TR－A－0018

ライブラリ　ＡＮＡ－Ｃ

赤木　正人

Masato　Akagi

１９８７．１２．９

ＡＴＲ視聴覚機構研究所

ライブラリANA_C

I. ファンクション名の与え方

基本的には、前3文字が変換前のパラメータを表し、後の3文字が変換後のパラメータを表す。

SIG	:	波形信号
PSD	:	ARモデルにおけるパワースペクトラム密度
COR	:	自己相関係数
COV	:	自己相関関数
ALF	:	ARモデルにおけるαパラメータ
LAR	:	対数断面積比
REF	:	PARCOR係数
POL	:	極の中心周波数とバンド幅
CEP	:	LPCケプストラム係数
BET	:	MAモデルにおける係数
ICF	:	内挿相関関数
PCP	:	直交多項式の係数の組
JAC	:	ヤコビ係数
CSM	:	複合正弦波モデルのパラメータ（声門開放時）
CSP	:	複合正弦波モデルのパラメータ（声門閉鎖時）
LSP	:	線スペクトル対
LIP	:	線インテンシティ対
POP	:	複合正弦波モデルにおける直交多項式の係数の組

他のものは、提唱者の名前などを用いている。

Ⅱ. ファンクション一覧

alfbet.c
alfcep.c
alflsp.c
alfnrp.c
alfpol.c
alfpop.c
alfpsd.c
alfref.c
alfsig.c
arccos.c
argrpz.c
bairst.c
betcov.c
cepalf.c
cepsig.c
cfft.c
chbpol.c
chebex.c
cmxrr.c
convol.c
coralf.c
coricc.c
corref.c
covcsm.c
covcsp.c
covicf.c
covlip.c
covref.c
csmcov.c
darccos.c
dcovcsm.c
dcovcsp.c
dcovicf.c
dct.c
ddot.c
dicfpcp.c
dnewton.c
dpascal.c
dvdmond.c
excheb.c
gdelay.c
goertz.c
hammin.c
hamwdw.c
hamwin.c
hankel.c
hanwdw.c
iccjac.c
icfcsm.c
icfft.c
icfjac.c
icfpcp.c
ifft.c
itcheb.c
ixham.c
ixhan.c
jacpcp.c
lagwdw.c
lagwin.c
larref.c
leroux.c
lspalf.c
lsppop.c
mpquad.c
mcorr.c
mulir.c
mulirr.c
mulrrr.c
newton.c
nrstep.c
pascal.c
pcpcsm.c
pcpjac.c
pcpomg.c
pitch.c
pitch2.c
polalf.c
polcep.c
polrt2.c
popalf.c
poplsp.c
pspec.c
r1fft.c
r2fft.c
refalf.c
refcor.c
refjac.c
reflar.c
refnrp.c
refres.c
refsig.c
reord.c
rfft.c
rrcmx.c
sigcor.c
sigdcor.c
sincov.c
window.c
xxcor.c
fft.c

Ⅲ．呼び出し形式

呼び出し例（Ｐ１１９参照）

```
#include        <stdio.h>
#include        <math.h>
#include        "/usr/lib/io.h"

main()
{
        int _n=0;
        int err;

           .

        err = ALFCEP(_n,&ip,alf,cep,&n);

           .

}
```

