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FINAL REPORT

CONTRACT NO. N00024-71-C-1246

SUPPORT TASKS FOR TRANSDUCER
ANALYSIS AND DIFFRACTION
INVESTIGATIONS

Distribution limited to U.S. Gov't. agencies only; Test and Evaluation; 18 SEP 1972. Other requests for this document must be referred to

Submitted to:

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1.0 INTRODUCTION

This report describes the work performed by Radian Corporation on Contract No. N00024-71-C1246 from 1 July 1971 to 1 September 1972. This work consisted of on-site support to Naval Undersea Research and Development Center (NUC) personnel in the area of sonar transducer analysis and design. In addition, work was performed to investigate the effects of diffraction and transmission characteristics of planar baffles on passive array performance.

2.0 TRANSDUCER ANALYSIS AND DESIGN

This section describes the work performed in the on-site support to the Transducer and Array Systems Division of NUC, San Diego. This work involves the computer-aided transducer analysis and design using SEADUCER (Steady-state Evaluation and Analysis of TransDUCERs). This computer model is designed to model any linear system which can be described as an interconnection of multi-port networks; however, its function for this contract was related strictly to sonar transducers. The on-site support included the following tasks:

- Reformat magnetic tapes supplied to NUC by General Dynamics/Electric Boat Division that contained impedances and velocities to be compatible with SEADUCER input format.

- Design and set up SEADUCER runs to analyze the properties of the 3C5 transducer elements varying the element configuration.

- Review documentation of Modest Improvement Plan (MIP) for the TR-208 active transducer element.

- Convert SEADUCER from UNIVAC 1108 EXEC 8 to UNIVAC 1108 EXEC II, and execute several example runs.

Reformatting the 9 track magnetic tapes to a format compatible with the SEADUCER input format was accomplished via subroutines written for the NUC UNIVAC 1108 facility. The data on the tapes supplied by GD/EB were impedance matrices and

velocities for different heads for the 3C5 transducer. The impedances matrices were reduced to determine an array of unique impedances to be used in the computation of various performance variables as a function of frequency. This process was done to reduce the computation time associated with the performance variables.

Radian assisted NUC personnel in the design and set-up of a single frequency design run to analyze the 3C5 element (Run No. 80168). The analysis consisted of examination of the element without a can, and then adding the can and mounts to determine their effect on the element performance. The 3C5 element was also analyzed with different transducer heads that were designed by GD/EB.

The documentation of the Modest Improvement Plan was reviewed by Radian. This documented work performed by NUC and assisted by Radian for improvement at the performance of the TR-208 active transducer element. The analysis consisted of computed critical performance variables as a function of frequency and displaying these via a Calcomp plotter.

The SEADUCER computer model was implemented at the Radian facility which utilizes a UNIVAC 1108 operating under the EXEC II operating system. This required some minor changes in control cards from the NUC UNIVAC 1108 EXEC 8 version. Radian converted the magnetic tape supplied by NUC using a program supplied by UNIVAC. After conversion of the tape, the model was checked by running the example runs that are included in the SEADUCER model documentation. Two of these example runs are included in Appendix A.

3.0 DIFFRACTION INVESTIGATIONS

This section describes the support effort that Radian has provided in connection with NUC investigations on passive-array baffle design. These efforts have been concerned with developing a computer model to investigate the effects of diffraction and transmission characteristics of planar baffles on passive-array performance.

The modeling efforts represent one facet of an overall exploratory development program whose objective is to provide design guidelines for improved baffles to enhance the low frequency, passive performance of wide aperture arrays. Due to the increased size and weight requirements associated with extending the conventional puffs baffle concept to lower frequencies, the goal of the development effort is to examine possible alternatives to design a functional baffle which is effective in shielding the array from internal machinery noise and simultaneously enhances low frequency, passive-array performance.

In connection with this program, Radian's support efforts have involved development of a computer model to characterize the scattering and transmission properties of planar strip baffles. To date a working computer model has been developed for calculating the pressure field in the vicinity of a planar baffle which accounts for the combined effects of transmission and diffraction from a half plane. A version of this computer program is operational on the UNIVAC 1230 at NUC and is being used in conjunction with an experimental investigation of scattering from rectangular plates of various materials for a wide range of frequencies. In addition, this model is currently being generalized to treat the case of a planar strip baffle according to the approach outlined in Appendix B.

These efforts represent an initial attempt, as part of a continuing investigation, toward the synthesis of a valid composite math model to perform parametric analyses of significant baffle parameters on performance of passive-arrays.

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Appendix A

Examples of SEADUCER Run Under UNIVAC 1108 EXEC II.

This appendix shows examples of the SEADUCER model run under UNIVAC 1108 EXEC II. The purpose of this task was to demonstrate that the SEADUCER model was written in standard FORTRAN and could operate under different operating systems, and also on different types of computers. The task also made available to potential users of the model a version that had compiled and executed correct under the EXEC II operating system.

The first example presented here is a single frequency transducer element design. The transducer element is described by defining network interconnections and specifying individual network types. Then for a variety of tail lengths, ceramic areas, and ceramic lengths, the problem is to determine the number of ceramic pieces required to minimize the voltage-velocity control impedance, Z_{ec}. The second example is strictly a matric calculation for a given transducer element configuration, and was included since it checks many of the features of the model.

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	001153
0002	*DATA	000013
0002	*LCMV	000014
0003	CATALG	001073
0004	BASICS	000006
0005	STATOT	000001
0006	TOTL	000002
0007	[illegible]	[illegible]
0010	[illegible]	[illegible]
0011	[illegible]	[illegible]
0012	CDESCN	000005
0013	SPECIC	000020
0014	CRMPCT	000004
0015	[illegible]	000001
0016	FLASH	000004
0017	CMPFIN	000003

EXTERNAL REFERENCES (BLOCK, NAME)

0020	PAGE	0021	STRLIN	0022	LDRCRT	0023	LDDT1	0024	LDDT4
0025	LDDT7	0026	ALOCAT	0027	SKPLIN	0030	LDIMTR	0031	HEAD24
0032	LDPRES	0033	PLOMKL	0034	RDCPRT	0035	LDDT11	0036	FNDTL
0037	LDCMTR	0040	ZTCA	0041	PRTMTR	0042	LDAM2S	0043	CMPGAM
0044	FMFN	0045	FNDFMS	0046	SNMFED	0047	FNDNLM	0050	PRPTBL
0051	PRCTLG	0052	[illegible]	0053	NICOD	0054	DSGRT	0055	NWDCS
0056	NSTOPS								

