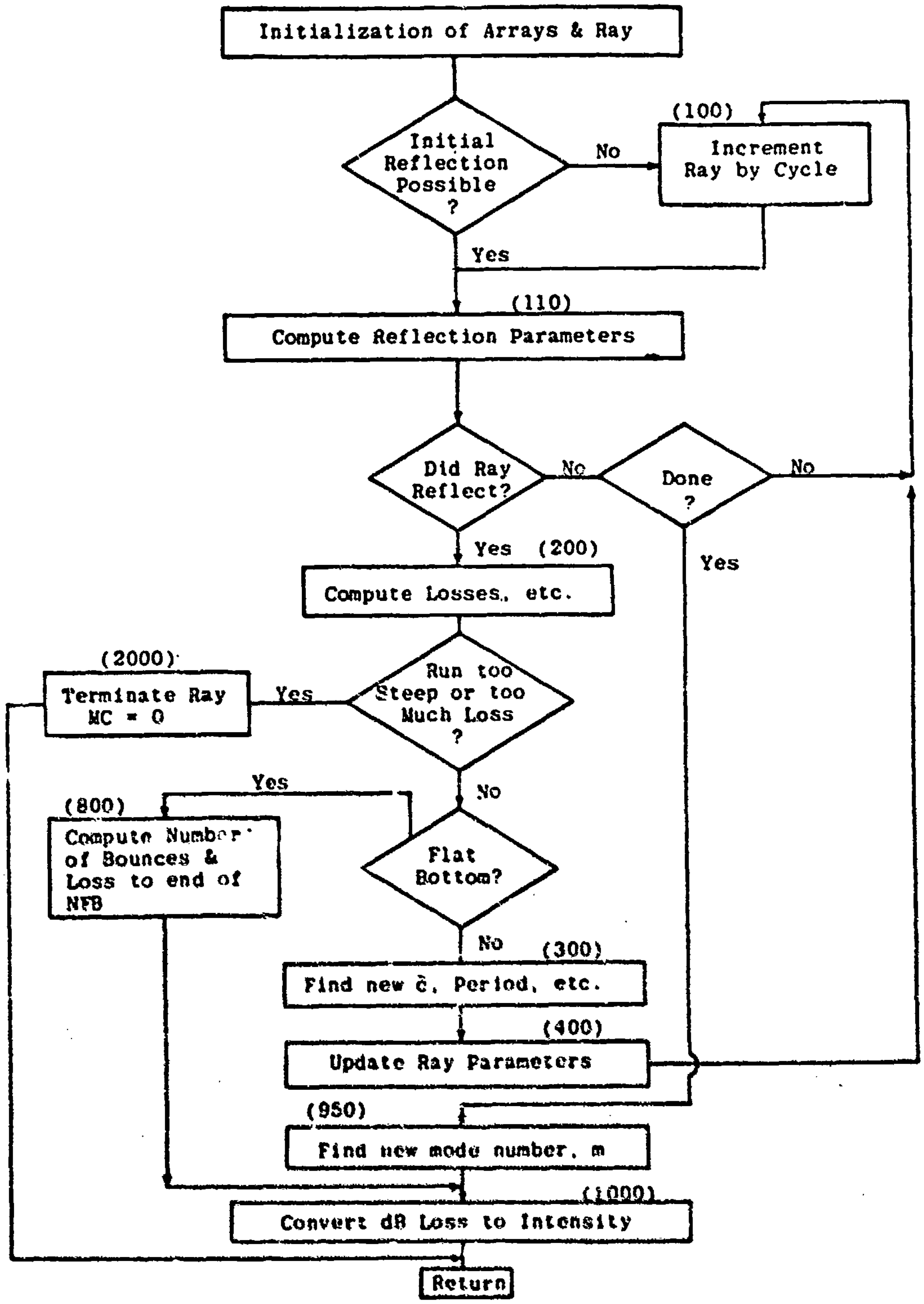

Figure 2.5. Flow of Subroutine TRACE

(1) BTMLOS(IBCNF,J,GAMMA)

where BTMLOS returns the dB loss per bounce and:

IBCNF = Bottom Class Index for NFB

J = Frequency Index

GAMMA = Grazing Angle

(2) PERIOD(I,CT,PNEW,ZUPNEW,ZT)

where

I = Water-mass index

CT = phase velocity

PNEW = period (CT)

ZUPNEW = upper turning-point depth (CT)

ZT = lower turning-point depth (CT)

(3) NEWMOD(CT,I,MP)

where

CT = phase velocity

I = water-mass index

MP = mode index (CT)

2.2.4.2 Subroutine PERIOD

PERIOD is called by TRACE to determine the ray period (PNEW) and upper (ZUP) and lower (ZDN) turning points corresponding to phase velocity CTILDA in water mass IX:

PERIOD(IX,CTILDA,P,ZUP,ZDN)

It uses the processed environmental water-mass data in /PRCENV/ to linearly interpolate in RCYCZ(CM),ZUP(CM),ZDN(CM). To speed up the calculation, the derivatives of each function with respect to CM have been computed external to PERIOD (in SECTON) and passed through /DRDCM/. When the ray turns deeper than the last mode the period is extrapolated assuming a pressure gradient profile from the surface to infinity. If CTILDA < CM(M = 1), the first-mode values are used. PERIOD calls no subroutines and returns control to TRACE.

2.2.4.3 Function BTMLOS

Function BTMLOS computes the bottom loss (dB) at a given frequency for a mode (ray) incident on the bottom at a given bottom grazing angle. The bottom loss is constant for grazing angles less than the critical angle or greater than the angle of maximum loss. Between these limits, the bottom loss varies linearly.

2.2.4.4 Subroutine NEWMOD

NEWMOD computes the new mode index, MC, corresponding to phase velocity, CTILDA, in water mass IX:

NEWMOD(CTILDA,IX,MC)

It compares CTILDA with CM(M,IX) and sets MC = first M for which CM(M,IX) ≥ CTILDA. If CTILDA > CM(MMAX,IX), MC = MMAX. NEWMOD uses processed environmental data from /PRCENV/, calls no subroutines, and returns control to TRACE.

2.2.5 Subroutine SLOPE

Subroutine SLOPE is called from subroutine ASEPTL. It takes the near-field bathymetry data which has been modified by subroutine SECTON and performs the following functions:

1. Determines which modes propagate after the near-field bathymetry adjustment.

2. Computes the amplitude for each mode at the specified range.

3. Sets limits on the modes established in Part 1.

4. Sets logical variables (which had been initialized to TRUE in subroutine INTIAL) to FALSE where modes still propagate

The following variables are directly affected by the action of subroutine SLOPE:

Variable	Description	Common
IFMDN(25)	Logical variable set to .FALSE. if modes still propagate	/FINISH/
IFDONE(6,25)	Logical variable set to .FALSE. if modes still propagate	/FINISH/
PHIRC(6,25)	Accumulated attenuation	/PHIRCV/
M1	Index of 1st propagating mode (after NFB)	/MODEMS/
M2	Index of last propagating mode (after NFB)	/MODEMS/

Subroutine SLOPE calls no other subroutines.

2.2.6 Subroutine AMPDP

Subroutine AMPDP computes the direct-path intensity at a range of 1 nmi with spherical spreading and two incoherent paths (see Volume I, Section 2.2.2). The following values are affected by a call to subroutine AMPDP:

Variable	Description	Common
Range(R)	Range at which TL computed Range(1) set to 1.0 if IEND=3. Range(2) = MAX (RNFB,2)	/RANGES/
AMPM(R,Z_s,f)	TL(R,Z_s,f) dB re 1 yd AMPM(1,Z_s,f) set to intensity at Range(1)	/TLINT/
IR	No. of range steps in TL(R); set = 1 if IEND = 3, otherwise set = 2	/RANGES/

Subroutine AMPDP is called from subroutine ASEPTL with 1 formal parameter, RNFB(INFB), the range to the end of the slope in NFB sector INFB.

Subroutine AMPDP calls no other subroutines; once execution is completed, control returns to subroutine ASEPTL.