プログラムの先頭で、#include "io.h" , int _n=0; を必ず宣言して下さい。io.hは、/usr/libにあります。

波形解析用プログラムは全て大文字で登録されています。

これは常識ですが、引き数は_n以外は全てアドレス渡しです。

ファンクションの中でエラーが生じていなければ、戻り値は－１です。

コンパイル＆リンクは

```
cc main.c .... -lana_c -lm ...
```

です。

以下に各ファンクションの呼び出し形式を示します。

```
int ALFBET(_n, IP, ALF, BET, N)
int _n;
int *IP;
double ALF[];
double BET[];
int *N;
```

```
int ALFCEP(_n, IP, ALF, CEP, N)
int _n;
int *IP;
double ALF[];
double CEP[];
int *N;
```

```
int ALFLSP(_n, IP, ALF, FREQ)
int _n;
int *IP;
double ALF[];
double FREQ[];


int ALFNRP(_n, IP, ALF, LPITCH, RESPOW)
int _n;
int *IP;
double ALF[];
int *LPITCH;
double *RESPOW;


int ALFPOL(_n, IP, ALF, FREQ, BW, FS, EPS)
int _n;
int *IP;
double ALF[];
double FREQ[];
double BW[];
double *FS;
double *EPS;


int ALFPOP(_n, IP, ALF, OPM, OPP)
int _n;
int *IP;
double ALF[];
double OPM[];
double OPP[];


int ALFPSD(_n, IP, ALF, PSD, N)
int _n;
int *IP;
double ALF[];
double PSD[];
int *N;


int ALFREF(_n, IP, ALF, REF, RESID, ISTABL)
int _n;
int *IP;
double ALF[];
double REF[];
double *RESID;
int *ISTABL;
```

```
double ALFSIG(_n, IP, ALF, STATE, XIN)
int _n;
int *IP;
double ALF[];
double STATE[];
double *XIN;


double ARCCOS(_n, X)
int _n;
double *X;


double ARGRPZ(_n, IP, ALF, OMEGA)
int _n;
int *IP;
double ALF[];
double *OMEGA;


int BAIRST(_n, N, A, RP, IP, EPS)
int _n;
int *N;
double A[];
double RP[];
double IP[I];
double *EPS;


int BETCOV(_n, IQ, BET, COV)
int _n;
int *IQ;
double BET[];
double COV[];


int CEPALF(_n, IP, CEP, ALF)
int _n;
int *IP;
double CEP[];
double ALF[];


double CEPSIG(_n, IP, CEP, STATE, XIN)
int _n;
int *IP;
```

```
double CEP[];
double STATE[];
double *XIN;


int CHBPOL(_n, N, C, POL)
int _n;
int *N;
double C[];
double POL[];


int CHEBEX(_n, N, A, B)
int _n;
int *N;
double A[];
double B[];


int CMXRR(_n, X, L)
int _n;
double X[];
int *L;


int CONVOL(_n, U, M, V, W, N)
int _n;
double U[];
int *M;
double V[];
double W[];
int *N;


int CORALF(_n, IP, COR, ALF, RESID)
int _n;
int *IP;
double COR[];
double ALF[];
double *RESID;


int CORICC(_n, N, COR, U)
int _n;
int *N;
double COR[];
double U[];
```

```
int CORREF(_n, IP, R, ALF, REF, RESID)
int _n;
int *IP;
double R[];
double ALF[];
double REF[];
double *RESID;


int COVCSM(_n, IP, COV, FREQ, SINT)
int _n;
int *IP;
double COV[];
double FREQ[];
double SINT[];


int COVCSP(_n, IP, COV, FREQ, SINT)
int _n;
int *IP;
double COV[];
double FREQ[];
double SINT[];


int COVICF(_n, N, COV, U)
int _n;
int *N;
double COV[];
double U[];


int COVLIP(_n, IP, COV, FREQ, SINT)
int _n;
int *IP;
double COV[];
double FREQ[];
double SINT[];


int COVREF(_n, IP, COV, ALF, REF, RESID)
int _n;
int *IP;
double COV[];
double ALF[];
double REF[];
double *RESID;
```

```
int CSMCOV(_n, N, FQ, SS, COV)
int _n;
int *N;
double FQ[];
double SS[];
double COV[];


double DARCCOS(_n, X)
int _n;
double *X;


double DCOREF(_n, IP, DR, DALF, DREF)
int _n;
int *IP;
double DR[];
double DALF[];
double DREF[];


int DCORREF(_n, IP, R, ALF, REF, RESID)
int _n;
int *IP;
double R[];
double ALF[];
double REF[];
double *RESID;


int DCOVCSM(_n, IP, COV, FREQ, SINT)
int _n;
int *IP;
double COV[];
double FREQ[];
double SINT[];


int DCOVCSP(_n, IP, COV, FREQ, SINT)
int _n;
int *IP;
double COV[];
double FREQ[];
double SINT[];
```

```
int DCOVICF(_n, N, COV, U)
int _n;
int *N;
double COV[];
double U[];


int DCT(_n, P, M, R, N, SINTBL, NN, INV)
int _n;
double P[];
int *M;
double R[];
int *N;
double SINTBL[];
int *NN;
int *INV;


double DDOT(_n, XX, YY, N)
int _n;
double XX[];
double YY[];
int *N;


int DICFPCP(_n, N, U, PC1, PC2)
int _n;
int *N;
double U[];
double PC1[];
double PC2[];


int DNEWTON(_n, N, A, X, EPS, IND)
int _n;
int *N;
double A[];
double X[];
double *EPS;
int *IND;


double DOT(_n, XX, YY, N)
int _n;
double XX[];
double YY[];
int *N;
```

```
int DPASCAL(_n, R, RW, LW, LMAX)
int _n;
double R[];
double RW[];
int *LW;
int *LMAX;


int DVDMOND(_n, N, A, B, X)
int _n;
int *N;
double A[];
double B[];
double X[];


int EXCHEB(_n, N, A, B)
int _n;
int *N;
double A[];
double B[];


int EXCHEB(_n, N, A, B)
int _n;
int *N;
double A[];
double B[];


int FFT(_n, XR, XI, M)
int _n;
double XR[];
double XI[];
int *M;


double GDELAY(_n, IP, ALF, OMEGA)
int _n;
int *IP;
double ALF[];
double *OMEGA;


int GETFIRST(_n, IDNO, IX, LD, LS, IE)
int _n;
int *IDNO;
```

```
short IX[];
int *LD;
int *LS;
int *IE;


int GETFRAME(_n, IDNO, IX, LD, LS, IE)
int _n;
int *IDNO;
short IX[];
int *LD;
int *LS;
int *IE;


double GOERTZ(_n, X, N, COSZ)
int _n;
double X[];
int *N;
double *COSZ;


int HAMMIN(_n, WDATA, N)
int _n;
double WDATA[];
int *N;


int HAMWDW(_n, WINDOW, N)
int _n;
double WINDOW[];
int *N;


int HAMWIN(_n, WINDOW, N)
int _n;
double WINDOW[];
int *N;


int HANKEL(_n, N, H, X)
int _n;
int *N;
double H[];
double X[];


int HANWDW(_n, WINDOW, N)
```

```
int _n;
double WINDOW[];
int *N;


int ICCJAC(_n, N, U, PH, PL, Q, R)
int _n;
int *N;
double U[];
double *PH;
double *PL;
double Q[];
double R[];


int ICFCSM(_n, N, U, FQ, SS)