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000067 100L	0000	000407 149F	0000	000427 150F	0000	000431 152F

```
0001    000036 1BCL      0001    001071 2CCL      0001    000434 2330      0001    000453 2400
0001    000514 2540      0000    000077 SF        0001    000632 99L       0000 R 000005 C3D4R
0002 D 000000 DATA       0004 D 000000 DF        0000 D 000065 DFBAND     0013 D 000002 DGECI
0000 D 000002 DGECMG     0000 D 000040 DGECMN     0013 D 000000 DGECR      0013 D 000006 DGICI
0013 D 000004 DGICR      0000 D 000085 FLG3D      0000 D 000071 DLMIN      0000 D 000057 DMGS
0004 D 000000 DMIDBA     0004 D 000000 DPI        0014 D 000000 DREACT     0014 D 000000 DRM
0006 D 000000 DTL        0007 D 000000 DTMASS     0013 D 000012 DZECI      0013 D 000010 DZECR
0013 D 000016 DZICI      0013 D 000014 DZICR      0000 R 000030 FACTOR     0000 I 000051 IAA2D
0000 I 000075 IAYZZ4     0003 I 001274 ICLGSB     0000 I 000034 ID2S       0016   000001 IECIC
0016 I 000003 IFLGLC     0016   000002 IFLGSP     0011 I 000000 IFMNPR     0000 I 000031 IFORM
0000 I 000033 IFRS       0016   000000 IFMNN      0003   000210 IPC        0000 I 000032 IPUNCH
0000 I 000035 IGGS       0003   000210 ITYPE      0000 I 000050 IZA2D      0000 I 000076 IZYZZ4
0000 I 000003 L          0000 I 000012 LNAMES     0003 I 001130 LOC        0037 I 000000 LOCMTR
0000 I 000016 LR2D1      0000 I 000074 LYZ        0000 I 000024 M          0017 I 000001 MAXSKP
0000 I 000042 MINCNT     0017   000000 MINSKP     0015 I 000000 MTRGVN     0003   000144 MTRSIZ
0005 I 000000 MXDATA     0000 I 000045 N          0003   000000 NAME       0003   000784 NDTSTR
0010 I 000000 NDPOT      0003   000154 NFCTOT     0012 I 000003 NPGEMN     0000 I 000044 NPHI
0000 I 000043 NPLO       0000 I 000035 NIMOS      0017 I 000002 NIPOLO     0017 R 000002 RAC3D
0012 R 000004 RAR2D1     0000 R 000037 RAYZZ3     0000 R 000073 RGECMN     0000 R 000067 RGICMG
0000 R 000046 RLC3D      0000 R 000054 RLGEMN     0012 R 000000 RLR2A1     0000 R 000047 RLR2D1
0012 R 000001 RLR2Z1     0000 R 000035 RLT2A1     0000 R 000027 RLYZZ4     0000 R 000026 RMYZZ4
0000 R 000071 RPGEMN     0000 R 000070 RPEACT     0000 R 000064 RTL        0000 R 000072 RTLC3D
0000 R 000063 RTMASS     0000 R 000000 T2AIL
```

```
00101      1*          IMPLICIT DOUBLE PRECISION (D)
00103      2*          COMMON / CATALG / NAME(100), MTR SIZ(100), I PC(100),
00103      3*         1    N PC TOT(100), I TYPE(100), N DT STR(100), LOC(100), I CLG SB
00104      4*          COMMON / BASIC S / D F, D OMEGA, D PI
00105      5*          COMMON / DTA TOT / MX DATA
00106      6*          COMMON /          / DATA(1310)
00107      7*          COMMON / TOT L / DT L
00110      8*          COMMON / TOT MAS / DT MASS
00111      9*          COMMON / PRT OFF / NO PRT
00112     10*          COMMON / C FMN PR / I FMN PR
00113     11*          COMMON / CDESGN / RL R2A1, RL R2Z1, RA C3D, NP GE MN, RA R2D1
00114     12*          COMMON/ GM EC IC /DGECR,DGECI,DGICR,DGICI, DZECR,DZECI,DZICR,DZICI
00115     13*          COMMON / C RM PCT / DRM, DREACT
00116     14*          COMMON / C SRMTR / MTR GVN
00117     15*          COMMON / FLG SPH / I MX NN, I EC IC, I FLG SP, I FLG LC
00120     16*          COMMON / CMN FMN / MIN SKP, MAX SKP, NI POL D
```

```
00121      DIMENSION T2A1 L(5)
00122      DIMENSION C3D AP(5)
00123      DIMENSION L NAMES(4)
00124      DIMENSION L R2D1(5)
00125      DATA (L NAMES(L), L=1,4 ) / 'TA','CD','EE','YZ' /
00127      DATA (L R2D1 (L), L=1,3 ) / 'VW','EE','CD'          /
00131      DATA( C3D AP(M), M=1,5 ) / .0049, .0065, .00752, .0081, .012898 /
00133      DATA( T2A1 L(L), L= 1, 5 ) /
00133     /  .0381247, .0762493, .114374, .152499, .190623 /
00135      DATA N1 HDG / 1 /
00137      MX DATA = 1310
00140
00140      CALL PAGE
00141      CALL STP LIN
00142      PRINT 5
00144    5 FORMAT(' MOD 8 RUN 80038 APR 23, 1970 $ LIKE MOD 7 RUN 70335'/
00144     /        '  DESIGN RUN $'/
00144     /        ' LINES OF CONSTANT TAIL LENGTH$' /
00144     /        ' CHARGE TO 16000501 ARRAY DESIGN'    )
00145
00145      CALL LD PORT ( 'S', '1B7D, -+1T1A, -+1R2A,$' )
00146      CALL LD PORT ( 'S', '2B7D,    1E2E,$' )
00147      CALL LD PORT ( 'S', '3B7D,    2R2A,$' )
00150      CALL LD PORT ( 'S', '4B7D,    1R2Z,$' )
00151      CALL LD PORT ( 'S', '5B7D,    2Y2Z,$' )
00152      CALL LD PORT ( 'S', '6B7D, -+2E2E,    1V2W,   1Y2Z,$' )
00153      CALL LD PORT ( 'S', '7B7D, -+1T1B,    2R2Z,   2V2W,$' )
00154
00154      CALL LD PORT ( 'S', '1A6D,    3C3D,$' )
00155      CALL LD PORT ( 'S', '2A6D,    5B5D,$' )
00156      CALL LD PORT ( 'S', '3A6D, -+2C3D,    2B5D,$' )
00157      CALL LD PORT ( 'S', '4A6D, -+1B5D,    1C3D,$' )
00160      CALL LD PORT ( 'S', '5A6D, -+3B5D,    1R2D,$' )
00161      CALL LD PORT ( 'S', '6A6D, -+4B5D,    2R2D,$' )
00162
00162      CALL LD DT1('E2S1$',441E.00,1.44261E-2,0.,0.,.0090693,4820.,0.,0.)
00163      RL R2A1 = .0072484
00164      CALL LD DT1('R2A1$',7702.80,7.90233E-4,0.,0.,.0072484,4970.,0.,0.)
00165      RL R2Z1 = .0008379
00166      CALL LD DT1('R2Z1$',7702.80,7.90233E-4,0.,0.,.0008379,4970.,0.,0.)
00167      CALL LD DT1('T2S1$',7700.00,2.[illegible]E-3,0.,0.,.0033570,4970.,0.,0.)
00170      CALL LD DT1('T2[illegible]$',7704.57,1.[illegible]E-3,0.,0.,.0033140,4970.,0.,0.)
00171      CALL LD DT1('T2S3$',7719.24,1.30693E-3,0.,0.,.0102145,4970.,0.,0.)
```

```
0172    60*        CALL LD DT1('T2S4S',7702.80,7.90233E-4,0.,0.,.0066790,4070.,0.,0.)
0173    61*        CALL LD DT1('V2W1S',4416.90,1.12776E-2,0.,0.,.0113701,4820.,0.,0.)
0174    62*        CALL LD DT1('V2W2S',4416.90,1.12776E-2,0.,0.,.0113701,4820.,0.,0.)
0175    63*        CALL LD DT1('V2W3S',7738.49,2.54934E-3,0.,0.,.0022244,5116.,0.,0.)
0176                CALL LD DT1('Y2Z1S',2702.81,3.46119E-3,0.,0.,.0113701,5200.,0.,0.)
0177                CALL LD DT1('Y2Z2S',2702.81,3.46119E-3,0.,0.,.0113701,5200.,0.,0.)
0178                CALL LD DT4('Y2Z3S'  )
0179                CALL PAGE
0200    66*        RM Y2Z4 = 2.755
0201    67*        RL Y2Z4 = .04516
0202    68*        FACTOR = 1.
0203    69*        I FORM = 0
0206    70*        CALL LD DT 7( 'Y2Z4S', FACTOR, I FORM)
0207    71*
0207    72*        IPUNCH = 1
0210    73*        IPUNCH = 0
0211    74*        MAX SKP = 1
0212    75*        NI POL 0 = 1
0213    76*
0213    77*        CALL ALOCAT('FS', 2, 8)
0214    78*        IF2S = LOC(I CLG S8)
0215    79*        CALL ALOCAT('DS', 2, 8)
0216    80*        ID2S = LOC(I CLG S8)
0217    81*        CALL ALOCAT( 'SS', 2, 8)
0220    82*        IS2S = LOC(I CLG S8)
0221    83*        CALL SKP LIN(1)
0222    84*        CALL LD I MTR(IF2S, 2)
0223    85*        CALL HEAD 24(' F2S UNIT MATRIX          ')
0224    86*        CALL LD I MTR(ID2S, 2)
0225    87*        CALL HEAD 24(' D2S UNIT MATRIX          ')
0226    88*        CALL LD I MTR(IS2S, 2)
0227    89*        CALL HEAD 24(' S2S UNIT MATRIX          ')
0230    90*
0230    91*        CALL PAGE
0231    92*        CALL LD FREQ ( 3500.00 )
0232    93*
0232    94*        DO 300 L = 1, 5
0235    95*        RL T2A1 = T2A1 L(L)
0236    96*        CALL LD DT1('T2A1S',7832.48,2.17225E-2,0.,0., RL T2A1,5116.,0.,0.)
0237    97*
0237    98*        DO 200 M = 1,5
0242    99*        RA C3D = C3D AR(M)
0243   100*        RAY2Z3 = RAC3D * 0.5
```

```
00244   103*        CALL LD DT1('Y2Z3$',2702.61,RAY2Z3 ,0.,0.,.0353544,5200.,0.,0.)
00245   104*        CALL BLD KKL('B7D$')
00246   105*        CALL RDC PRT( 'B 7D$', 'B5D$' )
00247   106*
00247   107*        DGECMN = 1.E30
00250   108*        MIN CNT = 0
00251   109*        NP LO = 2
00252   110*        NP HI = 26
00253   111*
00253   112*        DO 100 N = NP LO, NP HI, 2
00255   113*        RL C3D = .0130253
00257   114*        CALL LD DT 11('C3D$',N,7608.21, RA C3D ,0.0,0.0, RL C3D,
00257   115*       E .1411666.04, 0.00, .2419850-2,
00257   116*       G .2452070-1, 0.00, -.1974270-3,
00257   117*       S .9434950-11, 0.00, .1670290-2 )
00260   118*        CALL END T L ( L R2D1, 3 )
00261   119*        RL R2D1 = DT L - RL R2A1 - RL R2Z1
00262   120*        RA R2D1 = 5.71140E-4
00263   121*        CALL LD DT1('R2D1$',7702.90, RA R2D1 , 0.,0., RL R2D1,4970.,0.,0.)
00264   122*        IF ( NO PRT .EQ. 0 ) CALL PAGE
00266   123*        NO PRT = 0
00267   124*        NO PRT = 1
00270   125*
00270   126*        CALL BLD KKL('A6D$')
00271   127*        CALL RDC PRT( 'A6D$', 'A2D$' )
00272   128*
00272   129*        IZA2D = LOC MTR('AD', 2)
00273   130*        IAA2D = IZA2D+9
00274   131*        CALL Z TO A(IZA2D, IAA2D)
00275   132*        IF ( NO PRT .NE. 0 ) GO TO 99
00277   133*        CALL HEAD 24(' A A2D                    ')
00300   134*        CALL PRT MTR(IAA2D, 2)
00301   135*     99 CONTINUE
00302   136*
00302   137*        CALL LD A M2S
00303   138*        CALL CMP GAM(IAA2D)
00304   139*        DGECMG = DSQRT(DGECR**2+DGECI**2)
00305   140*        IF ( DGECMG .GE. DGECMN ) GO TO 100
00307   141*        DGECMN = DGECMG
00310   142*        RLGE MN = RL C3D
00311   143*        NPGEMN = N
00312   144*        MIN CNT = MIN CNT + 1
00313   145*    100 CONTINUE
```

```
0316   146*        IF( MIN CNT .LT. 2) CALL HEAD24(' NO MIN GAM EC              ')
0317   147*        IF ( MIN CNT .LT. 2 ) GO TO 200
0321   148*        I FMN PR = 1
0322   149*        I FMN PR = 0
0323   150*        DL C3D = RL GE MN
0324   151*        CALL FMFN( DL C3D, DNONE, DNONE, DL MIN, DGECMN )
0325   152*
0325   153*        CALL FND T MS
0326   154*        RT MASS = DT MASS + RM Y2Z4
0327   155*        CALL FND T L ( L NAMES, 4 )
0330   156*        RT L = DT L + RL Y2Z4
0331   157*        IF ( NO PRT .EQ. 0 ) CALL PAGE
0333   158*        DRM = 1.D-30
0334   159*        DF BAND = 3500.00
0335   160*        MTR GVN = 1
0336   161*        CALL SR MIDB( DF BAND,                    'MAX', 'IC', 'P', DRM )
0337   162*        I FLG LC = 0
0340   163*        RGICMG = DSQRT(DGICR**2+DGICI**2)
0341   164*        RREACT = DREACT
0342   165*        RPGEMN = NPGEMN
0343   166*        RTLC3D = DL MIN * RPGEMN
0344   167*        RGECMN = DGECMN
0345   168*        IF ( N1 HDG .EQ. 0 ) GO TO 160
0347   169*        N1 HDG = 0
0350   170*        CALL SKP LIN(1)
0351   171*        PRINT 149
0353   172*        IF(IPUNCH.NE.0) PUNCH 5
0356   173*        IF(IPUNCH.NE.0) PUNCH 149
0361   174*    149 FORMAT(       '  L T2A1     A C3D      L C3D    TOT MASS  TOT LENGTH',
0361   175*       /    '  REACTOR  GAMMA IC GAM EC MIN' )
0362   176*    160 CONTINUE
0363   177*        IF(IPUNCH.NE.0) PUNCH 150,RL T2A1,RA C3D,RTLC3D,RTMASS,RTL,RREACT,
0363   178*       1           RGICMG,RGECMN
0376   179*        PRINT 152, RL T2A1, RA C3D, RTLC3D, RTMASS, RTL, RREACT,
0376   180*       1            RGICMG, RGECMN,NPGEMN
0411   181*    150 FORMAT( 3E10.4)
0412   182*    152 FORMAT( 6E10.4, /21X, 'N =', I3 )
0413   183*
0413   184*    200 CONTINUE
0413   185*  C 200 EXIT C3D AREA LOOP
0415   186*
0415   187*        CALL SKP LIN(1)
0416   188*    300 CONTINUE
```

```
00416   189*   C DOC EXIT TZL LENGTH LOOP
00420   190*
00420   191*          CALL END NAM(*YZ*,LYZ)
00421   192*          IAYZZ4 = LOC(LYZ+4)
00422   193*          IZYZZ4 = IAYZZ4 + 8
00423   194*          CALL SKPLIN(2)
00424   195*          CALL HEAD 24(*   4 YZZ4                    *)
00425   196*          CALL PRT MTR(IA YZZ4,2)
00426   197*          CALL SKPLIN(2)
00427   198*          CALL HEAD 24(*   Z YZZ4                    *)
00430   199*          CALL PRT MTR(IZ YZZ4,2)
00431   200*
00431   201*          CALL PAGE
00432   202*          CALL PR PTBL
00433   203*          CALL PAGE
00434   204*          CALL PR CTLG
00435   205*          CALL PAGE
00436   206*          STOP
00437   207*          END

    END OF UNIVAC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
CONTRL  S       SYMBOLIC                    23 JUN 71  14:23:29   0  00273476    14    94  (DELETED)
CONTRL  R       RELOCATABLE                 23 JUN 71  14:23:29   1  00276142    48     1  (DELETED)
                                                                  0  00276222    14    70
```

```
[ FOR RLIMMG/S,RLIMMG/S,RLIMMG/R                                                    16:56:21.112
NIVAC 1108 FORTRAN V LEVEL 2206 0023


 SUBROUTINE RLIMMG     ENTRY POINT 000167

 STORAGE USED (BLOCK, NAME, LENGTH)

       0001   *CODE   000205
       0000   *DATA   000104
       0002   *BLANK  000310
       0003   COMNPR  000001
       0004   PRTOFF  000001
       0005   TOTL    000002
       0006   GMECIC  000020
       0007   CDESGN  000005


 EXTERNAL REFERENCES (BLOCK, NAME)

   0010   DSQRT          0011   PAGE           0012   LDDT11         0013   FNDTL          0014   LDDT1
   0015   BLDVKL         0016   RDCPRT         0017   LOCMTR         0020   ZTOA           0021   HEAD24
   0022   PRTMTR         0023   LD4M2S         0024   CMPSAM         0025   PRMARI         0026   NERR3$


 STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

  0001    000121 9L          0002 D 000000 DATA        0006 D 000002 DGECI       0006 D 000000 DGECR
  0006 D 000006 DGICI       0006 D 000004 DGICR       0010 D 000000 DSQRT       0005 D 000000 DTL
  0006 D 000012 DZECI       0006 D 000010 DZECR       0006 D 000016 DZICI       0006 D 000014 DZICR
  0000 I 000013 I4A2D       0003 I 000000 IFMNPR      0000   000072 INJPS       0000 I 000012 IZA2D
  0000 I 000005 L           0017 I 000000 LOCMTR      0000 I 000000 LR2DI       0000 I 000007 N
  0000 I 000006 NOPRSV      0004 I 000000 NOPRT       0007 I 000003 NPGEMN      0007 R 000002 RAC3D
  0007 R 000004 RAR2DI      0000 R 000010 RLC3D       0007 R 000000 RLR2A1      0000 R 000011 RLR2DI
  0007 R 000001 RLR2Z1


0:01      1*          SUBROUTINE RL IM MG(DX, DRL, DIM, DMG)
```

```
00103      2*          DOUBLE PRECISION DX, DRL, DIM, DMG
00104      3*          DOUBLE PRECISION DATA
00105      4*          DOUBLE PRECISION DSQRT
00106      5*          COMMON /          / DATA (100)
00107      6*          COMMON / C GMN PR / I FMN PR
00110      7*          COMMON / PRT OFF / NO PRT
00111      8*          DOUBLE PRECISION DT L
00112      9*          DOUBLE PRECISION DGECR,DGECI,DGICR,DGICI,DZECR,DZECI,DZICR,DZICI
00113     10*          COMMON / TOT L / DT L
00114     11*          COMMON/ GM EC IC /DGECR,DGECI,DGICR,DGICI,DZECR,DZECI,DZICR,DZICI
00115     12*          COMMON / CDESCN / RL R2A1, RL R2Z1, RA C3D, NP GE MN, RA R2D1
00116     13*          DIMENSION L R2D1(5)
00117     14*          DATA (L R2D1 (L), L=1,3 ) / 'VW','EE','CD' /
00121     15*          NO PR SV = NO PRT
00122     16*          NO PRT = 1 - I FMN PR
00123     17*          IF ( NO PRT .EQ. 0) CALL PAGE
00125     18*          N = NP GE MN
00126     19*          RL C3D = DX
00127     20*          CALL LD DT 11('C3D$',N,7588.21, RA C3D ,0.0,0.0, RL C3D,
00127     21*         E .1411666D4, 0.D0, .2419850-2,
00127     22*         G .2452070-1, 0.D0, -.187427D-3,
00127     23*         S .9404950-11,0.D0, .1670280-2)
00130     24*          CALL FND T L ( L R2D1, 3 )
00131     25*          RL R2D1 = DT L - RL R2A1 - RL R2Z1
00132     26*          CALL LD DT 1('R2D1$',7702.30,RA R2D1,0.,0.,RL R2D1,4970.,0.,09)
00133     27*          NO PRT = NO PR SV
00134     28*          CALL SLD KKL('A6D$')
00135     29*          CALL RDC PRT('A6D$', 'A2D$' )
00136     30*          IZA2D = LOC MTR('AD', 2)
00137     31*          IAA2D = IZA2D+2
00140     32*          CALL Z TO A(IZA2D, IAA2D)
00141     33*          IF ( NO PRT .NE. 0 ) GO TO 9
00143     34*          CALL HEAD 24('A A2D                    ')
00144     35*          CALL PRT MTR(IAA2D, 2)
00145     36*    9     CONTINUE
00146     37*          CALL LD A M2S
00147     38*          CALL CMP GAM(IAA2D)
00150     39*          DRL = DGECR
00151     40*          DIM = DGECI
00152     41*          DMG = DSQRT(DRL**2+DIM**2)
00153     42*          IF ( I FMN PR .EQ. 0 ) RETURN
00155     43*          CALL HEAD 24(' GAMMA EC                ')
00156     44*          CALL PR MAR1(1, 'DEG', DRL, DIM)
```

```
00137    4F*          RETURN
00160    4F*          END

    END OF UNIVAC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
  RLIMMG  S        SYMBOLIC                    23 JUN 71  14:25:41   0  00613172    14    40  (DELETED)
  RLIMMG  R        RELOCATABLE                 23 JUN 71  14:25:41   1  00614252    36     1  (DELETED)
                                                                     0  00614316    14    10
```