2.2.7 Subroutine MARCH

Subroutine MARCH propagates the model solution out in range (see Figure 2-2). The first environment is described by near-field bathymetry. Once the near-field bathymetric solution has been determined, a new water depth is introduced. MARCH calls subroutine COMPDW, which makes any parametric adjustments necessitated by the change in water depth. An intensity is then determined by a call to subroutine INTSUM. If it is determined that the solution is complete (see discussion of function DONE) control returns to subroutine ASEPTL. If not, the next environment is assimilated. In the event that the new environment is the first, the environmental index (KENV) is determined before proceeding.

Once KENV has been determined, a new depth, bottom class, and water mass index are assigned. If a new water mass has been encountered which has not been previously processed, COMPSI is called to compute basic mode parameters (see Section 2.2.3). Checks on whether the new depth or bottom class differs significantly from its previous value are performed by functions NEWDW and NEWBC, respectively. A change in water depth or water-mass index forces changes in source mode parameters, which are modified to include the depth by a call to COMPDW. If either the water mass or depth changes, and any significant bottom-reflected modes are still propagating (as determined by NEWBC), new bottom-loss rates are computed in subroutine PHIBL. The range increment, number of steps and losses per range increment are then determined by a call to RCOMP. Once these parameters have been established, intensity within a region is computed at each specified range step by subroutine INTSUM.

The following calls are issued by subroutine MARCH:

Subroutine	Parameters	Parameter Description	Subroutine Description
COMPDW	FIRST	Logical variable .TRUE. for NFB	Resets source modes for new depth
	DEPNEW	Depth at new range	
	IXNEW	Sequential water-mass index	
	PHINF(1, IXNEW)	Eigenfunction values	
function NEWDW	DEPNEW	New water depth	Logical function determines whether or not a significant depth change has occurred
	DEPOLD	Old water depth	
function NEWBC	IBCOLD	Old bottom class index	Logical function determines whether or not a change in bottom class has occurred
	IBCNEW	New bottom class index	
COMPSI	IXNEW	Sequential water mass index	Computes mode parameters for new environment
	PHINF(1, IXNEW)	Eigenfunction values	
PHIBL	IBCNEW	New bottom class index	Computes bottom loss rates for each mode and frequency
RCOMP	KENV	Environment index	Determines number of range steps, range increment
	NR	Range step number	
	DR	Range increment	
INTSUM	none		Attenuates and sums modes for a given range step
function DONE	N	Range step index	Logical function determines whether run is done

2.2.7.1 Subroutine COMPDW

Subroutine COMPDW has two basic operating modes. If FIRST = .TRUE., it treats the receiver by initializing the eigenfunctions at the end of the near-field bathymetry, adjusting them for finite depth, and computing the indices of the first surface and bottom-reflected modes as well as the initial phase integrals (PSIMR).

On subsequent calls (FIRST = .FALSE.) the source is treated with phase integrals (PSIMP) computed and new mode indices MP(M) determined by adiabatic mapping through subroutine COUPLE.

For both source and receiver, the surface loss, bottom-grazing angle, and eigenfunction values at the source are computed.

The following subroutines are called by subroutine COMPDW:

Subroutine	Formal Parameters	Parameter Description
DELPSI	DEPTH	New depth
	ZDN	Lower turning point depth
	ZUP	Upper turning point depth
	PSIZ	Phase integral of mode M (infinite ocean)
	PSI	New phase integral (finite ocean)
	RCYCZ	Range period of mode M (infinite ocean)
	RCYC	New range period (finite ocean)
	THBMD	Bottom grazing angle
	MBOTP	Index of 1st BR mode (new)
	M	Current mode index

In treating the source (FIRST = .FALSE.) the mode coupling is determined by:

Subroutine	Formal Parameters	Parameter Description
COUPLE	MPP	Max number of modes used to cover PSI
	MSURF	Index of 1st surface reflected mode
	MBOTP	Index of 1st BR mode
	PSIMR	Receiver phase integral
	PSIMP	New source phase integral
	MP	Coupling index

The following parameters are then computed for both source and receiver:

THBM(M)	Bottom grazing angle
RCYCM(M)	Ray/mode cycle distance
ZDNM(M)	Lower turning point depth for ray trace
SFLSNM(N,M)	Surface loss/nmi
PHIM(J,N,M)	Depth normalized eigenfunction

Subroutine COMPDW then returns control to subroutine MARCH.

2.2.7.1.1 Subroutine DELPSI

Subroutine DELPSI adjusts the phase integral, range period, bottom grazing angle and index of the first BR mode to account for changes in depth.

If the current mode is not bottom reflected, the bottom grazing angle is set to 0.0. The phase integral and the range period remain unchanged and control is returned to subroutine MARCH.

When the current mode is bottom reflected, a new bottom-grazing angle is computed. It is then used to compute a new phase integral and range period.

For a description of the call to subroutine DELPSI, see the preceding discussion of COMPDW. Subroutine DELSPI calls no other subroutines.

2.2.7.1.2 Subroutine COUPLE

Subroutine COUPLE computes the indices MP at the source corresponding (thru PSI) to modes M at the receiver, plus indices of the first surface reflecting mode and the first bottom reflecting mode. Subroutine COUPLE is called by subroutine COMPDW (for parameters in call see COMPDW description).

The following variables are modified by a call to subroutine COUPLE:

MP	Indices corresponding to M
MBOT	Index of first bottom reflecting mode
MSRF	Index of first surface reflecting mode

2.2.7.2 Function NEWDW

Function NEWDW is called by subroutine MARCH in an effort to determine whether a significant change in water depth has occurred. The function returns a value of .FALSE. if the last mode was not bottom reflected and will not become bottom reflected (new depth .GT. depth of last mode). Checks are also made to determine whether the first bottom reflected mode becomes non-bottom reflecting or the last non-bottom reflected mode becomes bottom reflected. In the event that there are some bottom reflected modes, a check is made to determine whether the change in water depth results in a change in phase sufficient to necessitate changes in the mapping.

2.2.7.3 Function NEWBC

Logical function NEWBC is used by subroutine MARCH to determine whether or not a significant change in bottom class has occurred. If the index of the 1st bottom reflecting mode is outside the range of the modes being considered or the new bottom class index is the same as the old bottom class index, no significant change in bottom class has occurred, and function NEWBC returns a value of .FALSE.. If these conditions are not satisfied, function NEWBC returns a value of .TRUE., which then prompts subroutine MARCH to call subroutine PHIBL to modify all necessary bottom loss parameters.

2.2.7.4 Subroutine PHIBL

Subroutine PHIBL is called by subroutine MARCH, conditionally dependent on the presence of a new bottom class. PHIBL computes the bottom loss (in dB/mile) for each propagating mode/frequency combination. Subroutine PHIBL tests to ascertain whether bottom loss calculations are necessary; if so, it determines whether a particular bottom loss has been previously calculated. If not, subroutine PHIBL invokes function BTMLOS to compute the actual bottom loss. Function BTMLOS is called in the following manner

BTMLOS(IB,N,THBM(M))

where

IB = new bottom class index

N = frequency index

THBM(M) = bottom grazing angle of the mode

The value returned from function BTMLOS is then divided by the mode (ray) cycle distance to yield the bottom loss in dB/mile which is then stored in array BLOSS(6,25). For a description of BTMLOS see Section 2.2.4.3.

2.2.7.5 Subroutine RCOMP

Subroutine RCOMP is called by subroutine MARCH to determine the number of range steps, the range step increment, and the attenuation/mode/step. A tentative calculation of the range step increment is made equal to the length of the current environmental step. If this value is less than or equal to the maximum permitted range step, the no. of range steps is then set equal to 1. If this value is greater than the maximum range step, more than one step is required, and a new range step increment is computed.

The attenuation/(mode/step) is then calculated with a call to subroutine DBTOIN, in the following form:

CALL DBTOIN(DR)

where DR = range step increment

Control is then returned to subroutine MARCH.

2.2.7.6 Subroutine DBTOIN

Subroutine DBTOIN determines the total attenuation arising from volume, surface, and bottom losses for each propagating mode and frequency combination. This total attenuation is expressed as an intensity reduction factor for each range-step increment. These values are stored in array ATTENR(6,25) in common block /ATTENS/.

