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TRANSFER FUNCTION, IMPULSE RESPONSE AND RERADIATED WAVEFORM FOR--ETC(U)  
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USL Technical Memorandum No.

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TRANSFER FUNCTION, IMPULSE RESPONSE AND  
RERADIATED WAVEFORM FOR AN ELLIPTICALLY SYMMETRIC  
RERADIATION FUNCTION IN THE FORM OF A LAGUERRE POLYNOMIAL  
(USL PROGRAM NO. 0838)

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⑩ by Donald A. Stremsky

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U. S. NAVY UNDERWATER SOUND LABORATORY  
FORT TRUMBULL, NEW LONDON, CONNECTICUT

TRANSFER FUNCTION, IMPULSE RESPONSE AND  
RERADIATED WAVEFORM FOR AN ELLIPTICALLY SYMMETRIC  
RERADIATION FUNCTION IN THE FORM OF A LAGUERRE POLYNOMIAL  
(USL PROGRAM NO. 0838)

by

Donald A. Stremsky

USL Technical Memorandum No. 2242-111-67

20 March 1967

INTRODUCTION

A computational program has been prepared by the Information Processing Division to compute a particular Reradiation Function  $w(x)$ , Transfer Function  $W(w, P)$ , Impulse Response  $w(t, P)$ , and Reradiated Waveform  $g(t, P)$  as defined below in terms of the incident plane wave pulse. This IBM 704 Program designated USL Program No. 0838, is in Fortran II language and is described in Appendixes A and B. Similar computational programs are described in USL Technical Memorandum No. 2242-156-67 and 2242-157-67.

THEORY

Reference (a) contains a description of the mathematical model constructed and the theory behind considering reflection as a re-radiation phenomenon.

This program computes for integer values of  $D$

(a)  $a_1 a_2 w(x)$

(b)  $W(w, P)$

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(c)  $k_w(t, P)$

(d)  $k_g(t, P)$

where

$$(1) w(x) = \frac{(-1)^n 2\pi}{a_1 a_2}$$

$$(2) w(w, P) = e^{-1/2(kw)^2} L_n[(kw)^2]$$

$$k = \frac{1}{c} [(a_1 p_1)^2 + (a_2 p_2)^2]^{1/2}$$

$$L_n(x) = \frac{e^x}{n!} \frac{d^n}{dx^n} (e^{-x} x^n)$$

= Laguerre polynomial

$$(3) w(t, P) = \frac{1}{n! k \sqrt{2\pi}} e^{-1/2(t/k)^2} \{ He_n(|t/k|) \}^2$$

$$He_n(x) = (-1)^n e^{1/2 x^2} \frac{d^n}{dx^n} (e^{-1/2 x^2})$$

= Hermite polynomial

$$(4) g(t, P) = \int_{-\infty}^{+\infty} f(\tau) w(t-\tau, P) d\tau$$

$$f(t) = \begin{cases} A(t) \cos((\omega_0 + \frac{\Delta\omega}{2})(t/\tau)) t + d \\ A(t) = 0 \text{ for } |t| > T \end{cases}$$

#### COMPUTER PROGRAM DESCRIPTION

A nomenclature listing for USL Program No. 0838 is Appendix A, the flow chart is Appendix B, and the IBM 704 Fortran II Program is Appendix C.

The basic input data deck required by the program consists of four cards.

Table 1

Card No.	Cols.	Contents
1	1-8	$a_1$
	9-16	$a_2$
	17-24	$x_1$
	25-32	$x_2$
	33-40	$c$
	41-48	$v$
	49-51	$j$
	52-54	ISKP (set equal to zero to compute Reradiation Function)
	55-57	JSKP (set to zero to compute Transfer Function)
	58-60	KSKP (set equal to zero to compute Impulse Response & Reradiated Waveform) For long jobs requiring the use of a dump tape at least one of the above option variables should not be set equal to zero.
2	1-8	Initial value of $\omega$
	9-16	Maximum value for $\omega$
	17-24	Initial value of $t$
	25-32	Initial value of $k$
	35-36	KK (if set equal to zero, initial value of $k$ will be computed)
	39-46	Maximum value of $k$
3	1-8	$\lambda_1$ }
	9-16	$\lambda_2$ }
	17-24	$N_1$ }
	25-32	$N_2$ }
	33-40	$\Delta x_1$
	41-48	$\Delta x_2$
	49-56	$\Delta t$
	57-64	Increment of $\omega$
	65-72	$\Delta k$
		Components of $N$