BLANK COMMON 156704 163777

STARTING ADDRESS 014000

CORE LIMITS 014000 050240 100000 114504 156676 156703

CONTRL/R	NSTOPS/RL22	DSQRT /RL22	NERRS /RL23	SQRT /RL22
0 100000-100564	1 015153-015164	1 015165-015222	0 100577-100736	1 015757-016021
1 014000-015152		2 100565-100576	1 015223-015756	2 100737-100744
NIERS /RL23	NFMTS /RL23	NFTVS /RL22	NCNVTS/RL23	NOTINS/RL23
0 100745-100745	1 015321-017204	1 017205-017227	1 017230-017447	1 017450-020036
1 016022-016320	2 101040-101053		2 101054-101140	2 101141-101203
2 100746-101037				
NIOINS/RL22	NOUTS /RL23	NTABS /RL22	NBDCVS/RL23	PRCTLG/R
1 020037-020105	0 101235-101242	0 101261-101620	0 101621-102004	0 102005-102063
2 101204-101234	1 020106-021027			1 021030-021104
	2 101243-101260			
PRPTBL/R	FNDNAM/R	SRMIDB/R	DACMUL/R	DCMMUL/R
0 102064-102143	0 102144-102156	0 102157-102531	0 102532-102541	0 102542-102551
1 021105-021163	1 021164-021227	1 021230-022562	1 022563-022623	1 022624-022660
MTRMUL/R	CASCDE/R	ATOZ /R	L2BY2/R	L4BY2/R
0 102552-102652	0 102653-102672	0 102673-102733	0 102734-102745	0 102746-102757
1 022661-023123	1 023124-023360	1 023361-023606	1 023607-023636	1 023637-023666
MTRMOV/R	TYPCAL/R	TYPE25/R	TYPE24/R	DCRCIP/R
0 102760-102776	0 102777-103024	0 103025-103045	0 103046-103066	0 103067-103076
1 023667-023735	1 023736-024217	1 024220-024301	1 024302-024401	1 024402-024434
TYPE22/R	TYPE21/R	TYPE20/R	TYPE15/R	TP1415/R
0 103077-103117	0 103120-103140	0 103141-103227	0 103230-103235	0 103236-103323
1 024435-024533	1 024534-024614	1 024615-025050	1 025051-025075	1 025076-025642