2.2.7.7 Subroutine INTSUM

Subroutine INTSUM attenuates the amplitude of each mode by the loss factor calculated by subroutine DBTOIN, and sums the product of the (attenuated) amplitude and the source eigenfunction value, dividing by the range. The minimum transmission loss is computed and logical variables indicating the end of processing are set if appropriate.

The following variables are affected by a call to subroutine INTSUM

PHIRC(6,25)	Attenuated mode amplitude	/PHIRCV/
IFDONE(6,25)	Logical variable indicating mode is fully attenuated at frequency M (.TRUE.)	/FINISH/
AMPM(400,3,6)	Transmission loss (intensity re 1 yd)	/TLINT/
IFMDN(25)	Logical variable indicating end of mode M processing (.TRUE.)	/FINISH)
IFALL	Logical variable indicates end of processing (.TRUE.). All modes attenuated below threshold	/FINISH/
TLSUM	Minimum TL (over frequencies)	/CONV/

Control returns to subroutine MARCH.

2.2.7.8 Function DONE

Logical function DONE returns a value of .TRUE. if calculations in subroutine MARCH should be terminated, setting the termination code for the run (IEND):

IEND	End Code Description	DONE
0	Processing not completed	.FALSE.
1	Maximum range reached	.TRUE.
2	Maximum number of range points reached	.TRUE.
3	All modes attenuated below threshold	.TRUE.
4	Approximation of transmission loss exceeds maximum transmission loss value TLMAX	.TRUE.

Control is returned to subroutine MARCH, which then allows continuation or termination of processing. Once MARCH returns control to ASEPTL and the final transmission loss is computed in TLFINT, an additional setting of the end code is possible. Specifically, if for all frequencies and ranges beyond some range short of the maximum range the loss exceeds TLMAX, the TL array is truncated and IEND is set to 5.

2.2.8 Subroutine TLFINT

Subroutine TLFINT converts total loss intensities to transmission loss in dB re 1 yd with the maximum possible transmission loss equal to TLMAX (an input value specified in subroutine INITAL). The conversion is done in place in array AMPM(400,3,6).

The following variables are modified by a call to subroutine TLFINT:

Variable	Description	Common
AMPM(400,3,6)	Loss (intensity) converted to loss in dB re 1 yd	/TLINT/
IR	No. of range steps in TL(R)	/RANGES/
IEND	Termination code set = 5 (see DONE)	/RANGES/

Subroutine TLFINT calls no other subroutines; once its execution is completed, control returns to subroutine ASEPTL.

2.2.9 Subroutine SMOOTH

Subroutine SMOOTH causes the current transmission loss curve to be evaluated for discontinuities and smoothed where appropriate. A call to subroutine SMOOTH may be issued either from the main program driver (DRIVER) or from the driver for the ASTRAL model (ASEPTL).

Discontinuities in the transmission-loss curve may arise from changes in water mass, changes in water depth, or neither of the above. A discontinuity is operationally defined as a change in transmission loss which exceeds a specified tolerance level. Once the presence of a discontiniuty has been established, one of the above reasons is identified as the source of the discontinuity.

A discontinuity arising from a change in water mass is treated by defining a transition region which extends from the middle of the previous water mass to the middle of the current water mass but no greater than 150 nmi in length nor closer than half way to the nearest discontinuity on both sides. As a simulation of a continuous change in water mass, all transmission loss values between these two selected endpoints are linearly interpolated in range between the point defining the transition region.

Discontinuities which arise from a change in water depth are made to approximate a more continuous change in water depth by isolating the point which reflects this discontinuity. The point is then linearly interpolated in range between the two points immediately adjacent to the discontinuity.

In the event that neither of the two aforementioned conditions are identifiable as the cause of the discontinuity, no smoothing is performed. For a more complete discussion of the methodology involved in the design of the smoothing algorithm, see Volume I, Section 3.2.4.

The sequence of execution of the call to subroutine SMOOTH is dependent on the value of the logical variable DEBUG(3). If the value of DEBUG(3) is .TRUE., the following sequence of events occurs:

1. Subroutine ASEPTL causes execution of the ASTRAL model.

2. Subroutine TLOUT is called by the main program driver. Raw transmission loss points as a function of range, depth, and frequency are printed.

3. Subroutine SMOOTH is called by the main program driver. The points printed in step 1 are inspected for discontinuities.

4. Subroutine TLOUT is again called by the main program driver. Smoothed transmission loss points as functions of range, depth, and frequency are printed.

In the event that the value of DEBUG(3) is .FALSE.,

1. Subroutine ASEPTL causes execution of the ASTRAL model.

2. Before returning control to the main program driver, subroutine ASEPTL issues a call to subroutine SMOOTH.

3. Control is returned to the main program driver, which then calls subroutine TLOUT. The smoothed transmission loss points (only) are printed.

Subroutine SMOOTH is called with no formal parameters. SMOOTH issues no calls to other subroutines.

Section 3
Input and Output

The ASTRAL Model was designed to function in two distinct operating environments. For most users, it is a stand-alone propagation loss model requiring card (or disc) input and printed (or disc) output. The I/O operations of ASTRAL in this mode are described in Section 3.1.

In the FNWC operating environment ASTRAL is only a portion of the overall ASEPS system. As such its I/O is handled entirely through common areas and ASEPTL is called directly with the DRIVER, ENVIN, etc. routines omitted. The operation of the model in this mode is described in Section 3.2.

In order to avoid redundant calculations several areas of processed data are defined for subsequent use on other runs. These need not be of concern to the external user; however, their intelligent utilization by "stacking" multiple runs may offer significant running time savings. They are the concern of the ASEPS program since they must be made available to ASEPTL on subsequent calls, and certain logical variables must be set indicating that the precomputed data are or are not available. Details of this structure are reserved for Section 3.2.

3.1 STAND-ALONE I/O

3.1.1 Input

Table 3-1 summarizes the user's input run deck with appropriate format statements and variable descriptions.

TABLE 3-1

USER INPUT SUMMARY

Subroutine/Data	Format	Description
ENVIN		
1. NZC(20)	(20I4)	environment indices; no. of points in profile
2. $\left.ZE(I,J),CE(I,J)_{i=1}^{NZC(J)}\right]_{j=1}^{\#\ profiles}$	(8F10.2)	profiles (ft and ft/sec)
3. WVHTE(J)	(F10.2)	waveheight (ft)
Repeat 2 & 3 for each profile.		
PARIN		
4. NRMAX,DRMAX	(I5,F10.2)	max. no. of range points (≤400), max. range step (nmi)
5. NZS,NF	(2I5)	no. of source depths (≤3); no. of frequencies (≤6)
6. $ZS(J)]_{j=1}^{NZS}$	(3F10.2)	source depths (ft)
7. $F(J)]_{j=1}^{NF}$	(6F10.2)	frequencies (Hz)
8. MMAX	(I5)	max. no. of modes (≤25)
9. $DEBUG(J)]_{j=1}^{5}$	(5L1)	debug option; set all=.FALSE. if no debug desired (see following discussion for details)

TABLE 3-1 (Cont.)

USER INPUT SUMMARY

Subroutine/Data	Format	Description
RCVIN		
10. NTRACK, ZR	(I5, F10.2)	no. of tracks, receiver depth (ft)
11. ZNFBZ(8)*	(8F10.2)	depth at zero range of NFB (ft)
12. THNFB(8)*	(8F10.2)	slope (rads, negative down from receiver)
13. RNFB(8)*	(8F10.2)	range to end of slope (nmi)
14. IBCNFB(8)*	(8I5)	bottom class on slope (0=perfect reflection)
TRAKIN		
15. NENV	(I5)	no. of environments ($\leq$400)
16. RMAX, THBRC,* INFB	(2F10.2, I5)	max. range (nmi), immediate slope on track (rads, negative down), index of NFB sector for track
17. INDEX(I), IBC(I), RENV(I), $DEP(I)_{i=1}^{NENV}$	(2I5, 2F10.2)	sequential water mass index, bottom class index, beginning range (nmi), depth of environment (ft)

*See Note on Page 3-27 concerning suspended receiver.

Figure 3-1 shows the flow of input in terms of the four input routines and ASEPTL. The input has been structured to allow the user to consider a basic "ocean" of up to 20 profiles (ENVIN) for a specific set (PARIN) of source parameters (depths/frequencies) and control parameters (NRMAX - typically 400, DRMAX - typically 30 nmi, and MMAX - typically 25 modes).