int _n;
int *N;
double U[];
double FQ[];
double SS[];


int ICFFT(_n, X, L)
int _n;
double X[];
int *L;


int ICFJAC(_n, N, U, PC1, PC2, Q, R)
int _n;
int *N;
double U[];
double PC1[];
double PC2[];
double Q[];
double R[];


int ICFPCP(_n, N, U, PC1, PC2)
int _n;
int *N;
double U[];
double PC1[];
double PC2[];


int IFFT(_n, X, Y, L)
```

```
int _n;
double X[];
double Y[];
int *L;


int ITCHEB(_n, N, V, A, COEF)
int _n;
int *N;
double V[];
double A[];
double COEF[];


int IXHAM(_n, N, IDATA, WDATA)
int _n;
int *N;
int IDATA[];
double WDATA[];


int IXHAN(_n, N, IDATA, WDATA)
int _n;
int *N;
int IDATA[];
double WDATA[];


int JACPCP(_n, N, Q, R, PC1, PC2)
int _n;
int *N;
double Q[];
double R[];
double PC1[];
double PC2[];


int LAGWDW(_n, WDATA, IP, HB)
int _n;
double WDATA[];
int *IP;
double *HB;


int LAGWIN(_n, WDATA, LW, IP)
int _n;
double WDATA[];
int *LW;
```

```
int *IP;


int LARREF(_n, IP, ZR, REF)
int _n;
int *IP;
double ZR[];
double REF[];


int LEROUX(_n, IP, COV1, REF, RES)
int _n;
int *IP;
double COV1[];
double REF[];
double RES[];


int LSPALF(_n, IP, FREQ, ALF)
int _n;
int *IP;
double FREQ[];
double ALF[];


int LSPPOP(_n, IP, FREQ, OPM, OPP)
int _n;
int *IP;
double FREQ[];
double OPM[];
double OPP[];


int MCORR(_n, V, VM, A, MINDEL, MAXDEL, M)
int _n;
double V[];
double VM[];
double A[];
int *MINDEL;
int *MAXDEL;
int *M;


int MPQUAD(_n, P, N, A)
int _n;
double P[];
int *N;
double *A;
```

```
int MULIR(_n, IX, YY, ZZ, N)
int _n;
int IX[];
double YY[];
double ZZ[];
int *N;


int MULIRR(_n, N, IX, YY, ZZ)
int _n;
int *N;
short IX[];
double YY[];
double ZZ[];


int MULRRR(_n, N, XX, YY, ZZ)
int _n;
int *N;
double XX[];
double YY[];
double ZZ[];


int NEWTON(_n, N, A, X, EPS, IND)
int _n;
int *N;
double A[];
double X[];
double *EPS;
int *IND;


int NRSTEP(_n, COEF, N, X)
int _n;
double COEF[];
int *N;
double *X;


int PASCAL(_n, R, RW, LW, LMAX)
int _n;
double R[];
double RW[];
int *LW;
int *LMAX;
```

```
int PCPCSM(_n, N, PC1, PC2, FQ, SS)
int _n;
int *N;
double PC1[];
double PC2[];
double FQ[];
double SS[];


int PCPJAC(_n, N, PC1, PC2, Q, R)
int _n;
int *N;
double PC1[];
double PC2[];
double Q[];
double R[];


int PCPOMG(_n, N, PP1, PP2, FF1, FF2)
int _n;
int *N;
double PP1[];
double PP2[];
double FF1[];
double FF2[];


int PITCH(_n, MAXT, COVMAX, VM, AAA, MINDEL, MAXDEL)
int _n;
int *MAXT;
double *COVMAX;
double VM[];
double *AAA;
int *MINDEL;
int *MAXDEL;


int PITCH2(_n, MAXT, COVMAX, VM, AAA, MINDEL, MAXDEL)
int _n;
int *MAXT;
double *COVMAX;
double VM[];
double *AAA;
int *MINDEL;
int *MAXDEL;
```

```
int POLALF(_n, IP, FREQ, BW, FS, ALF)
int _n;
int *IP;
double FREQ[];
double BW[];
double *FS;
double ALF[];


int POLCEP(_n, IP, FREQ, BW, FS, CEP, N)
int _n;
int *IP;
double FREQ[];
double BW[];
double *FS;
double CEP[];
int *N;


int POLRT2(_n, POLM, POLP, M, XM, XP, IER)
int _n;
double POLM[];
double POLP[];
int *M;
double XM[];
double XP[];
int *IER;


int POPALF(_n, IP, OPM, OPP, ALF)
int _n;
int *IP;
double OPM[];
double OPP[];
double ALF[];


int POPLSP(_n, IP, OPM, OPP, FREQ)
int _n;
int *IP;
double OPM[];
double OPP[];
double FREQ[];


int PSPEC(_n, X, L)
int _n;
```

```
double X[];
int *L;


int R1FFT(_n, X, L)
int _n;
double X[];
int *L;


int R2FFT(_n, X, Y, L)
int _n;
double X[];
double Y[];
int *L;


int REFALF(_n, IP, REF, ALF)
int _n;
int *IP;
double REF[];
double ALF[];


int REFCOR(_n, IP, REF, ALF, COR, N, RESID)
int _n;
int *IP;
double REF[];
double ALF[];
double COR[];
int *N;
double *RESID;


int REFJAC(_n, N, REF, Q, R)
int _n;
int *N;
double REF[];
double Q[];
double R[];


int REFLAR(_n, IP, REF, ZR)
int _n;
int *IP;
double REF[];
double ZR[];
```

```
int REFNRP(_n, IP, REF, LPITCH, RESID)
int _n;
int *IP;
double REF[];
int *LPITCH;
double *RESID;


int REFRES(_n, IP, REF, RES)
int _n;
int *IP;
double REF[];
double RES[];


double REFSIG(_n, IP, REF, STATE, XIN)
int _n;
int *IP;
double REF[];
double STATE[];
double *XIN;


int REORD(_n, N, X, Y)
int _n;
int *N;
double X[];
double Y[];


int RFFT(_n, X, L)
int _n;
double X[];
int *L;


int RRCMX(_n, X, L)
int _n;
double X[];
int *L;


int SIGCOR(_n, N, SIG, VO, COR, LMAX)
int _n;
int *N;
double SIG[];
double *VO;
```

```
double COR[];
int *LMAX;


int SIGDCOR(_n, N, SIG, POW, RHO, LMAX)
int _n;
int *N;
double SIG[];
double *POW;
double RHO[1];
int *LMAX;


int SINCOV(_n, N, F, S, V)
int _n;
int *N;
double F[];
double S[];
double V[];


int TCHTBL(_n, N, COEF)
int _n;
int *N;
double COEF[];


int VDMOND(_n, N, A, B, X)
int _n;
int *N;
double A[];
double B[];
double X[];


int WINDOW(_n, N, X, W, Y)
int _n;
int *N;
double X[];
double W[];
double Y[];


int WRPARA(_n, IUN, VAR, MAXT, COVMAX, PARA, IERR)
int _n;
int *IUN;
double *VAR;
int *MAXT;
```

```
double *COVMAX;
double PARA[];
int *IERR;


double XSIG(_n, AMP, MAXT, IV, INIT)
int _n;
double *AMP;
int *MAXT;
int *IV;
int *INIT;


int XXCOR(_n, N, XX, VO, RHO, LMAX)
int _n;
int *N;
double XX[];
double *VO;
double RHO[];
int *LMAX;
```