DCSNCS/R
0 103324-103343
1 025643-025725

DCMDIV/R
0 103563-103576
1 026413-026460

LS1415/R
0 103701-103714
1 027206-027254

TYPE11/R
0 103765-104056
1 027302-030316

DLOG /RL22
1 031017-031060
2 104306-104371

DECOMB/R
0 104566-105005
1 032262-034163

TYPE2 /R
0 105443-105564
1 034203-034540

NEXP15/RL22
1 036147-036202
2 106055-106055

FMFN /R
0 106173-106213
1 036451-036571

CMPGAM/R
0 106527-106624
1 037505-037755

SRCHSB/******
0 106716-106725

DSHCH /R
0 103344-103361
1 025726-025764

T14155/R
0 103577-103623
1 026451-026723

CESSFP/******
0 103715-103722

DCSHCH/R
0 104057-104076
1 030317-030376

T11SBP/R
0 104372-104427
1 031061-031355

DLOG10/RL22
1 034164-034202
2 105006-105036

TYPE1 /R
0 105565-105657
1 034541-034755

C3LD /******
0 106056-106056

PRBFIT/R
0 106214-106265
1 036572-036734

PRGMTR/******
0 106625-106625

PRTMTR/R
0 106726-106754

DEXP /RL23
0 103362-103363
1 025765-026123
2 103364-103474

DSCOR7/R
0 103624-103662
1 026724-027155

CM1415/******
0 103723-103754

DCACSH/R
0 104077-104122
1 030377-030470

LDS311/R
0 104430-104443
1 031356-031424

DCMSOL/******
0 105017-105434

BLDMTR/R
0 105660-105712
1 034756-035254

CMPZS /R
0 106057-106077
1 036203-036235

RLIMMG/R
0 106266-106371
1 036735-037141

CMNZS /******
0 106626-106631

ZTOA /R
0 106755-107015

FMATHA/RL22
1 026124-026176
2 103475-103510

CS1415/******
0 103663-103666

CMN15C/******
0 103755-103756

DCANG1/R
0 104123-104153
1 030471-030620

CZ3BY3/******
0 104444-104465

DECOND/******
0 105435-105436

FNDMTR/R
0 105713-105726
1 035255-035332

PRMARI/R
0 106100-106141
1 036236-036340

CGMNPR/******
0 105372-106372

LD&M2S/R
0 106632-106714
1 037756-040261

CZ2BY2/******
0 107015-107025

DSINCO/RL22
1 026177-025412
2 103511-103562

LZ3BY3/R
0 103667-103700
1 027156-027205

TYPE14/R
0 103757-103764
1 027255-027301

DATAN /RL22
1 030621-031016
2 104154-104305

TYPE7 /R
0 104466-104565
1 031425-032261

VALDET/******
0 105437-105442

UNPACK/R
0 105727-106054
1 035333-036146

FNDTMS/R
0 106142-106172
1 036341-036450

POLED /R
0 106373-106526
1 037142-037504

CFLGAZ/******
0 106715-106715

CA2BY2/******
0 107026-107035

```
                    1   040262-040366   1   040367-040614

LOCMTR/R            FNDTL /R            LDDT11/R            LDDRIM/R            CHKSTR/R
0   107036-107052   0   107053-107114   0   107115-107276   0   107277-107311   0   107312-107330
1   040615-040671   1   040672-041076   1   041077-041534   1   041535-041615   1   041616-041646

AIDOD /R            COMN11/******       RDCPRT/R            BLDKKL/R            FNDLCJ/R
0   107331-107355   0   107356-107416   0   107417-107542   0   107543-107631   0   107632-107662
1   041647-042047                       1   042050-043073   1   043074-043513   1   043514-044027

FNDNET/R            CMAGIC/******       CPRTIN/******       CNMRDC/******       LDFREQ/R
0   107663-107710   0   107711-107711   0   107712-107713   0   107714-107715   0   107716-107732
1   044030-044211                                                               1   044212-044242

HEAD24/R            LDIMTR/R            SKPLIN/R            ALOCAT/R            LDDT7 /R
0   107733-107755   0   107756-110002   0   110003-110014   0   110015-110042   0   110043-110303
1   044243-044365   1   044366-044455   1   044457-044512   1   044513-044575   1   044576-045477

NINPTS/RL23         NININS/RL23         LDDT4 /R            LDDT1 /R            DTASUB/******
0   110304-110305   1   046427-046566   0   110420-110513   0   110514-110636   0   110637-110637
1   045500-046426   2   110341-110417   1   046567-047063   1   047064-047465
2   110306-110340

LDPCPT/R            UPPTBL/R            CPTWRD/******       PRTTBL/******       STRLIN/R
0   110640-110730   0   110731-110756   0   110757-110760   0   110761-113075   0   113076-113122
1   047466-050011   1   050012-050206                                            1   050207-050223

PAGE  /R            CMNFMN/******       FLGSRH/******       CSRMTR/******       CRMRCT/******
0   113123-113131   0   113132-113134   0   113135-113140   0   113141-113141   0   113142-113145
1   050224-050240

GMECIC/******       CDESGN/******       CFMNPR/******       PRTOFF/******       TOTMAS/******
0   113146-113165   0   113166-113172   0   113173-113173   0   113174-113174   0   113175-113176

TOTL  /******       DTATOT/******       BASIC3/******       CATALG/******
0   113177-113200   0   113201-113201   0   113202-113207   0   113210-114504

END OF ALLOCATION 1103 0039A 0
```

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permit fully legible reproduction

```
*****************************************************************************
MOD 9 RUN 80038 APR 23, 1970 $ LIKE MOD 7 RUN 70335
 DESIGN RUN $
LINES OF CONSTANT TAIL LENGTHS
CHARGE TO 16000501 ARRAY DESIGN


* * * * * BD  7 NETWORK TABLE

S  1B7D, -+1T1A, -+1R2A,$
S  2B7D,   1E2E,$
S  3B7D,   2R2A,$
S  4B7D,   1R2Z,$
S  5B7D,   2Y2Z,$
S  6B7D, -+2E2E,   1V2W,  1Y2Z,$
S  7B7D, -+1T1B,   2R2Z,  2V2W,$


* * * * * AD  6 NETWORK TABLE

S  1A6D,   3C3D,$
S  2A6D,   5B5D,$
S  3A6D, -+2C3D,   2B5D,$
S  4A6D, -+1B5D,   1C3D,$
S  5A6D, -+3B5D,   1R2D,$
S  6A6D, -+4B5D,   2R2D,$


TYPE 1          RHO        AREA          ID       OD      LENGTH
E2E1$          4416.90   .148261-01  .000000 .137394  .009070
                C REAL    C IMAG        C MULT                      MASS
               4820.00    .000000       .000000                     .59394


TYPE 1          RHO        AREA          ID       OD      LENGTH
R2A1$          7712.80   .790233-03  .000000 .031720  .007248
                C REAL    C IMAG        C MULT                      MASS
               4970.00    .000000       .000000                     .09412


TYPE 1          RHO        AREA          ID       OD      LENGTH
```

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permit fully legible reproduction