Table 1 (cont'd)

Card No.	Cols.	Contents
4	1-3	Number of values of Reradiation Function to compute
	4-11	$\Delta \tau$
	12-19	Maximum value for t
	20-27	$\omega_0$
	28-35	$\Delta \omega$
	36-43	Maximum value of $\tau$
	44-51	Initial value of $\tau$
	52-59	$\theta$

FORMATS

- Card No. 1 - Format 6F8.3, 4I3  
 2 - Format 4F8.3, 2X, I2, 2X, F8.3  
 3 - Format 9F8.3  
 4 - Format I3, 7F8.3

Tape Units Required

Tape Unit No.	Tape Identification
3	Data input
4	Values for Reradiation Function, Transfer Function, and Impulse Response
5	Calcomp Plotter containing values for Reradiation Function
6	Reradiated waveform array (k,t)
7	Transfer Function Array (k,w)

Tape Units Required (cont'd)

Tape Unit No.	Tape Identification
8	Impulse Response Array (k,t)
{ 0	Dump Tape
SS-5 must be down to dump	
No other sense switches are used	

Subroutine Amp required - computes values of A array referred to under equation 4.

PROGRAM OUTPUT

Tape #4 contains:

(1) The values for the  $\bar{z}$  array plus the corresponding values for the Reradiation Function according to Format (1X, F10.5, 5X, F10.5)

(2) The values for the product of k and w plus the corresponding values of the Transfer Function according to Format (1X, F10.5, 5X, F10.5)

(3) The values for t/k plus the corresponding values for the Impulse Response according to Format (1X, F10.5, 5X, F10.5)

Tape #5 contains:

The values for the Reradiation Function (Calcomp Plotter tape)

Tape #6 contains:

The Reradiated Waveform Array (k,t) according to Format (F10.5)

Tape #7 contains:

The Transfer Function Array (k,w) with Format (F10.5)

Tape #8 contains:

The Impulse Response Array according to Format (F10.5)

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Tape #0 is a dump tape.

Notes: This program contains options to compute or not to compute any of the functions mentioned above. Tapes Unit Nos. 6, 7, and 8 can be used as input to USL Program No. 0809, "Representation of Surfaces: A Computer Program to Plot Contours and Draw Perspective Views", by Edward Beardsworth, Jr.

#### SUMMARY

An IBM 704 Fortran program, USL Program No. 0838, has been written to compute a particular Reradiation Function, Transfer Function, Impulse Response, and Reradiated Waveform in terms of the incident plane wave pulse.

*D. A. Stremsky*  
D. A. STREMSKY  
Mathematician

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LIST OF REFERENCES

- (a) Edward S. Eby, "Spectra and Waveforms of Bottom Reflected Pulses",  
USL Tech. Memo. No. 914-160-66 of 10 June 1966.

APPENDIX A

NOMENCLATURE LISTING FOR USL PROGRAM NO. 0838

S(I)	$\left(\frac{x_1}{a_1}\right)^2 + \left(\frac{x_2}{a_2}\right)^2$
Z(I)	$\sqrt{SCE}$
RERAD (I)	Element of Reradiation Function Array
TRFER (I)	Element of Transfer Function Array
AKW (LM,I)	k.w
RESP (LM,I)	Element of Impulse Response Array
RATIO (LM,I)	t/k
GSUM (LM,J)	Element of Reradiated Waveform Array
A1	$a_1$
A2	$a_2$
X1	$x_1$
X2	$x_2$
C	c
V	v
N	$\nu$
W	w
WMAX	Maximum value for w
T	Initial value for t
AK	k
AKMAX	Maximum value for k