Ⅳ．ファンクションの説明

注意：

1）ファンクションライブラリのすべてのファンクションを書きだしているわけではありません。

2）ＦＯＲＴＲＡＮ用の説明ですので、引き数の形がＣ言語とは異なっています。呼び出し形式はⅢ節を参照して下さい。違いは、引き数の最初に_nが必ず入ることです。

```
C. --- ALFBET ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ALF" INTO "BET".
C.     * COMPUTATION OF IMPULSE RESPONSE SEQUENCE OF AN ALL-POLE
C.       DIGITAL FILTER SPECIFIED BY "ALF".
C.     * MOVING AVERAGE REPRESENTATION OF AN AUTOREGRESSIVE PROCESS.
C.     * TAYLOR EXPANSION OF RESIPROCAL OF A POLYNOMIAL:
C.         A(Z)=1 + ALF(1)*Z + ALF(2)*Z**2 +...+ ALF(3)*Z**IP.
C.
C.   CALLING SEQUENCE:
C.            -------------------------
C.            CALL ALFBET(IP,ALF,BET,N)
C.            -------------------------
C.   IP       : INPUT.         INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   ALF(.)   : INPUT.         REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   BET(.)   : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.              IMPULSE RESPONSE; MA (MOVING AVERAGE) PARAMETERS.
C.              BET(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   N        : INPUT.         INTEGER.
C.              THE NUMBER OF REQUIRED POINTS OF IMPULSE RESPONSE.
C.              NOTE THAT THE DEGREE OF FREEDOM REMAINS IP.
```

```
C. --- ALFCEP ---
C.
C.  DESCRIPTION:
C.     * CONVERSION OF "ALF  INTO "CEP".
C.     * COMPUTATION OF CEPSTRUM OF AR-PROCESS SPECIFIED BY "ALF".
C.     * COMPUTATION OF SUM OF M-TH POWER OF LPC POLES, M=1,..,N,
C.       SINCE:          1     IP                M
C.             CEP(M)= --- * SUM ( (LPC POLE(I))  ).
C.                       M    I=1
C.
C.  CALLING SEQUENCE:
C.          -------------------------
C.          CALL ALFCEP(IP,ALF,CEP,N)
C.          -------------------------
C.  IP      : INPUT.        INTEGER.
C.            THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.            THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.  ALF(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.            LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.            ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.  CEP(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.            LPC (ALL-POLE MODELED) CEPSTRUM.
C.            CEP(0) IS IMPLICITLY ASSUMED TO BE ALOG(RESID/PI),
C.            WHERE "RESID" IS RESIDUAL POWER OF LPC/PARCOR.
C.  N       : INPUT.        INTEGER.
C.            THE NUMBER OF REQUIRED POINTS OF LPC-CEPSTRUM.
C.            NOTE THAT THE DEGREE OF FREEDOM REMAINS IP.
C.
```

```
C. --- ALFLSP --- F77
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ALF" INTO "LSP".
C.     * COMPUTATION OF LINE SPECTRUM PAIR FREQUENCIES FROM LINEAR
C.       PREDICTION COEFFICIENTS.
C.     * COMPUTATION OF ROOTS OF P(X) AND Q(X):
C.                                  IP
C.           P(X) = Z * A(Z) - Z    * A(1/Z)
C.                                  IP
C.           Q(X) = Z * A(Z) + Z    * A(1/Z)
C.       WHERE
C.                    IP            IP-1
C.           A(Z) = Z   + A(1) * Z     + .... + A(IP).
C.       IN CASE IP=EVEN, THE ROOTS OF P(X) ARE COSINE OF PI TIMES OF:
C.          0, FREQ(2), FREQ(4), ... , FREQ(IP);
C.       AND THE ROOTS OF P(X) ARE COSINE OF PI TIMES OF:
C.          FREQ(1), FREQ(3), ... ,FREQ(IP-1), 1.
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT ALL THE ROOTS OF POLYNOMIAL A(Z) LIE
C.       INSIDE THE UNIT CIRCLE.
C.
C.   CALLING SEQUENCE:
C.          ------------------------
C.          CALL ALFLSP(IP,ALF,FREQ)
C.          ------------------------
C.   IP       : INPUT.        INTEGER.     2 =< IP =< 14.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   ALF(.)   : INPUT.        REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   FREQ(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.              LSP FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.              CSM FREQUENCIES UNDER TWO DIFERRENT CONDITIONS,
C.                IP=EVEN:    FREQ(0)=0,ORDER=N / FREQ(N+1)=1,ORDER=N
C.                IP=ODD:     ORDER=N / FREQ(0)=0,FREQ(N+1)=1,ORDER=N-1,
C.              WHERE N=[(IP+1)/2].
C.              INCREASINGLY ORDERED.  FREQ(1)=<FREQ(2)=<.....
C.   NOTE: (1) IP MUST NOT BE GREATER THAN 20. (LIMIT IN "EXCHEB")
C.         (2) SUBROUTINE CALL: "EXCHEB", "NRSTEP".
C.
```

```
C. --- ALFNRP ---
C.
C.   DESCRIPTION:
C.     * COMPUTES NORMALIZED RESIDUAL POWER
C.       IN BOTH CASES OF VOICED AND UNVOICED
C.       FROM LINEAR PREDICTORS AND PITCH PERIOD.
C.
C.   CALLING SEQUENCE:
C.           --------------------------------
C.           CALL ALFNRP(IP,ALF,LPITCH,RESID)
C.           --------------------------------
C.
C.   IP      : INPUT.          INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   ALF(.)  : INPUT.          REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   LPITCH  : INPUT.          INTEGER.
C.             PITCH PERIOD. IF LPITCH = 0, IT MEANS UNVOICED SOUND.
C.   RESID   : OUTPUT.         REAL.
C.             LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.             RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.             FILTER MULTIPLIED BY SIGNAL POWER.
C.             POWER OF SOURCE SIGNAL REQUIRED FOR GETTING SYNTHETIC
C.             SPEECH OF POWER EQUAL TO "COV(1)".
C.
```

```