S221S	7702.80	.790233-03	.000000	.031720	.000838	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.00510
TYPE 1	RHO	AREA	ID	OD	LENGTH	
T231S	7730.00	.228639-02	.000000	.053955	.003357	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.05933
TYPE 1	RHO	AREA	ID	OD	LENGTH	
T232S	7724.87	.108402-02	.000000	.046305	.003314	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.04311
TYPE 1	RHO	AREA	ID	OD	LENGTH	
T233S	7719.24	.130699-02	.000000	.040794	.010214	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.10305
TYPE 1	RHO	AREA	ID	OD	LENGTH	
T254S	7702.80	.790233-03	.000000	.031720	.006679	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.04066
TYPE 1	RHO	AREA	ID	OD	LENGTH	
V2W1S	4416.90	.112776-01	.000000	.119829	.011370	
	C REAL	C IMAG	C MULT			MASS
	4820.00	.000000	.000000			.56637
TYPE 1	RHO	AREA	ID	OD	LENGTH	
V2W2S	4416.90	.112776-01	.000000	.119829	.011370	
	C REAL	C IMAG	C MULT			MASS
	4820.00	.000000	.000000			.56637
TYPE 1	RHO	AREA	ID	OD	LENGTH	
V2W3S	7788.48	.254984-02	.000000	.056979	.002224	
	C REAL	C IMAG	C MULT			MASS
	5116.00	.000000	.000000			.04418
TYPE 1	RHO	AREA	ID	OD	LENGTH	

```
Y221$          2702.81    .348119-02  .000000 .066575  .011370
               C REAL     C IMAG       C MULT                      MASS
               5200.00     .000000      .000000                    .10698

TYPE 1          RHO        AREA         ID       OD      LENGTH
Y222$          2702.81    .348119-02  .000000 .066576  .011370
               C REAL     C IMAG       C MULT                      MASS
               5200.00     .000000      .000000                    .10698

TYPE 4          UNIT MATRIX
Y223$            1.00
```

```
TPE 7          SCALE      MATRIX    NUMERATOR      DENOMINATOR      SYMMETRY
               FACTOR     FORM      ORDER          ORDER            FLAG
2245           .1000+01   3         3              1                -1
     COEF. TO CHECK NEW TYPE 7 WITH OLD TYPE 7
        POLYNOMIAL COEFFICIENTS FOR Z(I,J)=(C0+C1*F+...)/(D0+D1*F+...)

     NUMERATOR  POLYNOMIAL  COEFFICIENTS FOR MATRIX ELEMENT(  1,  1)
           .0000000000      -.8588996000+09
           .0000000000       .7711489000+05
           .0000000000      -.9040960000+01
           .0000000000       .1627919980-02

     DENOMINATOR POLYNOMIAL COEFFICIENTS FOR MATRIX ELEMENT(  1,  1)
           .0000000000       .0000000000
           .1000000000+01    .0000000000

     NUMERATOR  POLYNOMIAL  COEFFICIENTS FOR MATRIX ELEMENT(  1,  2)
           .0000000000       .8683080000+09
           .0000000000      -.7690410000+05
           .0000000000       .1246709980+02
           .0000000000      -.1830116830-02

     DENOMINATOR POLYNOMIAL COEFFICIENTS FOR MATRIX ELEMENT(  1,  2)
           .0000000000       .0000000000
           .1000000000+01    .0000000000

     NUMERATOR  POLYNOMIAL  COEFFICIENTS FOR MATRIX ELEMENT(  2,  2)
           .0000000000       .8691160000+09
           .0000000000      -.7743060000+05
           .0000000000      -.2671390000+00
           .0000000000      -.1807459960-02

     DENOMINATOR POLYNOMIAL COEFFICIENTS FOR MATRIX ELEMENT(  2,  2)
           .0000000000       .0000000000
           .1000000000+01    .0000000000


F2S UNIT MATRIX
D2S UNIT MATRIX
S2S UNIT MATRIX
```

```
* * * * * F =    3500.000000 * * * * *


TYPE 1          RHO        AREA          ID       OD      LENGTH
T2A1$          7832.48    .217225-01   .000000 .166307   .038125
               C REAL     C IMAG        C MULT                      MASS
               5116.00     .000000       .000000                   6.48658

REPLACE

TYPE 1          RHO        AREA          ID       OD      LENGTH
Y2Z3$          2702.81    .245000-02   .000000 .035852   .035354
               C REAL     C IMAG        C MULT                      MASS
               5200.00     .000000       .000000                    .23411

TYPE 11         RHO        AREA          ID       OD      LENGTH
C30$           7588.21    .490000-02   .000000 .078987   .013625
               C REAL     C IMAG        C MULT           N PIECES   MASS
               3743.27    .312617+01    .835144-03          2       1.01324

                    REAL                IMAG                MULT
        E33T    .1411666000+004   -.3416019970+001    .2419850000-002
        G33     .2452070000-001    .4595841239-005   -.1874270000-003
        S33D    .9404950000-011   -.1570899394-013    .1670290000-002

        K33     .6664539643+000   -.6940268089-004

TOTAL LENGTH =  .061285 FOR SECTIONS   VW   EE   CD


TYPE 1          RHO        AREA          ID       OD      LENGTH
R2D1$          7702.80    .571140-03   .000000 .026967   .053199
               C REAL     C IMAG        C MULT                      MASS
               4970.00     .000000       .000000                    .23404
```

Z SELF

MAG	ANG DEG	REAL	IMAG
.0000000000	.0000000000	.0000000000	.0000000000

L T2A1	A C3D	L C3D	TOT MASS	TOT LENGTH	REACTOR	GAMMA IC	GAM EC MIN
.3812-01	.4900-02	.1738+00	.1910+02	.3242+00	.4270-01	.1106+08	.1037+03
		N = 12					
.3812-01	.6500-02	.2086+00	.2315+02	.3590+00	.1997-01	.1231+08	.1373+03
		N = 16					
.3812-01	.7520-02	.2259+00	.2588+02	.3764+00	.1774-01	.1263+08	.1576+03
		N = 16					
.3812-01	.8100-02	.2345+00	.2747+02	.3850+00	.1313-01	.1271+08	.1693+03
		N = 18					
.3812-01	.1290-01	.2827+00	.4116+02	.4331+00	.6547-02	.1210+08	.2626+03
		N = 20					
.7625-01	.4900-02	.1291+00	.2372+02	.3176+00	.4755-01	.9667+07	.8358+02
		N = 10					
.7625-01	.6500-02	.1614+00	.2710+02	.3499+00	.2907-01	.1171+08	.1153+03
		N = 12					
.7625-01	.7520-02	.1782+00	.2944+02	.3668+00	.1945-01	.1249+08	.1355+03
		N = 14					
.7625-01	.8100-02	.1868+00	.3031+02	.3754+00	.1842-01	.1279+08	.1470+03
		N = 14					
.7625-01	.1290-01	.2387+00	.4315+02	.4273+00	.7201-02	.1291+08	.2434+03
		N = 18					
.1144+00	.4900-02	.1095+00	.2939+02	.3362+00	.6387-01	.8577+07	.7236+02
		N = 8					
.1144+00	.6500-02	.1385+00	.3236+02	.3652+00	.3691-01	.1077+08	.1007+03
		N = 10					
.1144+00	.7520-02	.1537+00	.3442+02	.3804+00	.2364-01	.1176+08	.1189+03
		N = 12					
.1144+00	.8100-02	.1615+00	.3563+02	.3882+00	.2252-01	.1219+08	.1293+03
		N = 12					
.1144+00	.1290-01	.2096+00	.4666+02	.4363+00	.8462-02	.1328+08	.2202+03
		N = 16					
.1525+00	.4900-02	.9843-01	.3542+02	.3633+00	.5775-01	.7851+07	.6559+02
		N = 8					
.1525+00	.6500-02	.1252+00	.3813+02	.3901+00	.3383-01	.1002+08	.9124+02

```
                    N = 10
.1525+00  .7520-02  .1391+00  .4000+02  .4039+00  .3140-01  .1105+08  .1076+03
                    N = 10
.1525+00  .8100-02  .1461+00  .4111+02  .4110+00  .3002-01  .1154+08  .1171+03
                    N = 10
.1525+00  .1290-01  .1697+00  .5112+02  .4545+00  .1045-01  .1329+08  .1998+03
                    N = 14

.1906+00  .4900-02  .9114-01  .4161+02  .3941+00  .9532-01  .7333+07  .6097+02
                    N =  6
.1906+00  .6500-02  .1183+00  .4414+02  .4192+00  .4949-01  .9430+07  .8459+02
                    N =  8
.1906+00  .7520-02  .1292+00  .4538+02  .4321+00  .2951-01  .1047+08  .9955+02
                    N = 10
.1906+00  .8100-02  .1357+00  .4690+02  .4386+00  .2827-01  .1096+08  .1081+03
                    N = 10
.1906+00  .1290-01  .1753+00  .5612+02  .4782+00  .1359-01  .1311+08  .1831+03
                    N = 12


A Y2Z4

 1     1     .9383815355+00     .0000000000
 2     1     .0000000000        .5132157777-05

 1     2     .0000000000        .5614587184+05
 2     2     .7585939197+00     .0000000000


Z Y2Z4

 1     1     .0000000000       -.1828434698+06
 2     1     .0000000000       -.1948493163+06

 1     2     .0000000000        .1948493163+06
 2     2     .0000000000        .1478118859+06
```

* * * * COMMON PRT TBL * * * * *

N	NET SP	I C	SIGN D	J PORT	N PORTS	NET NAM	NUM APO	NUM NPO	N AHEAD	N BACK	LC J ROW
1	S	1	1	1	7	BD	1	-1	4	0	1
2	S	-1	1	1	1	TA	1	1	3	0	858
3	S	-1	1	1	2	RA	1	2	7	2	380
4	S	1	1	2	7	BD	2	-2	6	1	2
5	S	1	1	1	2	EE	2	4	13	7	341
6	S	1	1	3	7	BD	3	-3	8	4	3
7	S	1	1	2	2	RA	3	3	5	3	381
8	S	1	1	4	7	BD	4	-4	10	6	4
9	S	1	1	1	2	RZ	4	6	18	13	419
10	S	1	1	5	7	BD	5	-5	12	8	5
11	S	1	1	2	2	YZ	5	9	14	15	652
12	S	1	1	6	7	BD	6	-6	16	10	6
13	S	-1	1	2	2	EE	6	5	9	5	342
14	S	1	1	1	2	VW	6	10	19	11	566
15	S	1	1	1	2	YZ	6	8	11	18	651
16	S	1	1	7	7	BD	7	-7	20	12	7
17	S	-1	1	1	1	TB	7	12	0	19	862
18	S	1	1	2	2	RZ	7	7	15	9	420
19	S	1	1	2	2	VW	7	11	17	14	567
20	S	1	1	1	6	AD	1	-1	22	16	197
21	S	1	1	3	3	CD	1	3	28	25	1024
22	S	1	1	2	6	AD	2	-2	24	20	198
23	S	1	1	5	5	BD	2	8	32	34	870
24	S	1	1	3	6	AD	3	-3	27	22	199
25	S	-1	1	2	3	CD	3	2	21	29	1023
26	S	1	1	2	5	BD	3	5	31	28	867
27	S	1	1	4	6	AD	4	-4	30	24	200
28	S	-1	1	1	5	BD	4	4	26	21	866
29	S	1	1	1	3	CD	4	1	25	0	1022
30	S	1	1	5	6	AD	5	-5	33	27	201
31	S	-1	1	3	5	BD	5	6	34	26	868
32	S	1	1	1	2	RD	5	9	35	23	1091
33	S	1	1	6	6	AD	6	-6	0	30	202
34	S	-1	1	4	5	BD	6	7	23	31	869

35 5 1 1 2 2 RD 6 1C 0 32 1992

* * * * * COMMON CATALG * * * * *

I	NAME	MTR SIZ	I PC	N PC TOT	I TYPE	N DT STR	LOC
1	BD	7	0	0	0	0	1
2	AD	6	0	0	0	0	197
3	EE	2	0	1	0	0	341
4	EE	2	1	1	1	7	357
5	RA	2	0	1	0	0	380
6	RA	2	1	1	1	7	396
7	RZ	2	0	1	0	0	419
8	RZ	2	1	1	1	7	435
9	TB	2	0	4	0	0	458
10	TB	2	1	4	1	7	474
11	TB	2	2	4	1	7	497
12	TB	2	3	4	1	7	520
13	TB	2	4	4	1	7	543
14	VW	2	0	3	0	0	566
15	VW	2	1	3	1	7	582
16	VW	2	2	3	1	7	605
17	VW	2	3	3	1	7	628
18	YZ	2	0	4	0	0	651
19	YZ	2	1	4	1	7	667
20	YZ	2	2	4	1	7	690
21	YZ	2	3	4	1	7	713
22	YZ	2	4	4	7	42	737
23	FS	2	0	0	0	0	795
24	DS	2	0	0	0	0	803
25	SS	2	0	0	0	0	811
26	TA	2	0	1	0	0	819
27	TA	2	1	1	1	7	835
28	TA	1	0	0	0	0	858
29	TB	1	0	0	0	0	862
30	BD	5	0	0	0	0	866
31	BD	0	0	0	0	0	966
32	BD	0	0	0	0	0	982
33	CO	3	0	0	11	33	1022
34	RO	2	0	1	0	0	1091
35	RO	2	1	1	1	7	1107
36	AD	2	0	0	0	0	1130