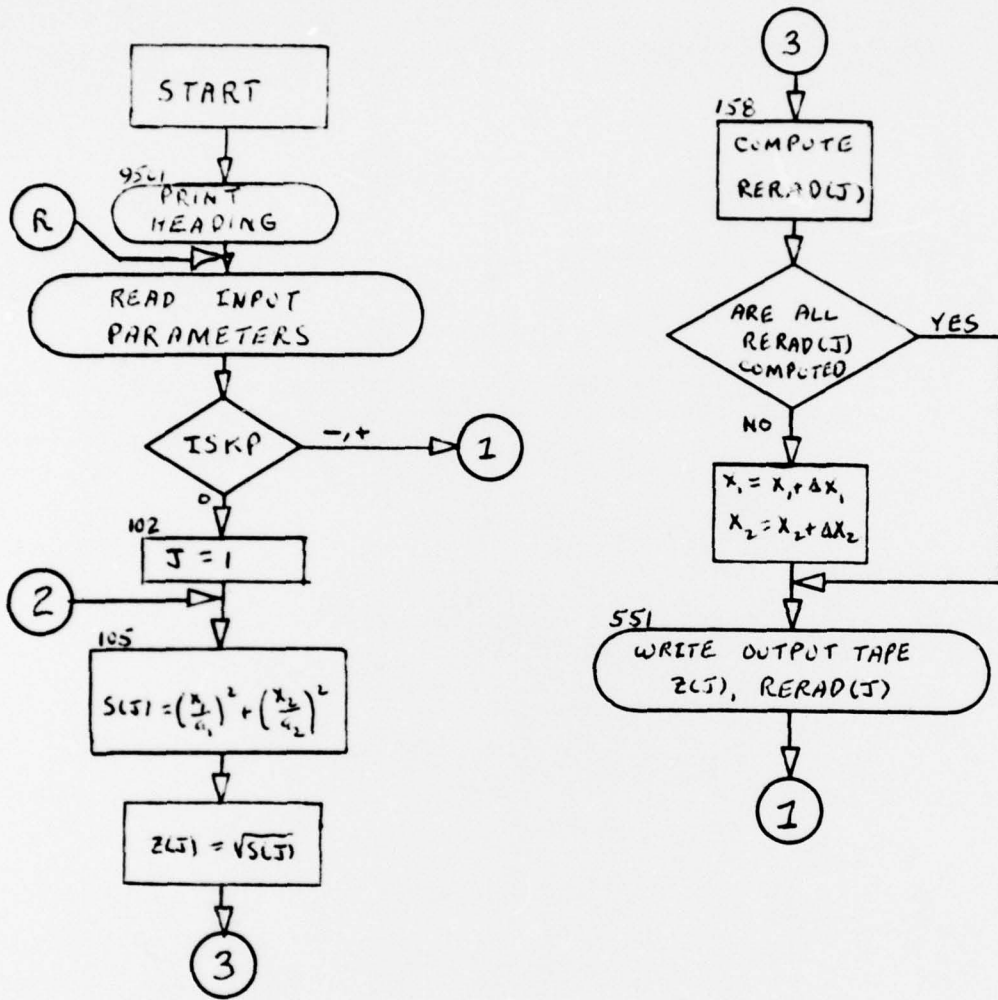
B1	$\lambda_1$	} components of $\lambda$
B2	$\lambda_2$	
B3	$N_1$	} components of $N$
B4	$N_2$	
B5	$\Delta x_1$	
B6	$\Delta x_2$	
B7	$\Delta t$	
B8	Increment of $w$	
B10	$\Delta \tau$	
B12	$\Delta k$	
Omega	$\omega_0$	
DELTA	$\Delta w$	
TT	Maximum value for $\tau$	
TAV	Initial value of $\tau$	
PHI	$\varphi$	
N1	Number of values of Reradiation Function to compute	
TMAX	Maximum value for T	