A receiver is then introduced (RCVIN) at a particular depth surrounded by up to 8 near-field bathymetry sectors of varying point-slope-range-reflectivity descriptions. An arbitrary number of tracks from this receiver may be considered as described (TRAKIN) in terms of their corresponding NFB sector, the immediate slope at the receiver, a maximum range, and up to 400 environmental regions of arbitrary length along the track, consisting of different water-mass (profile) indices, bottom classes, and depths.

The initialization for the receiver is performed once for all such tracks and as each NFB sector is encountered for the first time the mode-conversion effects are computed once and saved for subsequent (not necessarily sequential) runs. Similarly as each water mass is encountered for the first time the infinite-ocean eigenfunction data are computed and stored for later use. The track from a given receiver may encounter and re-encounter any water masses in any order. Similarly, different tracks may encounter NFB sectors in any order.

Once all NTRACK tracks are processed, a new receiver may be considered with entirely new NFB and track characteristics. For these tracks processed data will still be available for any water masses encountered which were encountered for previous receivers.

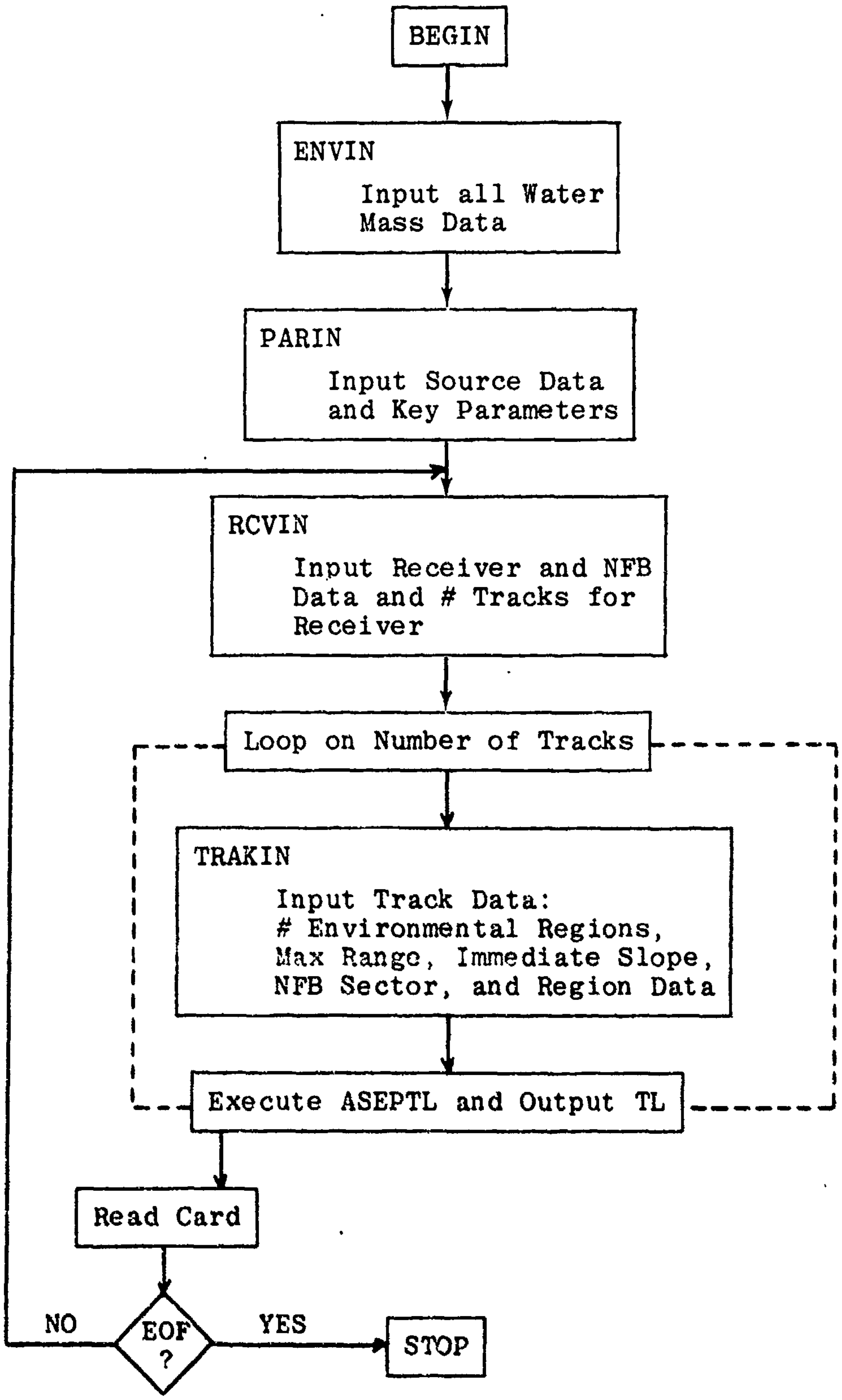

Figure 3-1. Overall Input Flow.

Figure 3-2 is a copy of a typical run deck for a short run. An option has been provided for debugging purposes which can generate considerable output from within the ASEPTL routine (and lower-level routines). In normal execution ASEPTL produces no output other than an execution time. The debug options are normally all set = .FALSE. The output which each generates is described in the following subsection.

3.1.2 Output

In normal execution (no debug printout) the following information is printed by the indicated routines:

Routine	Information
ENVIN	Number of points per profile Processed Status (should be all .FALSE.) Profiles with index and wave-height
PARIN	Number of Range Points Maximum Output Range Step Source Depths Frequencies Number of Modes (max) Debug Flags
RCVIN	Number of Tracks Receiver Depth NFB Parameters
TRAKIN	Number of Environmental Regions Maximum Range Immediate Slope NFB Index Track Region Summary Index, BC, Range, Depth
ASEPTL	Execution Time for this Track
TLOUT	Endcode Number of Range Steps Transmission Loss Matrix

```
   2    5    6
0.0          4776.0     18000.    5100.
0.0
0.0          5050.      100.       5052.      1000.      4925.      3000.      4830.
18000.       5100.
0.0
0.0          5070.      500.       5020.      1000.      5010.      3000.      5064.
5000.        4866.      18000.    5100.
0.0
  400   30.0
    3     4
100.         400.       800.
25.          100.       200.       400.
   25
FFF
    3   4000.
3600.        4200.
-0.05        -0.1
40.          20.
    3     1
    8
1000.        -.02        1
    1 *   3    0.0     16000.
    1     3  200.      14000.
    2     1  300.0     19000.0
    2     1  500.      18000.
    3     3  700.       18000.
    3     4  800.      15000.
    2     4  820.      12000.
    2     4   830.      2000.
    5
1000.0        0.1        1
    1*    3    0.0     16000.
    1     5   200.     18000.
    3     5  400.      18000.
    1     4  600.      17000.
    2     3  800.      15000.
    6
800.          -.2         2
    1*    3  0.0      18000.
    1     4  100.0      15000.
    2     4   200.     15000.
    2     4  220.      10000.
    2     4  240.       15000.
    1     5   300.     18000.
```

* Note - all "tracks" from a given "receiver" must have same SVP at range 0.

(Separator Card Indicating that new RCVR data follows would go here)
(New RCVR data would go here)

Figure 3-2. Sample Input

Figure 3-3 is a copy of the output generated by the run deck of Figure 3-2.

The value of the logical variable DEBUG(J,J=1,5) controls the extent of the output generated by a run of the ASTRAL Model. The minimum amount of output occurs when all values of DEBUG(J) are set to .FALSE..

The effect of a level 1 trace (DEBUG(1) = .TRUE.) is best seen by a description of the output which emanates from the individual subroutines.