37	AD	0	0	0	0	0	1146
38	AD	0	0	0	0	0	1210
39	ES	2	0	0	0	0	1242
40	MS	2	0	0	0	0	1250
41	GS	2	0	0	0	0	1258
42	HS	2	0	0	0	0	1266

TOTAL DATA CELLS USED IN MASTER STORAGE 1273

```
*****************************************************************************
SEADUCER RUN 80001 (LIKE MOD 7 RUN 70294) SEPT 26,1970
WARDS DUCER FOR MOD 8 DEVELOPMENT (K8D NETWORK)


* * * * * KD  8 NETWORK TABLE

S  1K8D, 1B2G,$
S  2K8D, 2B2B,$
S  3K8D, 3D3A,$
S  4K8D, 1B2B, 1B2C, -+2B2E,$
S  5K8D, 1B1D, -+2B2C, -+2B2R, $
S  6K8D, 1B2F, 1B2R, -+2B2G, $
S  7K8D, 1D3A, -+2B2F, $
S  8K8D, -+2D3A, 1B2E, $


TYPE 1          RHO        AREA          ID       OD      LENGTH
B2B1$          7815.00    .139960-02   .000000 .042214   .121570
                C REAL     C IMAG        C MULT                      MASS
                5116.00     .000000       .000000                   1.32972

TYPE 1          RHO        AREA          ID       OD      LENGTH
B2B2$          7815.00    .810000-02   .000000 .101554   .102400
                C REAL     C IMAG        C MULT                      MASS
                5116.00     .000000       .000000                   6.48207

TYPE 1          RHO        AREA          ID       OD      LENGTH
B2B3$          7815.00    .134200-02   .000000 .041336   .067854
                C REAL     C IMAG        C MULT                      MASS
                5116.00     .000000       .000000                    .71163


TYPE 1          RHO        AREA          ID       OD      LENGTH
B2C1$          7558.40    .101971-02   .000000 .036032   .003175
                C REAL     C IMAG        C MULT                      MASS
                5116.00     .000000       .000000                    .02447

TYPE 4          UNIT MATRIX
B2C2$            1.00
```

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TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2D1S	7746.00	.760378-03	.000000	.031115	.009601	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.05655
TYPE 2	RHO	A1	ID1	OD1		
B2D2S	7743.74	.760378-03	.000000	.031115		
		A2	ID2	OD2	LENGTH	
		.455310-03	.000000	.024077	.002540	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.01183
TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2D3S	7743.45	.455310-03	.000000	.024077	.003302	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.01164
TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2D4S	7737.80	.240258-03	.000000	.017490	.003600	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.00669
TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2R1S	7738.00	.240258-03	.000000	.017490	.010500	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.01952
TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2R2S	7738.00	.285023-03	.000000	.019050	.035250	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.07774
TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2R3S	7738.00	.197933-03	.000000	.015875	.474537	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.72680
TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2R4S	7738.00	.285023-03	.000000	.019050	.037290	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.03224

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TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2R5$	7738.00	.240258-03	.000000	.017490	.008246	
	C REAL	C IMAG	C MULT			MASS
	4970.00	.000000	.000000			.01533

TYPE 4	UNIT MATRIX	
B2E1$	1.00	

TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2E2$	7814.88	.426383-02	.000000	.073681	.031750	
	C REAL	C IMAG	C MULT			MASS
	5116.00	.000000	.000000			1.05795

TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2F1$	7802.15	.456037-02	.000000	.076200	.031750	
	C REAL	C IMAG	C MULT			MASS
	5116.00	.000000	.000000			1.12969

TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2G1$	7815.00	.260000-02	.000000	.057536	.010520	
	C REAL	C IMAG	C MULT			MASS
	5116.00	.000000	.000000			.21376

TYPE 1	RHO	AREA	ID	OD	LENGTH	
B2G2$	7815.00	.215000-02	.000000	.052321	.021340	
	C REAL	C IMAG	C MULT			MASS
	5116.00	.000000	.000000			.35856

TYPE 11	RHO	AREA	ID	OD	LENGTH	
D3A$	7440.00	.253354-02	.000000	.056796	.019198	
	C REAL	C IMAG	C MULT		N PIECES	MASS
	3479.30	.482230+01	.138600-02		26	9.40871

	REAL	IMAG	MULT
E33T	.1280390000+004	-.1771470370+001	.1383000000-002
G33	.2378780000-001	-.1207944484-004	.5076000000-003
3D	.1110300000-010	-.3077751600-013	.7720000000-002
K33	.6052162048+000	.7160454537-004	

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```
REPLACE

TYPE 4          UNIT MATRIX
B2E2$            1.00

REPLACE

TYPE 1          RHO        AREA          ID       OD       LENGTH
B2E1$          7814.88    .426383-02   .000000  .073681   .031750
                C REAL     C IMAG        C MULT                      MASS
                5116.00     .000000       .000000                   1.05795

REPLACE

TYPE 2          RHO         A1           ID1      OD1
B2D2$          7743.74    .760378-03   .000000  .031115
                            A2           ID2      OD2      LENGTH
                          .455310-03   .000000  .024077   .002540
                C REAL     C IMAG        C MULT                      MASS
                4970.00     .000000       .000000                    .01183

REPLACE

TYPE 1          RHO        AREA          ID       OD       LENGTH
B2D4$          7737.80    .240258-03   .000000  .017490   .003600
                C REAL     C IMAG        C MULT                      MASS
                4970.00     .000000       .000000                    .00669

REPLACE

TYPE 1          RHO        AREA          ID       OD       LENGTH
B2B1$          7815.00    .139960-02   .000000  .042214   .121570
                C REAL     C IMAG        C MULT                      MASS
                5116.00     .000000       .000000                   1.32972

REPLACE

TYPE 11         RHO        AREA          ID       OD       LENGTH
D3A$           7440.00    .253354-02   .000000  .056796    019198
                C REAL     C IMAG        C MULT           N PIECES  MASS
                [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
```

	REAL	IMAG	MULT
E33T	.1280890000+004	-.1771470870+001	.1383000000-002
G33	.2378720000-001	-.1207944484-004	.5078000000-003
S33D	.1110300000-010	-.3077751600-013	.2772000000-002
K33	.6052162044+000	.7160454537-004	

TOTAL MASS = 21.72491 KG. 47.89518 LBS.

TOTAL LENGTH = .886332 FOR SECTIONS BG BF DA BE BB

```
* * * * * F =    2500.000000 * * * * *

FINAL K3D MATRIX

   1      1     .8246889136+03    -.9647054664+05
   2      1    -.8518089926+03     .1639490892+06
   3      1     .5459747958+02    -.1129571571+05

   1      2     .8518089926+03    -.1639490892+06
   2      2    -.1464582941+04     .8957370445+05
   3      2     .5914333365+02    -.1980984506+04

   1      3     .5459747958+02    -.1129571571+05
   2      3    -.5914333365+02     .1980984506+04
   3      3     .5935133270+01    -.2570213422+04

Z K2D MATRIX

   1      1     .4594277801+03    -.4682782852+05
   2      1    -.5699045679+03     .1552435546+06