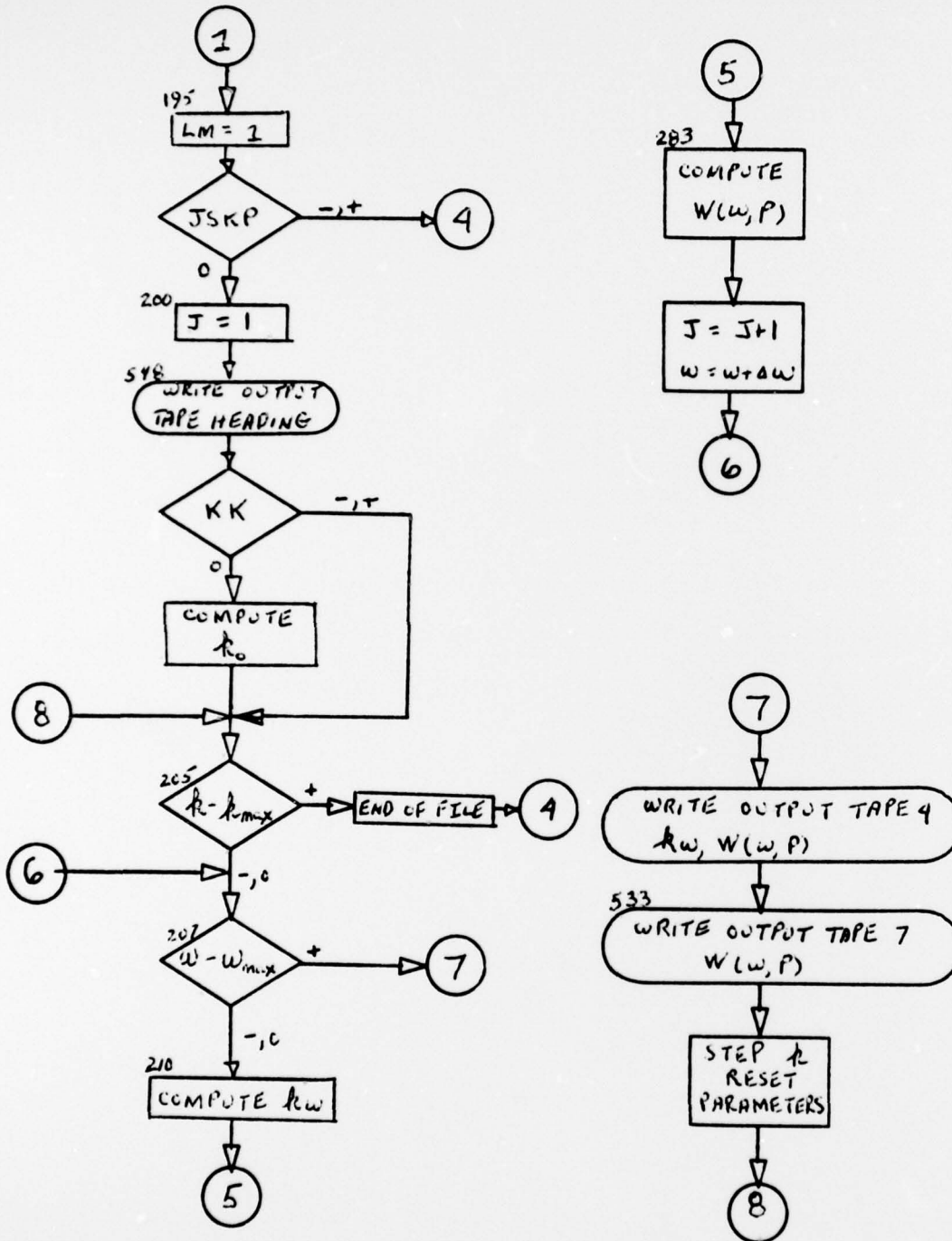
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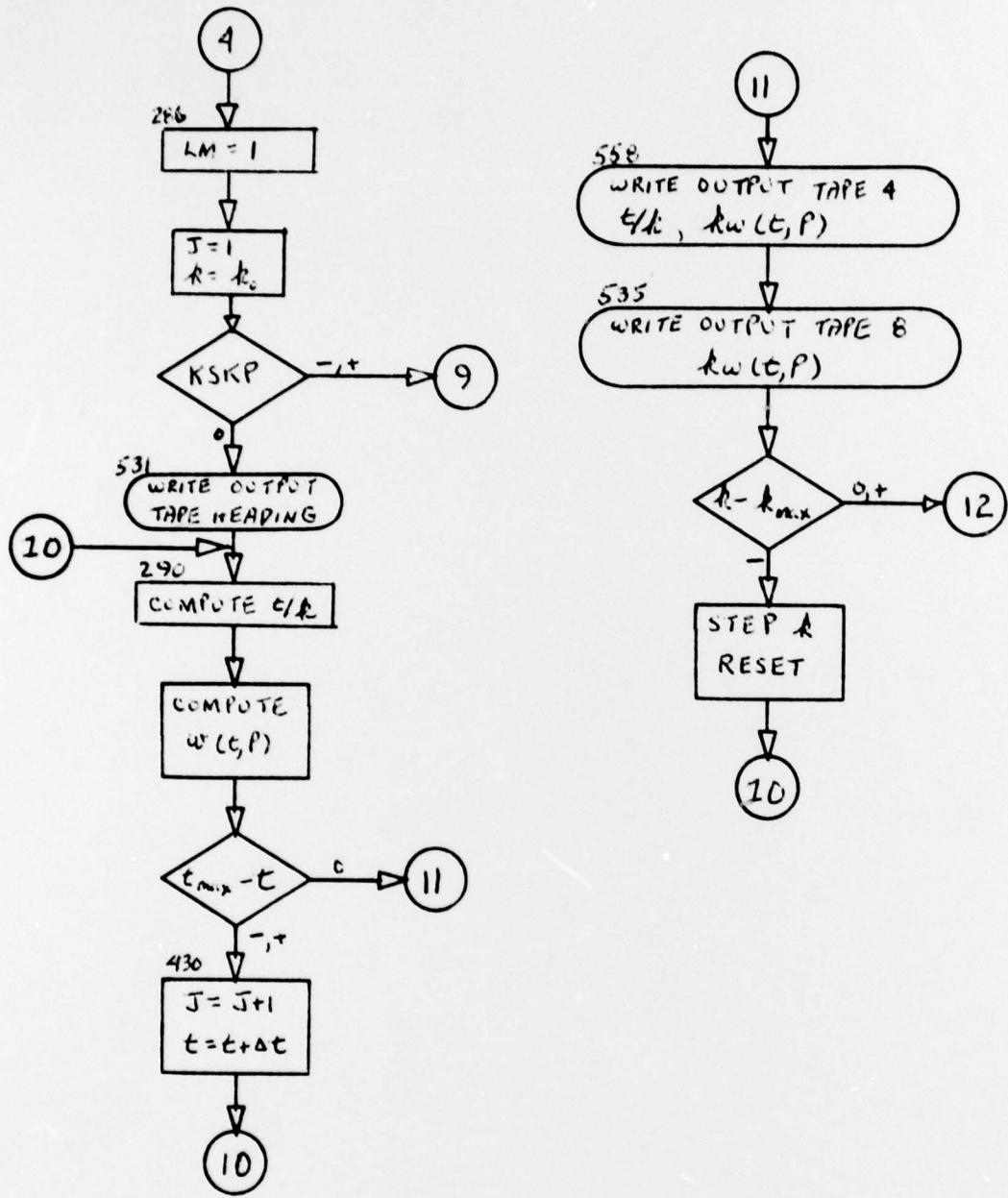
APPENDIX B