Subroutine	Results
ASEPTL	Prints messages tracing progress through modules called by ASEPTL
RCVR	Angles at receiver for each mode
COMPSI	Water mass index, for each mode: phase velocity, upper and lower turning point depths, phase integral and range period, and the eigenfunction values for each frequency-source-depth combination
SECTON	For each propagating mode: angle at receiver, mode indices for slope-converted rays, accumulated intensity losses
SLOPE	Mode limits for each mode and frequency: accumulated attenuation
MARCH	Environmental index Previous and current bottom class indices, depths, water mass indices Status of bottom class, water mass, depth, and any modules which make parametric adjustments
COMPDW	Sequential water mass index, depth, and location; also, indices of 1st surface reflected and 1st BR

```
ENVIRONMENTAL INPUT
NZP ... NUMBER OF POINTS PER PROFILE
                   2  5  6  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
IFPRE ARRAY      (LOGICAL STATUS OF ENV. PREPROCESSING
                   F  F  F  F  F  F  F  F  F  F  F  F  F  F  F  F  F  F  F  F

PROFILE SUMMARY            INDEX   WVHT              Z          C
                             1      0.0
                                                     0.0     4776.0
                                                 18000.0     5100.0
                             2      0.0
                                                     0.0     5050.0
                                                   100.0     5052.0
                                                  1000.0     4925.0
                                                  3000.0     4830.0
                                                 18000.0     5100.0
                             3      0.0
                                                     0.0     5070.0
                                                   500.0     5020.0
                                                  1000.0     5010.0
                                                  3000.0     5064.0
                                                  5000.0     4866.0
                                                 18000.0     5100.0

PARAMETRIC INPUT

MAXIMUM NUMBER OF RANGE POINTS          400
MAXIMUM RANGE STEP (NM)                30.0


SOURCE DEPTHS                          100.       400.       800.

FREQUENCIES                             25.       100.       200..      400.

MAXIMUM NUMBER OF MODES                 25

TRACE PRINTING
          LEVEL  1  F
          LEVEL  2  F
          LEVEL  3  F


START NEW RECEIVER
NUMBER OF TRACKS                    3
RECEIVER DEPTH (FT)         6000.
FRSRCV,FRSREH() INITIALIZED TO TRUE

MEAN FIELD BATHYMETRY SUMMARY
R-RANGE DEPTH(FT)              3600.00    4200.00       0.00       0.00       0.00       0.00       0.00       0.00
SLOPE ANGLE (RADS)                -.05       -.10       0.00       0.00       0.00       0.00       0.00       0.00
SLOPE RANGE (NM)                 40.00      20.00       0.00       0.00       0.00       0.00       0.00       0.00
SLOPE BOTTOM CLASS                   3          1          0          0          0          0          0          0



PROCESSING TRACK        1
```

Figure 3-3. Sample Output

```
NUMBER OF ENVIRONMENTS                          8
MAXIMUM RANGE(NM)                          1000.0
IMMEDIATE TRACK SLOPE(RADS)                  -.02
NEW INDEX                                       1

ENVIRONMENT(TRACK) SUMMARY
 I  INDEX    IHC    RENV       DEP
 1      1      3      0.    16000.
 2      1      3    200.    14000.
 3      2      1    300.    19000.
 4      2      1    500.    18000.
 5      3      3    700.    18000.
 6      3      4    800.    15000.
 7      2      4    820.    12000.
 8      2      4    930.     2000.

CASE EXECUTION TIME (SECONDS)     1.377
```

Figure 3-3. Sample Output (Cont.)

RESULTS-SUMMARY

TERMINATION CODE 5
NUMBER OF RANGE STEPS 34

TRANSMISSION LOSS

I	ZS(FT) / FREQ(HZ) / R(NM)	100. / 25.	100. / 100.	100. / 200.	100. / 400.	400. / 25.	400. / 100.	400. / 200.	400. / 400.	800. / 25.	800. / 100.	800. / 200.	800. / 400.
1	1.00	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7
2	40.00	90.4	89.0	91.6	92.2	89.7	89.9	91.4	92.0	89.7	89.7	91.3	91.9
3	66.67	92.6	92.2	93.0	94.0	92.0	92.1	93.0	94.8	91.0	92.0	93.6	94.6
4	93.33	94.1	93.7	95.5	96.9	93.4	93.6	95.4	96.8	93.3	93.5	95.2	96.6
5	120.00	95.2	94.8	96.7	98.5	94.5	94.7	96.6	98.6	94.4	94.6	96.4	98.2
6	146.67	96.1	95.7	97.7	99.0	95.4	95.6	97.6	99.8	95.3	95.5	97.4	99.6
7	173.33	96.8	96.4	98.6	101.2	96.1	96.4	98.5	101.1	96.0	96.2	98.3	100.5
8	200.00	97.4	97.1	99.4	102.4	96.8	97.1	99.2	102.2	96.7	96.9	99.1	102.1
9	225.00	97.9	97.6	100.0	103.4	97.3	97.6	99.9	103.2	97.2	97.4	99.7	103.1
10	250.00	98.4	98.1	100.6	104.3	97.7	98.1	100.4	104.2	97.6	97.9	100.3	104.0
11	275.00	103.1	104.7	109.4	112.2	99.5	99.9	103.7	108.0	98.1	98.4	101.7	105.7
12	300.00	107.9	111.2	118.3	120.0	101.3	101.7	106.9	111.8	98.4	98.8	103.1	107.4
13	328.57	111.4	116.3	125.2	126.3	102.7	103.1	109.5	115.0	100.4	100.9	104.3	109.0
14	357.14	115.1	121.4	132.0	132.5	104.2	104.6	112.0	118.2	100.8	101.3	105.5	110.5
15	385.71	118.7	126.4	138.9	138.8	105.6	106.0	114.6	121.3	101.1	101.6	106.6	112.1
16	414.29	119.0	126.8	139.3	139.7	105.9	106.3	115.1	122.2	101.4	102.0	107.1	113.0
17	442.86	119.3	127.1	139.8	140.5	106.2	106.7	115.5	123.1	101.7	102.3	107.5	113.8
18	471.43	119.6	127.4	140.2	141.4	106.5	107.0	115.9	123.9	102.0	102.6	107.9	114.7
19	500.00	119.9	127.7	140.6	142.2	106.7	107.3	116.3	124.7	102.3	102.9	108.3	115.5
20	528.57	120.1	128.0	141.0	143.0	107.0	107.5	116.7	125.5	102.5	103.2	108.7	116.3
21	557.14	120.3	128.2	141.3	143.8	107.2	107.8	117.1	126.3	102.7	103.4	109.1	117.1
22	585.71	120.6	128.5	141.7	144.6	107.4	108.1	117.4	127.1	102.9	103.7	109.5	117.9
23	614.29	120.9	128.7	142.1	145.4	107.6	108.3	117.6	127.9	103.2	103.9	109.8	118.7
24	642.86	120.2	126.0	138.3	142.7	107.8	107.9	116.9	127.3	103.4	104.2	110.1	119.4
25	671.43	119.7	123.3	134.5	140.1	108.0	107.4	116.0	126.7	103.5	104.4	110.5	120.2
26	700.00	119.1	120.6	130.8	137.4	108.2	107.0	115.2	126.1	103.7	104.6	110.8	121.0
27	725.00	118.3	116.9	125.7	133.6	106.6	106.3	113.9	125.0	105.2	104.7	110.6	120.7
28	750.00	117.4	113.2	120.6	129.7	104.8	105.6	112.6	124.9	105.4	104.9	110.9	121.3
29	775.00	117.6	113.4	120.9	130.4	106.9	105.8	112.9	124.5	105.5	105.1	111.2	122.0
30	800.00	117.7	113.6	121.1	131.0	107.1	106.0	113.1	125.1	105.6	105.3	111.4	122.6
31	820.00	120.7	121.9	137.1	143.7	107.3	109.7	118.6	131.6	105.8	105.4	111.7	123.1
32	840.00	122.1	126.0	145.2	150.0	117.4	110.1	121.3	134.8	115.8	113.8	121.7	130.2
33	858.33	150.0	144.6	150.0	150.0	147.1	138.1	150.0	150.0	144.1	137.4	150.0	150.0
34	866.67	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0

END OUTPUT

PROCESSING TRACK 2

TRACK DATA

NUMBER OF ENVIRONMENTS

Figure 3-3. Sample Output (Cont.)

```
IMMEDIATE TRACK SLOPE(RADS)                .10


NER INDEX                                    1

ENVIRONMENT(TRACK) SUMMARY
 I  INDEX   IRC   RENV      NER
 1      1     3     0.   16000.
 2      1     5   200.   18000.
 3      3     5   400.   18000.
 4      1     4   600.   17000.
 5      2     3   800.   15000.

CASE EXECUTION TIME (SECONDS)          .545
```

Figure 3-3. Sample Output (Cont.)