   1      2     .5699045679+03    -.1552435546+06
   2      2    -.1376936933+04     .8804802498+05
```

* * * * * COMMON PRT TBL * * * * *

N	NET SP	I SIGN C	D	J PORT	N PORTS	NET NAM	NUM APO	NUM NPO	N AHEAD	N BACK	LC J ROW
1	S	1	1	1	8	KD	1	-1	3	0	1
2	S	1	1	1	2	BG	1	1	18	0	17
3	S	1	1	2	8	KD	2	-2	5	1	2
4	S	1	1	2	2	BB	2	4	20	6	258
5	S	1	1	3	8	KD	3	-3	7	3	3
6	S	1	1	3	3	DA	3	7	9	23	811
7	S	1	1	4	8	KD	4	-4	11	5	4
8	S	1	1	1	2	BB	4	3	4	18	257
9	S	1	1	1	2	BC	4	8	13	6	342
10	S	-1	1	2	2	BE	4	11	12	24	646
11	S	1	1	5	8	KD	5	-5	15	7	5
12	S	1	1	1	1	BD	5	12	17	10	878
13	S	-1	1	2	2	BC	5	9	24	9	343
14	S	-1	1	2	2	BR	5	14	16	17	515
15	S	1	1	6	8	KD	6	-6	19	11	6
16	S	1	1	1	2	BF	6	15	21	14	708
17	S	1	1	1	2	BR	6	13	14	12	514
18	S	-1	1	2	2	BG	6	2	8	2	748
19	S	1	1	7	8	KD	7	-7	22	15	7
20	S	1	1	1	3	DA	7	5	23	4	809
21	S	-1	1	2	2	BF	7	16	0	16	709
22	S	1	1	8	8	KD	8	-8	0	19	8
23	S	-1	1	2	3	DA	8	6	6	20	810
24	S	1	1	1	2	BE	8	10	10	13	645

* * * * * COMMON CATALG * * * * *

I	NAME	MTR SIZ	I PC	N PC TOT	I TYPE	N DT STR	LOC
1	KD	8	0	0	0	0	1
2	BB	2	0	3	0	0	257
3	BB	2	1	3	1	7	273
4	BB	2	2	3	1	7	296
5	BB	2	3	3	1	7	319
6	BC	2	0	2	0	0	342
7	BC	2	1	2	1	7	356
8	BC	2	2	2	4	8	381
9	BD	2	0	4	0	0	405
10	BD	2	1	4	1	7	421
11	BD	2	2	4	2	8	444
12	BD	2	3	4	1	7	468
13	BD	2	4	4	1	7	491
14	BR	2	0	5	0	0	514
15	BR	2	1	5	1	7	530
16	BR	2	2	5	1	7	553
17	BR	2	3	5	1	7	576
18	BR	2	4	5	1	7	599
19	BR	2	5	5	1	7	622
20	BE	2	0	2	0	0	645
21	BE	2	1	2	1	7	661
22	BE	2	2	2	4	8	685
23	BF	2	0	1	0	0	708
24	BF	2	1	1	1	7	724
25	BG	2	0	2	0	0	747
26	BG	2	1	2	1	7	763
27	BG	2	2	2	1	7	786
28	DA	3	0	0	11	33	809
29	BD	1	0	0	0	0	878
30	KD	3	0	0	0	0	882
31	KD	0	0	0	0	0	918
32	KD	0	0	0	0	0	1018
33	KD	2	0	0	0	0	1078
34	KD	0	0	0	0	0	1094
35	KD	0	0	0	0	0	1098

TOTAL DATA CELLS USED IN MASTER STORAGE 1105

Radian Corporation 8500 SHOAL CREEK BLVD. • P. O. BOX 9948 • AUSTIN, TEXAS 78766 • TELEPHONE 512 - 454-9535

Appendix B

Scattering from Translucent Baffles

Scattering from Translucent Baffles

The purpose of this discussion is to outline an approach for treating the combined effects of transmission and edge diffraction for plane wave scattering from a planar baffle. The scope of the discussion includes a brief description of an integral formulation of the problem and some of the difficulties inherent in an approximate approach.

A rigorous formulation of the problem of interest differs from that of an opaque baffle in the requirement of characterizing the response of the baffle material to a distribution of forces on its surfaces. In effect, this requirement is equivalent to the determination of a Green's function or "influence" function for the baffle material.*

Knowing the influence function for the baffle material, one can write an integral relationship between the force distribution on the baffle surfaces and the velocity field on the baffle surface. Since the baffle is immersed in a fluid which is assumed inviscid, the force at a given point on the baffle is normal to the surface. Consequently, the normal velocity $V_n(\vec{r})$ at a point $\vec{r}$ on the baffle surface depends on the normal force per unit area, i.e., the pressure, p, according to the relation:

$$V_n(\vec{r}) = \int_{S_b} K(\vec{r}|\vec{r}\,')p(\vec{r}\,')dS' \quad , \qquad \text{(B-1)}$$

---

* See Sec. IV of Ref. [B-1] for an analogous approach to transducer dome interaction.

where $K(\vec{r}|\vec{r}')$ is the n-n component of the influence dyadic [B-1] for the baffle material. The integral in Equation (B-1) is taken over both sides of the baffle.

It is important to note that the kernel, $K(\vec{r}|\vec{r}')$, depends only on the geometrical and physical properties of the baffle, i.e., it is independent of the conditions existing at any point of the fluid in which the baffle is immersed. Also we note that Equation (B-1) is a generalized impedance relationship; more correctly $K(\vec{r}|\vec{r}')$ has the units of an admittance per unit area. As such, Equation (B-1) is a mathematical formulation of the transmissive properties of the baffle material. Furthermore, any baffle material having linear constitutive equations gives rise to an impedance relationship of the form given in Equation (B-1)*, i.e., the form of Equation (B-1) does not depend on any assumptions regarding baffle geometry.

To complete the specification of the scattering of a plane wave

$$p_i(\vec{r}) = e^{i\vec{k}\cdot\vec{r}} \qquad \text{(B-2)}$$

by the baffle, we use the Helmholtz representation of the total field:

$$p(\vec{r}) = p_i(\vec{r}) + \int_{S_b} \left[p(\vec{r}')\frac{\partial g}{\partial n'}(\vec{r}|\vec{r}') - \frac{\partial p}{\partial n'}(\vec{r}')g(\vec{r}|\vec{r}') \right] dS' \quad , \qquad \text{(B-3)}$$

---

* For cases of locally reacting surfaces, the kernel is proportional to a (surface) "delta function".

where $p(\vec{r})$ is the total pressure field at the point $\vec{r}$ in the fluid, and g is the free space Green's function for the fluid medium.[B-1]

The above relationships, in conjunction with the definition

$$V_n(\vec{r}) = \frac{1}{ik\rho c} \frac{\partial p}{\partial n}(\vec{r})\Big]_{S_b} , \qquad \text{(B-4)}$$

where k is the wave number and ρc is the fluid, acoustical impedance, serve to define a solution to the problem. In particular, Equation (B-1), and the limiting form of Equation (B-3) as the field point $\vec{r}$ approaches the baffle surface, give rise to a pair or coupled integral equations which, by virtue of Equation (B-4), relate the unknown pressure and velocity fields on the baffle surface, p and V_n, respectively, to the incident pressure field p_i. A simultaneous solution of these integral equations defines the terms appearing in the integral of Equation (B-3), hence Equation (B-3) defines the pressure field at every point in the fluid.

While the above approach is conceptually applicable to general baffle shapes in either two or three dimensions, the practical aspects of implementing the formalism is limited first of all to baffles for which the influence function can be evaluated analytically and secondly by computational difficulties of obtaining an approximate solution to the coupled integral equations.*

In view of the difficulties mentioned, it would be desirable to have an alternative, approximate approach to represent the essential features of the pressure field. In order to

* Additionally the formalism would need to be modified for treating "reasonance" wave numbers associated with the baffle.

derive such an approximation it is necessary to limit the discussion to specialized geometrical configurations. In particular, we limit the subsequent discussion to the case of a planar baffle.

As a first approximation, we assume that the pressure and velocity fields on the baffle surfaces are not influenced appreciably by the presence of the edge. This assumption corresponds in some sense to the Kirchhoff approximation used previously for analysis of opaque baffles. Furthermore, the assumption enables one to write

$$p(\vec{r}\,')\Big]_{S_b} = \begin{cases} e^{i\vec{k}\cdot\vec{r}} + R(\vec{k})e^{i\vec{k}_1\cdot\vec{r}} & \text{on } S_i \\ T(\vec{k})e^{i\vec{k}\cdot\vec{r}} & \text{on } S_s \end{cases} \qquad \text{(B-5)}$$

where $R(\vec{k})$, $T(\vec{k})$ denote, respectively, the (amplitude) reflection and transmission coefficients for a layer of the baffle material which incorporate the physical properties of the baffle*, $\vec{k}_1$ denotes the propagation vector of the reflected wave, S_i denotes the illuminated baffle surface, and S_s denotes the shadow baffle surface. In writing the above relationship, we have implicitly assumed the baffle thickness is negligible relative to the acoustical <u>fluid</u> wavelength. This assumption simplifies the discussion and can easily be removed.

---

* See Reference B-2 for the definition of the transmission and reflection coefficients for a composite layer.

If, in addition to Equation (B-5), we assume an analogous equality for the normal derivative on the baffle surface, then the resulting approximate pressure field takes the form:

$$p(\vec{r}) = e^{i\vec{k}\cdot\vec{r}} + \left[1 - T(\vec{k})\right]U(\vec{r}|\vec{k}) + R(\vec{k})U(\vec{r}|\vec{k}_1) \qquad \text{(B-6)}$$

where

$$U(\vec{r}|\vec{k}) = \int_{S_s} \left[g(\vec{r}|\vec{r}\,')\frac{\partial}{\partial n'}e^{i\vec{k}\cdot\vec{r}\,'} - e^{i\vec{k}\cdot\vec{r}\,'}\frac{\partial g}{\partial n'}(\vec{r}|\vec{r}\,')\right]dS' \quad . \qquad \text{(B-7)}$$

The above relationships result from substituting Equations (B-2), (B-5) into Equation (B-3) and using the fact that the integral over S_i is the negative of the integral over S_s because of the assumption of negligible thickness of the baffle.

As in the case for opaque baffles, the approximation scheme described above gives rise to an approximate Green's function which violates the reciprocity principle. It has been noted previously (B-4) that the problem of plane wave scattering corresponds to a limiting process on the Green's function in which the source point moves to infinity. Furthermore physical considerations have indicated that for an opaque baffle, a more accurate approximation for plane wave scattering can be obtained from a Kirchhoff approximation to the Green's function by interchanging field and source coordinates before taking the limit. Whether this holds true for the present approximation remains to be investigated, but the assumption that it does gives rise to an approximation which replaces Equation (B-6) by an integral representation which involves reflection and transmission coefficients