C. --- ALFPOL ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ALF" INTO
C.       POL" (COMBINATION OF "FREQ" AND "BW").
C.     * SOLVE ALGEBRAIC EQUATION AND OBTAIN POLE FREQUENCIES AND
C.       BAND WIDTHS.
C.
C.   CALLING SEQUENCE:
C.           ----------------------------------
C.           CALL ALFPOL(IP,ALF,FREQ,BW,FS,EPS)
C.           ----------------------------------
C.   IP       : INPUT.         INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   ALF(.)   : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   FREQ(.)  : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.              POLE FREQUENCIES. RANGING BETWEEN 0 AND FS.
C.              ORDERED BY MAGNITUDE. (INCREASING)
C.   BW(.)    : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.              POLE BAND WIDTHS.
C.              BW(I) CORRESPONDS TO FREQ(I).
C.   FS       : INPUT.         REAL.
C.              SAMPLING FREQUENCY; OR FREQUENCY NORMALIZATION CONSTANT.
C.              ( 0.0  =OR<  FREQ(.)  =OR<  FS )
C.   EPS      : INPUT.         REAL.
C.              CONVERGENCE CRITERION IN BAIRSTOW ITERATIVE ALGORITHM.
C.
C.   NOTE: * THE CONTENTS OF ARRAY "ALF" ARE NOT SAVED.
C.
```

```
C. --- ALFPOP --- F77
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ALF" INTO "POP".
C.     * COMPUTATION OF POLYNOMIALS QM(X) AND QP(X):
C.       IN CASE IP=EVEN,
C.                                   IP                                 (IP+1)
C           QM(X) = (  Z * A(Z) + Z   * A(1/Z)  ) / ( Z + 1 ) / 2
C.                                   IP                                 (IP+1)
C.          QP(X) = (  Z * A(Z) - Z   * A(1/Z)  ) / ( Z - 1 ) / 2
C.
C.       IN CASE IP=ODD,
C.                                   IP                 (IP+2)
C.          QM(X) = (  Z * A(Z) + Z   * A(1/Z)  ) / 2
C.                                   IP                     2          IP
C.          QP(X) = (  Z * A(Z) - Z   * A(1/Z)  ) / ( Z  - 1 ) / 2
C.
C.       WHERE
C.                       IP          IP-1
C.          A(Z) = Z   + A(1) * Z     + .... + A(IP).
C.                 2
C.          X = ( Z  + 1 ) / 2
C.
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       ALTERNATING ROOTS OF P(X) AND Q(X) IS THAT ALL THE ROOTS OF
C.       THE POLYNOMIAL A(Z) LIE INSIDE THE UNIT CIRCLE.
C.
C.   CALLING SEQUENCE:
C.          ---------------------------
C.          CALL ALFPOP(IP,ALF,OPM,OPP)
C.          ---------------------------
C.   IP      : INPUT.        INTEGER.     IP =< 20.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   ALF(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   OPM(.)  : OUTPUT.       REAL ARRAY : DIMENSION=[(IP+1)/2].
C.             CSM ORTHOGONAL POLYNOMIAL COEFFICIENTS OF ASSUMED SPECTRUM,
C.             (1+COSW)S(W) (IP=EVEN) OR S(W) (IP=ODD).
C.   OPP(.)  : OUTPUT.       REAL ARRAY : DIMENSION=[IP/2].
C.             CSM ORTHOGONAL POLYNOMIAL COEFFICIENTS OF ASSUMED SPECTRUM,
C.             (1-COSW)S(W) (IP=EVEN) OR (1-COSW)(1+COSW)S(W) (IP=ODD).
C.             WHERE W=(OMEGA) ANGULAR FREQUENCY, S(W)=POWER SPECTRUM.
C.
C.             OPM(.) AND OPP(.) ARE RELATED TO CSM ANALYSIS UNDER
C.             CONSTRAINT CONDITIONS SUCH AS,
C.               IP=EVEN:   FREQ(0)=0,ORDER=N / FREQ(N+1)=1,ORDER=N
C.               IP=ODD:    ORDER=N / FREQ(0)=0,FREQ(N+1)=1,ORDER=N-1,
```

```
C.             WHERE N=[(IP+1)/2].
C.
C.    NOTE: (1) SUBROUTINE CALL: EXCHEB
C.          (2) "IP" MUST NOT BE GREATER THAN 20. (LIMIT OF "EXCHEB")
C.
```

```
C. --- ALFPSD ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ALF" INTO "PSD".
C.     * COMPUTATION OF POWER SPECTRUM DENSITY OF AR-PROCESS
C.       FROM AR COEFFICIENTS (LPC).
C.
C.   CALLING SEQUENCE:
C.           -------------------------
C.           CALL ALFPSD(IP,ALF,PSD,N)
C.           -------------------------
C.   IP       : INPUT.        INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   ALF(.)   : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   PSD(.)   : OUTPUT.       REAL ARRAY : DIMENSION=N+1
C.              POWER SPECTRUM DENSITY OF AR PROCESS AT EQUALLY
C.              SPACED N+1 FREQUENCIES.
C.              PSD(1)   IS DENSITY AT ANGULAR FREQUENCY = 0.
C.              PSD(N+1) IS DENSITY AT ANGULAR FREQUENCY = PI.
C.   N        : INPUT.        INTEGER, = OR < 256.
C.              THE NUMBER OF REQUIRED POINTS OF SPECTRUM DENSITY.
C.              NOTE THAT THE DEGREE OF FREEDOM REMAINS IP.
C.
```

```
C. --- ALFREF ---
C.
C.    DESCRIPTION:
C.      * CONVERSION OF "ALF" INTO "REF".
C.      * DISCRIMINATION OF STABILITY OF ALL-POLE FILTER SPECIFIED
C.        BY "ALF".
C.      * DISCRIMINATION IF SEQUENCE "ALF" IS OF MINIMUM PHASE OR NOT.
C.
C.    CALLING SEQUENCE:
C.            ------------------------------------
C.            CALL ALFREF(IP,ALF,REF,RESID,ISTABL)
C.            ------------------------------------
C.    IP       : INPUT.          INTEGER.
C.               THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.               THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.    ALF(.)   : OUTPUT.         REAL ARRAY : DIMENSION=IP.
C.               LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.               ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.    REF(.)   : OUTPUT.         REAL ARRAY : DIMENSION=IP.