RESULTS-SUMMARY

TERMINATION CODE 1
NUMBER OF RANGE STEPS 36

TRANSMISSION LOSS

I	ZS(FT) / FREQ(HZ) / R(NM)	100. / 25.	100. / 100.	100. / 200.	100. / 400.	400. / 25.	400. / 100.	400. / 200.	400. / 400.	800. / 25.	800. / 100.	800. / 200.	800. / 400.
1	1.00	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7
2	40.00	91.6	91.7	94.2	94.8	91.6	91.6	94.2	94.8	91.5	91.5	94.0	94.6
3	66.67	93.9	94.0	96.6	97.6	93.8	93.9	96.5	97.5	93.7	93.8	96.4	97.4
4	93.33	95.3	95.5	98.2	99.6	95.3	95.4	98.1	99.5	95.1	95.3	98.0	99.4
5	120.00	96.4	96.6	99.4	101.2	96.4	96.5	99.3	101.1	96.2	96.4	99.2	101.0
6	146.67	97.3	97.5	100.4	102.6	97.2	97.4	100.3	102.5	97.1	97.3	100.2	102.4
7	173.33	98.0	98.3	101.3	103.9	98.0	98.2	101.2	103.8	97.8	98.0	101.0	103.6
8	200.00	98.6	98.9	102.0	105.0	98.6	98.8	101.9	104.9	98.5	98.7	101.8	104.8
9	228.57	99.2	99.5	102.8	106.2	99.2	99.4	102.7	106.1	99.0	99.3	102.5	106.0
10	257.14	99.7	100.1	103.4	107.3	99.7	100.0	103.3	107.2	99.6	99.9	103.2	107.0
11	285.71	100.2	100.6	104.0	108.3	100.1	100.5	103.9	108.2	100.0	100.4	103.8	108.1
12	314.29	100.6	101.0	104.6	109.3	100.6	100.9	104.5	109.2	100.4	100.8	104.3	109.1
13	342.86	103.1	102.7	106.7	111.5	101.3	101.3	105.3	110.5	100.8	101.2	104.9	110.0
14	371.43	105.6	104.4	108.9	113.8	102.1	101.7	106.2	111.8	101.2	101.6	105.3	110.9
15	400.00	108.2	106.1	111.1	116.0	102.8	102.1	107.0	113.0	101.5	102.0	105.8	111.8
16	428.57	110.6	107.7	113.2	118.2	103.5	102.8	107.8	114.3	102.9	102.1	106.8	112.5
17	457.14	113.1	109.4	115.3	120.4	104.2	103.1	108.6	115.5	103.2	102.4	107.3	113.3
18	485.71	115.5	111.0	117.4	122.6	104.9	103.4	109.4	116.7	103.4	102.7	107.7	114.2
19	514.29	115.9	111.3	117.8	123.4	105.1	103.7	109.8	117.5	103.7	103.0	108.1	115.0
20	542.86	113.8	110.2	116.5	122.9	105.0	104.0	110.2	118.3	103.9	103.3	108.4	115.8
21	571.43	111.9	109.2	115.1	122.3	104.8	104.2	110.5	119.1	104.2	103.5	108.8	116.6
22	600.00	109.9	108.1	113.8	121.8	104.6	104.5	110.9	119.9	104.4	103.8	109.2	117.4
23	628.57	108.0	107.0	112.5	121.2	104.4	104.3	109.1	118.5	103.5	104.2	108.9	118.3
24	657.14	106.0	106.0	111.2	120.7	104.2	104.6	109.4	119.2	103.7	104.4	109.3	119.1
25	685.71	104.0	104.9	109.8	120.1	104.0	104.8	109.7	120.0	103.9	104.7	109.6	119.9
26	714.29	104.2	105.1	110.1	120.9	104.2	105.0	110.0	120.8	104.0	104.9	109.9	120.6
27	742.86	107.2	109.3	116.3	126.0	105.0	105.9	111.8	123.1	104.2	105.1	110.2	121.4
28	771.43	110.3	113.6	122.5	131.1	105.9	106.8	113.6	125.5	104.4	105.3	110.5	122.1
29	800.00	113.3	117.9	128.7	136.2	106.7	107.6	115.4	127.9	104.5	105.5	110.8	122.8
30	828.57	116.3	122.1	135.8	140.8	107.6	108.5	117.2	130.2	104.5	105.5	112.2	124.3
31	857.14	119.4	126.3	142.9	145.4	108.4	109.4	119.0	132.6	104.7	105.7	112.9	125.0
32	885.71	122.4	130.6	150.0	150.0	109.2	110.2	120.7	134.9	104.8	105.9	112.8	125.7
33	914.29	122.5	130.7	150.0	150.0	109.4	110.4	121.0	135.7	104.9	106.0	113.0	126.4
34	942.86	122.7	130.9	150.0	150.0	109.5	110.6	121.3	136.4	105.1	106.2	113.3	127.1
35	971.43	122.8	131.1	150.0	150.0	109.7	110.7	121.6	137.1	105.2	106.4	113.6	127.8
36	1000.00	122.9	131.2	150.0	150.0	109.8	110.9	121.8	137.8	105.3	106.5	113.8	128.5

END OUTPUT

PROCESSING TRACK 3

TRACK DATA

Figure 3-3. Sample Output (Cont.)

```
NUMBER OF ENVIRONMENTS                          6


MAXIMUM RANGE(NM)                           800.0
IMMEDIATE TRACK SLOPE(RADS)                  -.20
NER INDEX                                       2

ENVIRONMENT(TRACK) SUMMARY
 I  INDEX     IPC    RENV        DEP
 1      1       3      0.    18000.
 2      1       4    100.    15000.
 3      2       4    200.    15000.
 4      2       4    220.    10000.
 5      2       4    240.    15000.
 6      1       5    300.    18000.


CASE EXECUTION TIME (SECONDS)            .736
```

Figure 3-3. Sample Output (Cont.)