integrated over all angles. This form arises by using the plane wave integral representation for the Green's function given in Reference B-2. Presumably, the latter approximation accounts partially for the fact that the presence of the edge modifies the source strengths appearing in Equation (B-3) from the zero order approximation given by Equation (B-5). This point requires more investigation. In the final analysis it may be required to check any approximation with the pair of coupled integral equations for justification of the assumptions.

The above relationships represent approximate expressions for the pressure field which are applicable to either plates or strips. In the former case g denotes the three-dimensional free space Green's function and the integral is taken over the shadowed surface of the plate.* In the latter case, the integral can be considered as one-dimensional with g denoting the two-dimensional Green's function:

$$g(\vec{r}|\vec{r}') = \frac{i}{4} H_0(k|\vec{r}-\vec{r}'|) \qquad \text{(B-8)}$$

with H_0 denoting the zero order Hankel function of the first kind.

* The functional form of the integral in Equation (B-7) is such that its value is determined strictly by the edge line of the plate.

The subsequent discussion is concerned with a specialization of Equations (B-6) and (B-7) for the case of a strip baffle.

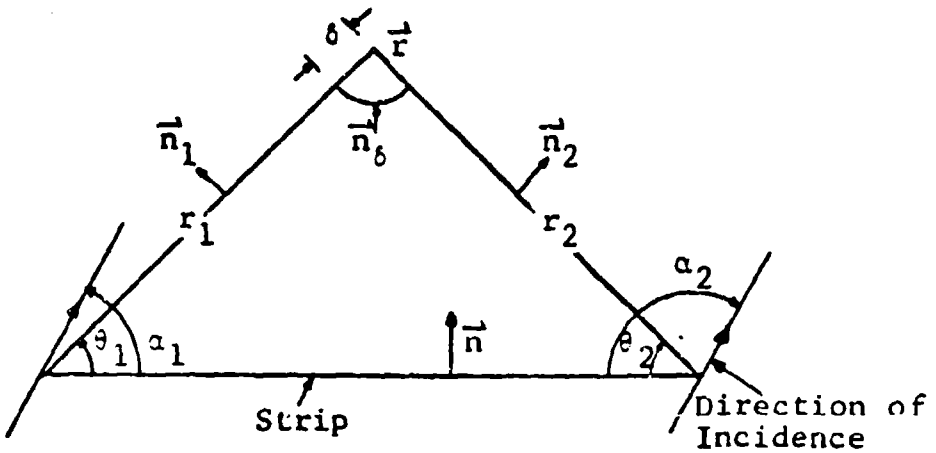

FIG. B-1 - GEOMETRY OF PLANE WAVE SCATTERING FROM A STRIP

Consider the geometrical situation depicted in Figure B-1. It is convenient to reference the arbitrary field point $\vec{r}$ relative to both edges in terms of two systems of cylindrical coordinates as indicated in Figure B-1.

To evaluate Equation (B-7), we make use of the fact that the line integral can be taken over any contour having its end points on the edges of the strip and lying on the same side of the field point as the strip. In particular, the contour can be taken to consist of S_1: the straight line from the left edge to the point a small distance δ from the field point as indicated in Figure B-1; S_δ: the portion of a circle of radius δ centered at the field point and contained between rays from the field point passing through the edges of the strip; S_2: the straight line joining the field point to the right-hand baffle edge taken from a distance δ away from the field point to the right-hand edge.

It is important to note that the contribution from S_δ does not vanish as the radius δ shrinks to zero. The simplest means of evaluating this limit is to recognize that it is equal to the limit for the integral taken over an entire circle multiplied by the ratio of the angle subtended by S_δ and 2π. Recognizing that the angle subtended at $\vec{r}$ by S_δ is $\pi - \theta_1 - \theta_2$, and that the limit over the entire circle is $-e^{-i\vec{k}\cdot\vec{r}}$ according to the Helmholtz integral formula, we obtain

$$U_\delta \xrightarrow[\delta\to 0^+]{} -\left[\frac{\pi - \theta_1 - \theta_2}{2\pi}\right] e^{i\vec{k}\cdot\vec{r}} \quad .$$

Also by observing that on S_1 the normal derivative of G is identically zero we find in the limit as δ approaches zero that

$$U_1 \xrightarrow[\delta\to 0^+]{} \left[\frac{\sin(\theta_1-\alpha_1)}{4} \int_0^{kr_1} dt\, H_o(t) e^{-it\cos(\theta_1-\alpha_1)}\right] e^{i\vec{k}\cdot\vec{r}} \quad ,$$

where we have used Equation (B-3) and the fact that $\vec{k}$ has an angular orientation α_1 relative to the left-hand edge.

A similar result is obtained for the right-hand edge except that the angles are referenced with the subscript 2. Combination of the results gives

$$U(\vec{r}|\vec{k}) = e^{i\vec{k}\cdot\vec{r}}\left[\frac{\theta_1 + \theta_2 - \pi}{2\pi} + \frac{\sin\psi_1}{4}\int_0^{kr} dt\, H_o(t) e^{-it\cos\psi_1}\right.$$

$$\left. + \frac{\sin\psi_2}{4}\int_0^{kr_2} dt\, H_o(t) e^{-it\cos\psi_2}\right] \quad , \qquad \text{(B-9)}$$

where

$$\psi_1 = \theta_1 - \alpha_1, \quad \psi_2 = \theta_2 - \alpha_2 \quad .$$

A method of evaluating the integrals in Equation (B-9) has already been discussed in the appendix of Reference B-3. An alternative means of evaluation will be discussed subsequently, but first it is convenient to consider the limiting case of Equation (B-9) as the right-hand edge moves to infinity keeping the field point $\vec{r}$ fixed. According to Figure B-1 this amounts to letting r_2 approach infinity and simultaneously allowing θ_2 to approach zero. Thus

$$\lim_{\substack{r_2 \to \infty \\ \theta_2 \to 0}} U(\vec{r}|\vec{k}) = e^{i\vec{k}\cdot\vec{r}} \left[\frac{\theta_1 - \pi}{2\pi} + \frac{\sin\psi_1}{4} \int_0^{kr_1} dt\, H_o(t) e^{-it\cos\psi_1} - \frac{\sin\alpha_2}{4} \int_0^{\infty} dt\, H_o(t) e^{-it\cos\alpha_2} \right] .$$

Using the integral representation of the Hankel function and rotating the contour in the t- plane by 90° it may be shown that

$$\frac{\sin\alpha}{4} \int_0^{\infty} dt\, H_o(t) e^{it\cos\alpha} = \frac{\alpha}{2\pi} \quad \text{for } -\pi \le \alpha \le \pi, \text{ and periodic outside this interval.} \tag{B-10}$$

This result in conjunction with the identity $\alpha_2 = \pi - \alpha_1$ eivdent from Figure B-1 gives:

$$\lim_{\substack{r_2 \to \infty \\ \theta_2 \to 0}} U(\vec{r}|\vec{k}) = u(kr_1, \psi_1) e^{-i\vec{k}\cdot\vec{r}} , \qquad \text{(B-11)}$$

where

$$u(kr_1, \psi_1) = \frac{\psi_1 - \pi}{2\pi} + \frac{\sin\psi_1}{4} \int_0^{kr_1} dt\, H_o(t) e^{-it\cos\psi_1} , \qquad \text{(B-12)}$$

the above relation being valid under the assumption that α_1 is less than π. A similar analysis shows

$$\lim_{\substack{r_1 \to \infty \\ \theta_1 \to 0}} U(\vec{r}|\vec{k}) = u(kr_2, \psi_2) e^{-i\vec{k}\cdot\vec{r}} . \qquad \text{(B-13)}$$

The relation (B-12) is the same as Equation (3.23) derived by a different method in Reference B-5 if we recognize that Reference B-5 uses the complement of ψ_1. It corresponds to the field diffracted by the edge of a black half-plane the geometric shadow occurring for $\psi_1 \leq 0$.

Furthermore we have according to Equations (B-9), (B-11), (B-12), and (B-13) that

$$U(\vec{r}|\vec{k}) = e^{-i\vec{k}\cdot\vec{r}} \left[1 + u(kr_1, \psi_1) + u(kr_2, \psi_2) \right] ,$$

which in conjunction with Equation (B-7) shows that the field is the superposition of the effects from the two edges.

Making use of Equation (B-10) it follows that Equation (B-12) can be written as

$$u(kr,\psi) = f(\psi) - \frac{\sin\psi}{4}\int_{kr}^{\infty} dt\, H_o(t)e^{-it\cos\psi} , \quad \text{(B-14)}$$

where

$$f(\psi) = \begin{cases} 0 & \psi > 0 \\ -1 & \psi < 0 \end{cases} .$$

A simple approximation to the integral in Equation (B-14) can be obtained by using the asymptotic form of the Hankel function to get

$$v(kr,\psi) = \frac{\sin\psi}{4}\int_{kr}^{\infty} dt\, H_o(t)e^{-it\cos\psi}$$

$$\approx \frac{\sin\psi}{4}\ \frac{2}{\pi}\, e^{-i(\pi/4)}\int_{kr}^{\infty} dt\, \frac{e^{i(1-\cos\psi)t}}{\sqrt{t}} .$$

Or

$$v(kr\ \psi) \approx \cos(\tfrac{\psi}{2})\left[\frac{1-i}{2}\int_{x}^{\infty} dt\, e^{i(\pi/2)t^2}\right] , \quad \text{(B-15)}$$

where

$$x = 2\sqrt{\frac{kr}{\pi}}\sin\psi/2 . \quad \text{(B-16)}$$

Equation (B-16) is valid only for $\psi \geq 0$ and we use the fact that the original expression is odd to determine the approximate representation in the shadow. Note that curves of constant x are parabolic.

While Equation (B-16) is strictly valid only for kr large relative to unity, in practice the approximation compares well with the previous representation given in Reference B-3 for distances greater than 2 or 3 wavelengths. Furthermore a slight modification of the previous analysis shows that applying the approximation in Equation (B-16) to the case of a black half-plane gives a pressure field in the shadow region that differs from the Sommerfeld function [B-6] by the factor cos $\psi/2$.

The above relationships provide an approximate representation for the scattering from a translucent strip baffle which is straightforward from a computational point of view. Furthermore it is not difficult to show that Equation (B-6) reduces to the solution for an infinite planar baffle as the edges of the strip move to infinity. This fact can be obtained most simply by recognizing that for this case the integral in Equation (B-7) can be evaluated in terms of the Helmholtz integral formula if one recognizes that the integral over a large semicircle drawn in the shadow region vanishes. Consequently we find

$$U(\bar{r}|\bar{k}) = \begin{cases} -e^{i\vec{k}\cdot\vec{r}} & \text{in the shadow} \\ 0 & \text{in the illuminated region} \end{cases}$$

$$U(\bar{r}|\bar{k}_1) = \begin{cases} 0 & \text{in the shadow} \\ e^{i\vec{k}_1\cdot\vec{r}} & \text{in the illuminated region.} \end{cases}$$

Substitution of these relations into Equation (B-6) gives the usual results for an infinite planar baffle.

Previous investigations[(B-3),(B-4)] concerning diffraction from opaque baffles have shown that the diffracted field computed according to the above approach gives good agreement with known exact results for strip baffles greater than or equal to four wavelengths.* Consequently one might expect similar criteria to apply also in the present case. On the other hand, it should be noted that the above approximation does not account for the additional structural modes of vibration resulting from the boundary conditions on the plate edges which are not present in an infinite plate. The extent to which these modes affect the pressure field in the vicinity of a finite plate remains to be investigated.

* Note that an opaque baffle can be characterized in terms of Equation (B-6) by setting the transmission coefficient to zero and the reflection coefficient to plus or minus unity.

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