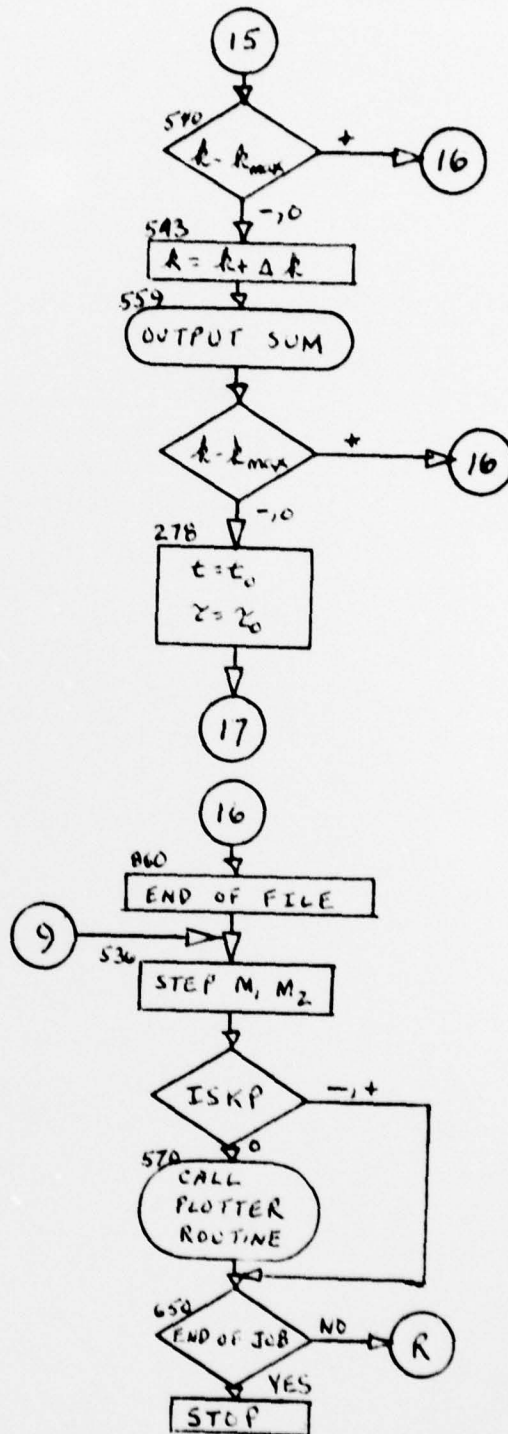
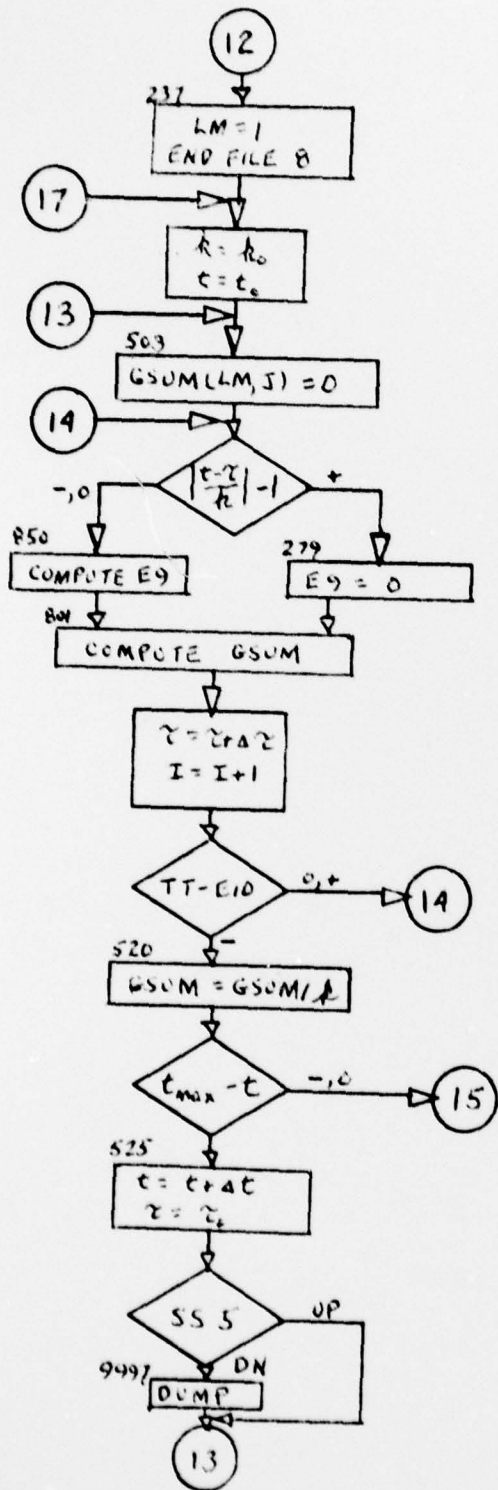
FLOW CHART FOR USL PROGRAM NO. 0838