RESULTS-SUMMARY

TERMINATION CODE 1
NUMBER OF RANGE STEPS 30

TRANSMISSION LOSS

I	ZS(FT) / FREQ(HZ) / R(NM)	100. / 25.	100. / 100.	100. / 200.	100. / 400.	400. / 25.	400. / 100.	400. / 200.	400. / 400.	800. / 25.	800. / 100.	800. / 200.	800. / 400.
1	1.00	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7	64.7
2	20.00	84.6	84.1	84.2	84.5	83.9	84.0	84.1	84.4	83.9	83.9	84.0	84.3
3	46.67	88.2	87.8	88.2	88.9	87.7	87.8	88.0	88.7	87.6	87.6	87.9	88.6
4	73.33	90.2	89.9	90.3	91.4	89.7	89.8	90.2	91.3	89.6	89.7	90.0	91.1
5	100.00	91.6	91.3	91.8	93.3	91.0	91.2	91.7	93.2	91.0	91.1	91.5	93.0
6	125.00	92.7	92.3	92.9	94.7	92.0	92.3	92.7	94.6	92.0	92.1	92.6	94.5
7	150.00	93.5	93.1	93.8	96.0	92.8	93.1	93.7	95.0	92.8	92.9	93.5	95.8
8	175.00	98.8	97.6	96.7	97.2	95.0	94.5	94.5	97.9	94.2	93.6	94.9	97.5
9	200.00	104.2	102.0	99.6	98.3	97.1	95.9	95.2	100.0	95.6	94.3	96.3	99.2
10	220.00	112.3	108.6	103.6	100.6	99.0	97.7	97.7	102.3	97.3	96.3	97.8	100.9
11	240.00	113.8	111.5	108.8	106.1	101.4	99.4	101.5	105.7	98.5	97.3	100.0	103.4
12	270.00	116.0	115.8	116.5	114.3	103.5	102.4	106.2	110.8	100.2	100.5	103.2	107.0
13	300.00	107.1	106.7	107.8	109.2	100.3	100.0	102.7	107.4	98.6	99.0	101.1	105.5
14	329.41	105.6	105.2	106.5	109.0	99.9	99.6	102.4	107.5	98.6	99.0	101.1	105.9
15	358.82	104.1	103.7	105.2	108.7	99.6	99.7	102.0	107.6	98.5	99.0	101.0	106.3
16	388.24	102.7	102.2	103.9	108.4	99.2	99.5	101.7	107.6	98.5	99.0	101.0	106.7
17	417.65	101.2	100.7	102.5	108.2	98.9	99.3	101.4	107.7	98.5	99.0	100.9	107.2
18	447.06	99.7	99.2	101.2	107.9	98.5	99.1	101.1	107.8	98.4	99.0	100.9	107.6
19	476.47	100.0	99.5	101.6	108.8	98.8	99.4	101.5	108.7	98.7	99.3	101.3	108.5
20	505.88	100.2	99.8	102.1	109.6	99.1	99.7	101.9	109.5	99.0	99.6	101.7	109.3
21	535.29	100.5	100.1	102.4	110.5	99.3	100.0	102.3	110.3	99.2	99.8	102.1	110.2
22	564.71	100.7	100.3	102.8	111.3	99.5	100.3	102.7	111.2	99.5	100.1	102.5	111.0
23	594.12	100.9	100.6	103.2	112.1	99.8	100.6	103.1	112.0	99.7	100.4	102.9	111.8
24	623.53	101.2	100.8	103.5	112.9	100.0	100.8	103.4	112.8	99.9	100.6	103.2	112.6
25	652.94	101.4	101.1	103.9	113.7	100.2	101.0	103.8	113.6	100.1	100.9	103.6	113.4
26	682.35	101.6	101.3	104.2	114.5	100.4	101.3	104.1	114.3	100.3	101.1	103.9	114.1
27	711.76	101.7	101.5	104.6	115.2	100.6	101.5	104.6	115.1	100.5	101.3	104.2	114.9
28	741.18	101.9	101.7	104.9	116.0	100.7	101.7	104.8	115.9	100.6	101.5	104.6	115.7
29	770.59	102.1	101.9	105.2	116.8	100.9	101.9	105.1	116.6	100.8	101.7	104.9	116.4
30	800.00	102.3	102.1	105.5	117.5	101.1	102.1	105.4	117.4	101.0	101.9	105.2	117.2

END OUTPUT

Figure 3-3. Sample Output (Cont.)

Subroutine	Results
	mode (new receiver phase integrals, range period or cycle distance, bottom grazing angle) for propagating modes
RCOMP	Environmental index, range steps, range increment

A level 2 trace is instigated by setting the value of DEBUG(2) = .TRUE. In this instance, debug output (module by module) consists of:

INITAL	Frequencies, bottom parameters, volume loss, conversion factor, tolerance levels, angle increments
EIGEN	Geometric intensities, frequencies, α_{dn}, $\hat{z}_{dn}$, $h_{c_{dn}}$, $\hat{z}_{up}$, $h_{c_{up}}$, α_{up}, eigenfunction values
TRACE	Details of ray trace
COMPDW	Source depths, depth normalized eigenfunctions
DBTOIN	Attenuation for each mode-freq. combination
INTSUM	For each mode, frequency, source attenuated mode amplitude, source weighting

If DEBUG(3) = .TRUE., a raw transmission loss curve is printed. This curve is then inspected for discontinuities and smoothed, if necessary (see section on subroutine SMOOTH). The smoothed transmission loss curve is then printed.

DEBUG(4) and DEBUG(5) are, at present, inactive.

3.2 ASEPS I/O

All I/O to ASEPTL is through labelled commons. Four types of variables are passed:

(1) User Specified Input - used by ASEPTL but never modified

(2) User Set Input - logical variables set by the user to indicate a condition (environment or near-field bathymetry sector) which has not been encountered on a previous run. Once the condition is treated in ASEPTL, ASEPTL will reset the logical variable so that in subsequent encounters processed, saved (see Type (3)) data will be used rather than recomputed

(3) Processed Information - generated by ASEPTL and required by ASEPTL for subsequent treatments of either a given sound-speed profile, receiver, or near-field bathymetry section. The user needs to do nothing with this other than have it available

(4) Output for the User - ASEPTL generated information on propagation-loss for the user

The commons and variables described in Table 3-2 are all that is relevant to the I/O process. The following notes refer to the "Add'l Notes" column in Table 3-2.

1. This block contains input and computed receiver-relevant data. When a receiver is being treated for the first in a series of tracks, FRSRCV should be set = .TRUE. (It will be reset to .FALSE. in ASEPTL after processing.)

TABLE 3-2

ASEPTL I/O INTERFACES

COMMON	VARIABLES	TYPE (see discussion) (1)	(2)	(3)	(4)	DESCRIPTION	ADD'L NOTES
/RECVER/		✓	✓	✓		Receiver Data	1
	FRSRCV		✓			Logical Variable (Totally New Receiver?)	
	MMIN			✓		Index of First Mode Receiver Couples to (Pre-Slope)	
	ZR	✓				Receiver Depth (ft)	
	THBRC	✓				Immediate Slope Along Track (Radians, negative down)	
	THR(25)			✓		Angle at receiver (radians, always positive) of mode	
	DSTHR(25)			✓		Solid angle at receiver of mode	
/NFB/		✓	✓			Near-Field Bathymetry Data	2
	INFB	✓				Index of Near-Field Bathymetry Sector For This Track	
	FRSNFB(8)		✓			Logical Variable For This Sector (Treated before?)	3
	ZNFBZ(8)	✓				Depth at range 0 of NFB (extended) slope	
	THNFB(8)	✓				Slope angle (radians, negative down from rcvr)	
	RNFB(8)	✓				Range (nmi) to end of slope	
	IBCNFB(8)	✓				Bottom Class on slope (=0, Perfectly Reflecting)	
/RCVNFB/						Processed Near-Field Bathymetry Data	4
	MUP (50,8)			✓		Mode Indices For $\pm\theta_R$ slope-converted rays	
	ATUP (300,8)			✓		Accumulated Intensity Losses (Actually (6,2,25,8))	
/ENVDET/		✓				Environmental Pointers and Bottom Info. Along Track	5
	NENV	✓				Number of Separate Environments	

TABLE 3-2 (Cont.)

ASEPTL I/O INTERFACES

COMMON	VARIABLES	TYPE (see discussion) (1)	(2)	(3)	(4)	DESCRIPTION	ADD'L NOTES
						(Chg in SS/DW/BC) ≤ 400	
	INDEX(400)	✓				Index in arrays in /ENVS/ of sequential water masses	6
	RENV(400)	✓				Beginning Range (nmi) of New Environment	
	DEP(400)	✓				Depth (ft) of This Environment	
	IBC(400)	✓				FNWC 1-5 (Reset to 1,3,4) Bottom Class For Environment	
/ENVS/		✓	✓			Water-Mass Information	7
	IFPRE(20)		✓			Logical Variable (Corresponding Profile Processed?)	8
	NZC(20)	✓				No. of Points in Corresponding Profile	
	ZE(25,20)	✓				Depth of Point on Profile (ft)	
	CE(25,20)	✓				Sound-Speed of Point on Profile (ft/sec)	
	WVHTE(20)	✓				Wave-Height (ft) of Corresponding Section	
/PRCENV/		✓		✓		Processed Mode Info By Water Mass	9
	MMAX	✓				Max number of modes (≤ 25) Resolution Control	
	MSURF(20)			✓		Index of First Surface-Reflected Mode	
	CM(25,20)			✓		Phase Velocities of Modes (ft/sec)	
	PSIZ(25,20)			✓		Phase Integral (Infinite Ocean) of Modes (sec)	
	RCYCZ(25,20)			✓		Range Period (Infinite Ocean) of Modes (nmi)	
	ZUP(25,20)			✓		Upper Turning Point Depth (ft)	
	ZDN(25,20)			✓		Lower Turning-Point Depth (ft) (Infinite Ocean)	
	PHINF(450,20)			✓		Eigenfunction Values (actually (6,3,25,20))	10
	SURFLS(6,25,20)			✓		Surface Loss (dB/bounce) for each mode/ frequency	
/SRCFRQ/		✓				Source and Frequency Data	11
	NZS	✓				No. of source depths	

TABLE 3-2 (Cont.)