C.               PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.               ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.    RESID    : OUTPUT.         REAL.
C.               LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.               RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.               FILTER.
C.    ISTABL   : OUTPUT.         INTEGER/LOGICAL.
C.               INDEX IF "ALF" IS OF MINIMUM PHASE (STABLE) OR NOT.
C.                  =0 (STABLE), =-1 (UNSTABLE).
C.                  =FALSE,      =TRUE.
C.
```

```
C. --- ALFSIG --- F77
C.
C.  DESCRIPTION:
C.     * CONVERSION OF "ALF" INTO "SIG".
C.     * SPEECH SYNTHESIZER FILTER WHOSE COEFFICIENTS ARE "ALF".
C.     * DIRECT FORM ALL-POLE FILTER.
C.
C.  CALLING SEQUENCE:
C.             ------------------------
C.             ALFSIG(IP,CEP,STATE,XIN)
C.             ------------------------
C.  IP       : INPUT.        INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.  ALF(.)   : INPUT.        REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.  STATE(.): INPUT/OUTPUT. REAL ARRAY : DIMENSION=IP.
C.             INNER STATE IN THE CEPSTRUM FILTER. LET BE ALL 0
C.             FOR INITIALIZATION.
C.  XIN      : INPUT.        REAL.
C.             FILTER INPUT SAMPLE.
C.
```

```
C. --- ARCCOS ---
C.
C.   DESCRIPTION:
C.     * FUNCTION TO COMPUTE ARC COSINE OF X DEFINED IN (-1,1).
C.
C.   CALLING SEQUENCE:
C.             ---------
C.             ARCCOS(X)
C.             ---------
C.   ARCCOS  : OUTPUT.       REAL.
C.             ARC COSINE OF X.  0 =< ARCCOS =< PI.
C.   X       : INPUT.        REAL.
C.             COSINE VALUE.  -1 =< X =< 1.
C.
```

```
C. --- ARGRPZ ---
C.
C.   DESCRIPTION:
C.     * COMPUTE ARGUMENT OF R(Z)=B(Z)/A(Z); Z=EXP(J*OMEGA)
C.       WHERE B(Z)=Z**IP * A(1/Z)
C.     * COMPUTE ANGULAR DELAY OF ALL-PASS FILTER, R(Z).
C.
C.   CALLING SEQUENCE:
C.             --------------------
C.             ARGRPZ(IP,ALF,OMEGA)
C.             --------------------
C.
C.   ARGRPZ  : OUTPUT.      REAL FUNCTION.
C.             ARGUMENT ANGLE OF RP(Z).  VALUED BETWEEN -PI AND +PI.
C.   IP      : INPUT.       INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             ARBITRARY INTEGER NUMBER.
C.   ALF(.)  : INPUT.       REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   OMEGA   : INPUT.       REAL.
C.             ARGUMENT ANGLE OF Z IN RADIANS. (0-PI)
C.
C.   NOTE: NONE
C.
```

```
C. --- BAIRST ---
C.
C.   DESCRIPTION:
C.     * SOLVE REAL-COEEFICIENT ALGEBRAIC EQUATION BY BAIRSTOW
C.       ITERATIVE ALGORITHM.
C.
C.   CALLING SEQUENCE:
C.           ---------------------------
C.           CALL BAIRST(N,A,RP,IP,EPS)
C.           ---------------------------
C.   N       : INPUT.         INTEGER.
C.             ORDER OF THE ALGEBRAIC EQUATION.
C.   A(.)    : INPUT.         REAL ARRAY : DIMENSION=N.
C.             COEFFICIENTS.  THE POLYNOMIAL IS GIVEN AS:
C.                X**N + A(1)*X**(N-1) +....+ A(N).
C.             A(0) IS IMPLICITLY ASSUMED TO BE 1.
C.   RP(.)   : OUTPUT.        REAL ARRAY : DIMENSION=N.
C.             REAL PARTS OF THE ROOTS(SOLUTION).
C.   IP(.)   : OUTPUT.        REAL ARRAY : DIMENSION=N.
C.             IMAGINARY PARTS OF THE ROOTS (SOLUTION).
C.   EPS     : INPUT.         REAL.
C.             CONVERGENCE CRITERION IN BAIRSTOW ITERATIVE ALGORITHM.
C.
```

```
C. --- BETCOV ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "BET" INTO "COV".
C.     * COMPUTATION OF AUTOCORRELATION FUNCTION "COV" OF A MA-
C.       PROCESS FROM MA PARAMETERS "BET".
C.     * COMPUTATION OF AUTOCORRELATION FUNCTION "COV" OF AN AR-
C.       PROCESS FROM TRUNCATED IMPULSE RESPONSE "BET".
C.     * THIS SUBROUTINE ALSO CAN BE USED FOR COMPUTATION OF
C.       AA-PARAMETERS FROM "ALF" BY:
C.          CALL BETCOV(IP,ALF,AA)    ; DIMENSION ALF(IP),AA(IP+1)
C.
C.   CALLING SEQUENCE:
C.          ----------------------
C.          CALL BETCOV(IQ,BET,COV)
C.          ----------------------
C.   IQ      : INPUT.        INTEGER.
C.             THE ORDER OF MOVING AVERAGE; THE NUMBER OF ZEROS.
C.   BET(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.             MA (MOVING AVERAGE) PARAMETERS.
C.             BET(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   COV(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP+1.
C.             AUTOCORRELATION FUNCTION.
C.             COR(1) IS THE POWER (VARIANCE) OF THE SIGNAL.
C.
```

```
C. --- CEPALF ---
C.
C.    DESCRIPTION:
C.      * CONVERSION OF "CEP" INTO "ALF".
C.      * COMPUTATION OF AR-COEFFICIENTS "ALF" FROM ITS CEPSTRUM.
C.      * COMPUTATION OF POLYNOMIAL COEFFICIENTS FROM M-TH POWER OF
C.        ITS ZEROS (ROOTS), FOR M=1,...,IP, SINCE:
C.      * COMPUTATION OF LPC CEPSTRUM FROM LPC POLES:
C.                         1     IP                 M
C.             CEP(M)= --- * SUM ( (LPC POLE(I))   ).
C.                         M     I=1
C.      * CONVERSION FROM THE SUM OF M-TH POWER OF COMPLEX NUMBERS
C.        FOR M=1,...,IP INTO THEIR SYMMETRIC HOMOGENEOUS
C.        POLYNOMIALS, I.E.,
C.        GIVEN ARE                       M     M          M
C.                       M * CEP(M) = Z1  + Z2  +...+ ZP  .