"RERADIATION FUNCTION, TRANSFER FUNCTION, IMPULSE RESPONSE (CASE 2)"









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APPENDIX C

FORTRAN PROGRAM NO. 0838

```

C RERADIATION FUNCTION, TRANSFER FUNCTION, IMPULSE RESPONSE (CASE 2)
C D. A. STREMSKY
  DIMENSION Z(500), RERAD(500), TRFER(50,50), AKW(50,50), RATIO(50,50), R
  IESP(50,50), SUM(50), HSLM(50), S(500), GSUM(50,50), R(1000), IDUMP(18)
  DIMENSION BUFFER(1024), XAXIS(500), YAXIS(500)
STDJN ALF *0838
STECD ALF *
  WRITE OUTPUT TAPE 4,9501
 9501 FORMAT(1H1)
  READ INPUT TAPE 3,9502,DI
 9502 FORMAT(A5)
  IF (TDJN-DI)9503,9504,9503
 9503 PAUSE 6
 9504 WRITE OUTPUT TAPE 4,9502,DI
  WRITE OUTPUT TAPE 4,9505
 9505 FORMAT(10X32HD,A,STREMSKY,ROOM 3126, CODE 2242)
  READ INPUT TAPE 3,100,A1,A2,X1,X2,C,V,N,ISKP,JSKP,KSKP
 100 FORMAT(6F8,3,4I3)
  READ INPUT TAPE 3,101,W,WMAX,T,AK,KK,AKMAX
 101 FORMAT(4F8,3,2X,I2,2X,F8,3)
  READ INPUT TAPE 3,103,B1,B2,B3,B4,B5,B6,B7,B8,B12
 103 FORMAT(9F8,3)
  READ INPUT TAPE 3,104,N1,B10,TMAX,AMEGA,DELTA,TT,TAU,PHI
 104 FORMAT(I3,7F8,3)
  W1=W
  AK1=AK
  T1=T
  TAU1=TAU
  PIE=3.1415
  PCP=2.5066
  DEG=180./PIE
  NP1=N-1
  NP2=N+2
  SLM(1)=0.
  SLM(2)=1.
  IF (ISKP)195,102,195
 102 J=1
 105 S(J)=(X1/A1)**2+(X2/A2)**2
  ZX=S(J)
  Z(J)=SQRT(ZX)
  IF (N)156,156,157
 156 SIGN=1.
  GO TO 158
 157 SIGN=(-1)**N
 158 RERAD(J)=SIGN*2.0*PIE*A1*A2
  IF (N1-J)546,546,175
 175 J=J+1
  X1=X1+P5
  X2=X2+P6
  GO TO 105
 546 WRITE OUTPUT TAPE 4,551
 551 FORMAT(1X36HZ RERADIATION FUNCTION)
  WRITE OUTPUT TAPE 4,552,(Z(I),RERAD(I),I=1,N1)
 552 FORMAT(1X,F10,5,5X,F10,5)
  WRITE OUTPUT TAPE 4,553
 553 FORMAT(///)
 195 LM=1