ASEPTL I/O INTERFACES

COMMON	VARIABLES	TYPE (see discussion) (1)	(2)	(3)	(4)	DESCRIPTION	ADD'L NOTES
	NF	✓				No. of frequencies	
	ZS(3)	✓				Source Depths (ft)	
	F(6)	✓				Frequencies (Hz)	
/RANGES/		✓			✓	Range Information for TL(R)	
	NRMAX	✓				Max. No. of range points (≤ 400)	
	DRMAX	✓				Max. Range Step for TL (nmi)	12
	RMAX	✓				Max. Range for TL(R)	13
	IR				✓	Actual No. of Range Steps in TL(R)	
	IEND				✓	Termination Code for TL(R)	14
	RANGE(400)				✓	Actual Ranges at Which TL was computed (nmi)	
/TLINT/						Transmission Loss Data	
	AMPM(400,3,6)				✓	TL(R,Z_s,f) dB Re 1 Yd (≤ TLMAX = 130 dB)	
/STATUS/						Debug and I/O Control	
	DEBUG(5)	✓				Debug Flags	
	NIN	✓				Input Device (Not used by ASEPTL)	
	NOUT	✓				Output Device (For timing and debug)	
		✓					

2. This common controls the near-field bathymetry data (8 or fewer sectors) specified in terms of the NFB slope intercept at zero range (not necessarily the receiver depth), the slope and its extent, and the bottom class on the slope (with special option BC = 0 for perfectly reflecting at all angles). Information for this sector is computed and stored in /RCVNFB/.

3. This logical variable indicates whether (=.TRUE.) or not (=.FALSE.) this is the first time this NFB sector has been encountered. If it is, the data in /RCVNFB/ will be computed and FRSNFB set to .FALSE. If not the data will be used.

4. This block contains computed receiver data relevant to each near-field bathymetry sector (the index dimensioned 8). MUP and ATUP are treated internally (once INFB has been set) as two arrays MUPDN (2,25) and ATUPDN (6,2,25) through subroutine calls to avoid the CDC restriction on four-dimensional arrays.

5. This common contains the environmental descriptors as they occur sequentially along the track. The track is divided into "environments," I, beginning at RENV(I) and ending at RENV(I+1) except for the last one - I = NENV which persists indefinitely - i.e., until RMAX). A new environment occurs whenever the water mass, depth, or bottom reflectivity changes.

6. INDEX(I) is the index in the water-mass arrays in /ENVS/ and /PRCENV/ for this environment. Note that the water masses may be in any order in these commons. INDEX(I) controls their order along the track.

7. The variable dimensioned-20 - in this common refers to a given water mass. When a water mass is encountered for the first time a number of properties of the modes will be computed and stored in variables in /PRCENV/. When this environment is encountered again these stored parameters will be used.

8. IFPRE tells ASEPTL whether the mode properties for this water mass are available (=.TRUE.) or not (=.FALSE.) When a track is set up for input to ASEPTL this should be set to .TRUE. only if the corresponding mode information is put into the corresponding parts of /PRCENV/. ASEPTL will set to .TRUE. after first processing.

9. This block contains the processed information for each water mass (index dimensioned 20). These data must be provided in the appropriate location (INDEX(K) if IFPRE (INDEX(K)) = .TRUE. Otherwise they will be computed.

10. This array is treated internally (for a given value of INDEX) as a three-dimensional array XPHINF (6,3,25) passed through subroutine calls to avoid the CDC restriction on four-dimensional arrays.

11. This block contains the source depths and frequencies for the TL computations. All combinations (Z_s*f) are computed. If Z_s=0 two incoherent paths (at the surface) are assumed for computing noise, equivalent to 60-foot incoherent TL(R). For future reference a shallow (~20 foot) coherent source should probably be used but with modified surface ship source levels. The Z_s=0 result should be appropriate to present source levels.

12. The user specified max range step between computed values of TL(R) (suggested as ~30 miles) will be used except for the first range interval from 1 nmi to the end of the nearfield bathymetry sector. Here the step might be larger.

13. The TL(R) computation might terminate before RMAX (due to loss of energy, etc.) but never beyond.

14. IEND will indicate the reason for terminating the TL(R) computation as follows:

IEND	Reason
1	Max range (RMAX) reached within 0.5 nmi
2	Max number of range points (NRMAX) reached

IEND	Reason
3	All modes attenuated below threshold
4	Upper-bound on best possible TL exceeded (irreversibly)
5	Computed TL exceeds TLMAX from last range on.

The Input and Output from a user-oriented point of view are summarized in Tables 3-3 and 3-4, respectively.

TABLE 3-3
INPUT SUMMARY

ZR

THBRC

FRSRCV Set = .TRUE. First Time (ASEPTL sets = .FALSE.)

If FRSRCV = .FALSE. Make Available

MMIN, THR, DSTHR

INFB

ZNFBZ(INFB)

THNFB(INFB)

RNFB(INFB)

IBCNFB(INFB)

FRSNFB(INFB) Set = .TRUE. For First Treatment of Sector (ASEPTL sets = .FALSE.)

If FRSNFB(INFB) = .FALSE. Make Available

MUP(1,INFB), ATUP(1,INFB)

NENV

INDEX(I), I=1, NENV

RENV(I), DEP(I), IBC(I), I=1, NENV

NZC(INDEX(I))

ZE(J,INDEX(I)), J=1, NZC(INDEX(I))

CE(J,INDEX(I)), J=1, NZC(INDEX(I))

WVHTE(INDEX(I))

IFPRE(INDEX(I)) Set = .FALSE. For First Treatment of Water Mass (ASEPTL sets = .TRUE.)

If IFPRE = .TRUE. Make Available

MSURF(INDEX(I))——→SURFLS(1,1,INDEX(J))

MMAX

NZS

NF

ZS(K), K=1, NZS

F(K), K=1, NF

NRMAX

DRMAX

RMAX

TABLE 3-4

OUTPUT SUMMARY

IR

IEND

RANGE(I), I=1, IR

AMPM(I,J,K), K=1, NF; J=1, NZS; I=1, IR

3.3 SUSPENDED RECEIVER OPTION

While ASTRAL is designed primarily for predictions for bottom-mounted receivers, a suspended receiver over a locally flat bottom may be invoked by proper setting of the following input parameters:

In RCVIN

ZNFBZ	Set to water depth at receiver
THNFB	Set to < - 1.5 (e.g. -2.0)
RNFB	Set to 2.0
IBCNFB	Irrelevant

In TRAKIN

THBRC	Set to < - 1.5 (e.g. -2.0)

By setting THNFB < - 1.5 the front-end ray trace is skipped and the depth functions are computed assuming the water depth is = ZNFBZ.

Note - this will over-ride the depth specified for the first environment (DEP (1)) in computing the loss at 2 nm. DEP (1) will be used from 2 nm to the next depth change. By setting THBRC < - 1.5 all modes are included. Note that THBRC is used after the ray trace (which is done for all ray up- and down-going ray-equivalents explicitly by skipping) to eliminate ray-equivalents shallower than the assumed immediate slope. Hence, for example if NFB = -2, but THBRC ≈ 0.0 only the paths leaving the receiver at positive angles will be included.

For a suspended reciever over a locally sloping bottom, the local slope should be defined by ZNFBZ,THNFBZ, etc., in RCVIN, and THBRC set < - 1.5.

Finally, there are instances when a receiver may be bottom-mounted but the user wishes to include interface effects. This may be done for some cases, approximately, by use of the existing input options. If the receiver was, in fact, at the zero-range depth of the near-field or local slope (i.e. if ZR=ZNFBZ), then by suspending the receiver a small distance above the slope (e.g. reset ZR to ZNFBZ - 10 ft. and set THBRC < -1.5) paths downgoing into the slope will be reflected immediately (with losses governed by IBCNFB). This approach cannot be used if ZNFBZ is substantially different from ZR. A preferable approach is to add an effective vertical "beam pattern" at the receiver (in terms of θ_R) directly into the code in subroutine SLOPE. This allows all the flexibility of the present approach plus a receiver response independent from the near-field reflectivity.

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