C.        COMPUTED ARE  ALF(1) = Z1+Z2+Z3+.................+ZP
C.                      ALF(2) = Z1*Z2+Z1*Z3+Z1*Z4+..+Z(P-1)*ZP
C.                                   ............
C.                      ALF(P) = Z1*Z2*Z3*...*ZP.
C.
C.    CALLING SEQUENCE:
C.           -----------------------
C.           CALL CEPALF(IP,CEP,ALF)
C.           -----------------------
C.    IP       : INPUT.         INTEGER.
C.               THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.               THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.    CEP(.)   : INPUT.         REAL ARRAY : DIMENSION=IP.
C.               LPC (ALL-POLE MODELED) CEPSTRUM.
C.               CEP(0) IS IMPLICITLY ASSUMED TO BE ALOG(RESID/PI),
C.               WHERE "RESID" IS RESIDUAL POWER OF LPC/PARCOR.
C.    ALF(.)   : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.               LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.               ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.
C.    NOTE: * THE CONTENTS OF ARRAY "CEP" WILL BE CHANGED.
C.
```

```
C. --- CEPSIG ---
C.
C.  DESCRIPTION:
C.    * CONVERSION OF "CEP" INTO "SIG".
C.    * SPEECH SYNTHESIZER FILTER WHOSE COEFFICIENTS ARE LPC-CEPSTRA.
C.
C.  CALLING SEQUENCE:
C.            ------------------------
C.            CEPSIG(IP,CEP,STATE,XIN)
C.            ------------------------
C.  CEPSIG  : OUTPUT.        REAL FUNCTION.
C.            SAMPLE OUTPUT OF LPC-CEPSTRUM ALL-POLE FILTER.
C.  IP      : INPUT.         INTEGER.
C.            THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.            THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.  CEP(.)  : INPUT.         REAL ARRAY : DIMENSION=IP*2.
C.            LPC (ALL-POLE MODELED) CEPSTRUM.
C.            CEP(0) IS IMPLICITLY ASSUMED TO BE ALOG(RESID/PI),
C.            WHERE "RESID" IS RESIDUAL POWER OF LPC/PARCOR.
C.  STATE(.): INPUT/OUTPUT. REAL ARRAY : DIMENSION=IP.
C.            INNER STATE IN THE CEPSTRUM FILTER. LET BE ALL 0
C.            FOR INITIALIZATION.
C.  XIN     : INPUT.         REAL.
C.            FILTER INPUT SAMPLE.
C.
```

```
C. --- CHBPOL --- F77
C.
C.   DESCRIPTION:
C.     * AN N-TH ORDER RECIPROCAL POLYNOMIAL OF Z:
C.                          N           N-1
C.       P(Z) = C(1) * Z  + C(2) * Z    + .... + C(N) +
C.                                     N-1                N
C.             .... + C(2) * (1/Z)    + C(1) * (1/Z)
C.       IS CONVERTED INTO A POLYNOMIAL OF X:
C.                 1           1
C.            X = --- * ( Z + --- ).
C.                 2           Z
C.                                     K     1  K
C.     * A LINEAR COMBINATION OF  Z  + (---)  , FOR K=N,N-1,..,0 IS
C.                                           Z
C.                                                1           1
C.       CONVERTED INTO A POLYNOMIAL OF  X = --- * ( Z + --- );
C.                                                2           Z
C.       THAT IS RELATED TO TCHEBYCHEFF POLYNOMIAL THEORY.
C.
C.   CALLING SEQUENCE:
C.          --------------------
C.          CALL CHBPOL(N,C,POL)
C.          --------------------
C.   N       : INPUT.        INTEGER.
C.             THE ORDER OF THE POLYNOMIAL.
C.   C(.)    : INPUT.        REAL ARRAY : DIMENSION=N+1.
C.             COEFFICIENTS OF N-TH ORDER ORTHOGONAL POLYNOMIAL.
C.             SOLUTION OF A HANKEL MATRIX EQUATION OF DIMENSION N.
C.   POL(.)  : OUTPUT.       REAL ARRAY : DIMENSION=N+1.
C.             POLE FREQUENCIES. RANGING BETWEEN 0 AND FS.
C.             INCREASINGLY ORDERED.  FREQ(1)=<FREQ(2)=<.....
C.
```

```
C. --- CHEBEX --- F77
C.
C.   DESCRIPTION:
C.     * ORTHOGONAL EXPANSION BY TCHEBYCHEFF POLYNOMIALS APPLIED TO
C.       A POLYNOMIAL OF X.  SUPPOSE A POLYNOMIAL OF X IS GIVEN:
C.                   N           N-1
C.           S(X) = X  + A(1) * X    + .... + A(N).
C.
C.       THEN, OBTAIN ITS TCHEBYCHEFF ORTHOGONAL EXPANSION:
C.
C.           S(X) = T(X,N) + B(1) * T(X,N-1) + .... + B(N) * T(X,0)
C.
C.       WHERE T(X,K) DENOTES K-TH TCHEBYCHEFF POLYNOMIAL OF X.
C.     * THIS PROBLEM IS EQUIVALENT TO THE SUBSTITUTION:
C.                           K       K
C.                 X  =  ( Z  + 1 / Z  ) / 2
C.                                N
C.       AND MULTIPLICATION BY 2   APPLIED TO A POLYNOMIAL OF X.
C.     * THIS PROBLEM IS EQUIVALENT TO THE CONVERSION OF A POLINOMIAL
C.       OF COS(X) INTO A LINEAR COMBINATION OF COS(K*X), K=1,...,N.
C.     * SUPPOSE A POLYNOMIAL OF X:
C.                   N          N-K       N
C.           S(X) = SUM A(K) * X    = PRODUCT( X - COS( W  ) )
C.                  K=0                K=1               K
C.             ( A(0) = 1, IMPLICITLY)
C.       THEN, OBTAIN A RECIPROCAL POLYNOMIAL OF Z:
C.                     N          N-1
C.           T(Z) =   Z  + B(1)*Z    +...+ B(N-1)*Z + B(N)
C.                                    -1            1-N    -N
C.                  + B(N) + B(N-1)*Z  +...+ B(1)*Z    + Z
C.
C.                              (NOTE THAT B(N) APPEARS TWICE !)
C.                     N
C.                = PRODUCT ( Z - EXP(JW  ) ) * ( Z - EXP(-JW ) )
C.                    K=1                K                  K
C.
C.   CALLING SEQUENCE:
C.           ------------------
C.           CALL CHEBEX(N,A,B)
C.           ------------------