```

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      IF (JSKP) 286,200,266
200 J=1
548 WRITE OUTPUT TAPE 4,554
554 FORMAT (1X34HKW
      TRANSFER FUNCTION)
      IF (KK) 205,202,205
202 P1=B1-C*B3/V
      P2=B2-C*B4/V
      CR=(A1*P1)**2+(A2*P2)**2
      AK=SQRT(CR)/C
205 IF (AK-AKMAX) 207,207,285
207 IF (W-WMAX) 210,210,250
210 AKW(LM,J)=AK*W
      R2=AKW(LM,J)**2
      R3=-R2/2.
      CCEF1=EXPF(R3)
      IF (N) 230,230,215
215 DC 225 I=3,NP2
      AIM3=I-3
      IM1=I-1
      IM2=I-2
      PAR=2.*AIM3+1.-R2
      PART=AIM3**2
      SUM(I)=-PAR*SUM(IM1)-PART*SUM(IM2)
225 CONTINUE
230 NPRCD=1
      IF (N) 280,280,260
260 DC 275 L=1,N
      NEWL=L
      NPRCD=NPRCD*NEWL
275 CONTINUE
280 PRCD=NPROD
      IF (N) 281,281,282
281 SIGN=1.
      GO TO 283
282 SIGN=(-1)**N
283 TRFER(LM,J)=CCEF1*SUM(NP2)*SIGN/PROD
      J=J+1
      W=W+RR
      GO TO 207
250 N2=J-1
      N4=LM
      WRITE OUTPUT TAPE 4,555,((AKW(LM,I),TRFER(LM,I),I=1,N2),LM=N4,N4)
555 FORMAT(1X,F10.5,5X,F10.5)
533 WRITE OUTPUT TAPE 7,515,((TRFER(LM,I),I=1,N2),LM=N4,N4)
515 FORMAT(F10.5)
      J=1
      W=W1
      LM=LM+1
      AK=AK+R12
      GO TO 205
285 END FILE 7
      END FILE 7
286 LM=1
      J=1
      AK=AK1
      IF (KSKP) 536,531,536
531 WRITE OUTPUT TAPE 4,557
557 FORMAT(1X34HT/K
      IMPLLSF RESPONSE)

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```

290 RATIO(LM,J)=T/AK
   G2=RATIO(LM,J)**2
   G3=-G2/2.
   IF (JSKP) 291,297,291
291 NPRCD=1.
   IF (N) 296,296,292
292 DO 295 L=1,N
   NEWL=L
   NPRCD=NPRCD*NEWL
295 CONTINUE
296 PRCD=MPROD
297 DEN=PROD*PCP
   G4=EXP(G3)
   CCEF2=G4/DEN
   G5=RATIO(LM,J)
   IF (G5) 300,320,320
300 G6=-G5
   GO TO 350
320 G6=G5
350 HSUM(1)=0.
   HSUM(2)=1.
   IF (N) 410,410,360
360 DO 400 K=3,NP2
   AKM3=K-3
   KM1=K-1
   KM2=K-2
   HSUM(K)=G6*HSUM(KM1)-AKM3*HSUM(KM2)
400 CONTINUE
410 G7=HSUM(NP2)
   G8=G7**2
425 RESP(LM,J)=CCEF2*GA
   IF (TMAX-T) 500,430,430
430 J=J+1
   T=T+B7
   GO TO 290
500 N3=J-1
   N4=LM
   WRITE OUTPUT TAPE 4,55R,((RATIO(LM,I),RESP(LM,I),I=1,N3),LM=N4,N4)
558 FORMAT(1X,F10.5,5X,F10.5)
535 WRITE OUTPUT TAPE 8,516,((RESP(LM,I),I=1,N3),LM=N4,N4)
516 FORMAT(F10.5)
   IF (AK=AKMAX) 495,237,237
495 AK=AK+R12
   LM=LM+1
   J=1
   T=T1
   GO TO 290
237 LM=1
   END FILE 8
   END FILE 8
   N5=0
   AK=AK1
   I=1
502 D11=R7/AK
   T=T1
   J=1
   D12=AR5F(D11)
503 GSLM(LM,J)=0.

```

```

505 FRACT=TAU/TT
      F1=AMEGA*DELTA*FRACT/2.0
      E2=F1*TAU
      E3=E2*PHI
      E4=CCSF (E3/DEG)
      CALL AMP (TAU,R)
      FCN=R (I)*E4
      TDIF=(T-TAU)/AK
      GRAPE=ABSF (TDIF)
      PLUM=GRAPE-1.0
      IF (PLUM) 850,850,279
279 E9=0.0
      GO TO 801
850 E5=GRAPE/D12
      NE5=E5
      IA=NE5+1
      IB=NE5+2
      E6=GRAPE-RATIO (LM,IA)
      E7=E6/D11
      E8=1.0-E7
      RSPN=E7*RESP (LM,IB)+E8*RESP (LM,IA)
      E9=FCN*RSPN*B10
801 GSUM (LM,J)=GSUM (LM,J)+E9
      TAU=TAU+B10
      I=I+1
      E10=ARSF (TAU)
      IF (TT-E10) 520,505,505
520 GSUM (LM,J)=GSUM (LM,J)/AK
      IF (TMAX-T) 540,540,525
525 T=T+B7
      J=J+1
      TAU=TAU1
      IF (SENSE SWITCH 5) 9997,9999
9997 DO 9998 LK=1,15
      IDUMP (LK)=+0
9998 CONTINUE
      IDUMP (16)=-6
      IDUMP (17)=+0
      IDUMP (18)=N5
      CALL DUMP (IDUMP)
9999 GO TO 503
540 IF (AK=AKMAX) 543,543,860
543 AK=AK+B12
      N3=J-1
      N4=LM
      WRITE OUTPUT TAPE 6,559,((GSUM (LM,I),I=1,N3),LM=N4,N4)
559 FORMAT (F10.5)
      N5=N5+J
      IF (AK=AKMAX) 278,278,860
278 LM=LM+1
      T=T1
      TAU=TAU1
      I=1
      GO TO 502
860 END FILE 6
      END FILE 6
536 M1=N1+1
      M2=N1+2

```

```
IF (ISKP) 650, 570, 650
570 CALL PLOTS (BUFFER (1024), 1024, 5)
DC 560 J=1, N1
XAXIS (J)=Z (J)
YAXIS (J)=RERAD (J)
560 CONTINUE
CALL PLOT (0.0, 5.0, -3)
CALL SCALE (YAXIS, 5.0, N1, 1, 10.0)
CALL SCALE (XAXIS, 10.0, N1, 1, 10.0)
CALL LINE (XAXIS, YAXIS, N1, 1, 1, 1)
CALL AXIS (0.0, 0.0, 20, RERADIATION FUNCTION, 20, 5.0, 90.0, YAXIS (M1), Y
1AXIS (M2), 10.0)
CALL AXIS (0.0, 0.0, 1, HZ, -1, 10.0, 0.0, XAXIS (M1), XAXIS (M2), 10.0)
CALL PLOT (0.0, 0.0, 999)
650 READ INPUT TAPE 3, 9502, ED
IF (ED=TEOD) 9503, 9509, 9503
9509 WRITE OUTPUT TAPE 4, 9511
9511 FORMAT (4HOEND)
END FILE 4
9510 STOP 5
END (1, 1, 0, 1, 1)
```