C.   N        : INPUT.        INTEGER.   N =< 10.
C.   A(.)     : INPUT.        REAL ARRAY : DIMENSION=N.
C.   B(.)     : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.
C.     * NOTE: ARRAYS "A" AND "B" CAN BE IDENTICAL.
C.
```

```
C. --- CMXRR ---
C.
C.    DESCRIPTION:
C.      * TRANSFORM COMPLEX TO REAL-REAL. DATA TYPE CONVERSION.
C.        X ,X ,X ,X ,...,X   . ---> X ,X ,X ,X ,...,X     ,X ,X ,...,X  .
C.         1  2  3  4      2N         1  3  5  7      2N-1  2  4      2N
C.
C.    CALLING SEQUENCE:
C.            ---------------
C.            CALL CMXRR(X,L)
C.            ---------------
C.
C.    X(.)    : INPUT/OUTPUT. COMPLEX ARRAY: DIMENSION=2**M.
C               INPUT = COMPLEX DATA OF DIMENSION (2**L).
C               OUTPUT= TWO REAL DATA ARRAYS OF DIMENSION (2**L).
C.    L       : INPUT.        INTEGER.
C.              EXPONENT.  I.E., DIMENSION = 2**L.  (NONNEGATIVE)
C.
```

```
C. --- CONVOL ---
C.
C.   DESCRIPTION:
C.     * CONVOLUTION OF TWO SYMMETRICAL ARRAYS.
C.        U*V=W, * = CONVOLUTION, WHERE U AND V ARE SYMMETRICAL
C.       ARRAYS SUCH AS CORRELATION FUNCTIONS. CONVOLVED RESULT
C.       W IS ALSO A SYMMETRICAL ARRAY.
C.       FOR EAXMPLE:
C        U -- IMPULSE RESPONSE AUTOCORRELATION OF A LINEAR FILTER.
C        V -- INPUT SIGNAL AUTOCORRELATION.
C.       W -- OUTPUT SIGNAL AUTOCORRELATION.
C.
C.   CALLING SEQUENCE:
C.           -----------------------
C.           CALL CONVOL(U,M,V,W,N)
C.           -----------------------
C.   U(.)     : INPUT.       REAL ARRAY : DIMENSION=M.
C.              ELEMENTS OF A SYMMETRICAL ARRAY,
C.               U(0),U(1),U(2),...,U(M-1),
C.              WHERE U(I)=U(-I) FOR I=1,2,...,M-1.
C.   M        : INPUT.       INTEGER.
C.              THE DIMENSION OF THE ARRAY U(.).
C.   V(.)     : INPUT.       REAL ARRAY : DIMENSION=M+N.
C.              ELEMENTS OF A SYMMETRICAL ARRAY,
C.               V(0),V(1),V(2),...,V(M+N-1),
C.              WHERE V(I)=(V-I) FOR I=1,2,...,M+N-1.
C.   W(.)     : OUTPUT.      REAL ARRAY : DIMENSION=N.
C.              ELEMENTS OF A SYMMETRICAL ARRAY,
C.               W(0),W(1),W(2),...,W(N-1),
C.              WHERE W(I)=W(-I) FOR I=1,2,...,N-1.
C.   N        : INPUT.       INTEGER.
C.              THE DIMENSION OF THE ARRAY W(.).
C.
```

```
C. --- CORALF ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COR" INTO "ALF".
C.     * LPC ANALYSIS VIA PARCOR RECURSIVE ALGORITHM WITHOUT
C.       GETTING PARCOR COEEFICIENTS ("REF").
C.     * RECURSIVE ALGORITHM FOR SOLVING TOEPLITZ MATRIX EQUATION.
C.       EXAMPLE(IP=3):  SOLVE IN RESPECT TO A1, A2, AND A3.
C.           ( V0 V1 V2 )    ( A1 )      ( V1 )
C.           ( V1 V0 V1 ) * ( A2 ) = - ( V2 )
C.           ( V2 V1 V0 )    ( A3 )      ( V3 )
C.       WHERE V0 = 1, VI = COR(I), AI = ALF(I).
C.     * RECURSIVE COMPUTATION OF COEFFICIENTS OF A POLYNOMIAL:(EX,IP=3)
C.                  | V0    V1    V2    V3    |    /       | V0    V1    V2 |
C.       A(Z)= DET | V1    V0    V1    V2    |   /   DET | V1    V0    V1 |
C.                  | V2    V1    V0    V1    |  /         | V2    V1    V0 |
C.                  | 1     Z    Z**2 Z**3   | /
C.            = Z**3 + ALF(1) * Z**2 + ALF(2) * Z + ALF(3).
C.     * GRAM-SCHMIDT ORTHOGONALIZATION OF A SEQUENCE, ( 1, Z, Z**2,
C.       Z**3, ... ,Z**(2N-1) ), ON THE UNIT CIRCLE, GIVING THEIR INNER
C.       PRODUCTS:
C.                              K      L
C.            V(K-L) = ( Z    , Z     ),      0 =< K,L =< IP.
C.       COEFFICIENTS OF IP-TH ORDER ORTHOGONAL POLYNOMIAL ARE OBTAINED
C.       THROUGH THIS SUBROUTINE. (ALF(1),...,ALF(IP))
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT TOEPLITZ MATRIX ( V(I-J) ), I,J=0,1,...
C.       BE POSITIVE DEFINITE.
C.   CALLING SEQUENCE:
C.         -----------------------------
C.         CALL CORALF(IP,COR,ALF,RESID)
C.         -----------------------------
C.   IP       : INPUT.        INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   COR(.)   : INPUT.        REAL ARRAY : DIMENSION=IP
C.              AUTOCORRELATION COEFFICIENTS.
C.              COR(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   ALF(.)   : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   RESID    : OUTPUT.       REAL.
C.              LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.              RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.              FILTER.
C.
```

```
C. --- CORREF ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COR" INTO "REF".
C.       "ALF" IS SIMULTANEOUSLY OBTAINED.
C.     * COMPUTATION OF PARCOR COEFFICIENTS "REF" OF AN ARBITRARY
C.       SIGNAL FROM ITS AUTOCORRELATION "COR".
C.     * COMPUTATION OF ORTHOGONAL POLYNOMIAL COEFFICIENTS FROM
C.       AUTOCORRELATION FUNCTION.
C.     * RECURSIVE ALGORITHM FOR SOLVING TOEPLITZ MATRIX EQUATION.
C.       EXAMPLE(IP=3):  SOLVE IN RESPECT TO A1, A2, AND A3.
C.            ( VO V1 V2 )    ( A1 )      ( V1 )
C.            ( V1 VO V1 ) * ( A2 ) = - ( V2 )
C.            ( V2 V1 VO )    ( A3 )      ( V3 )
C.       WHERE VO = 1, VJ = COR(J), AJ = ALF(J).
C.     * RECURSIVE COMPUTATION OF COEFFICIENTS OF A POLYNOMIAL:(EX,IP=4)
C.                  | VO    V1    V2    V3    |    /      | VO    V1    V2 |
C.       A(Z)= DET | V1    VO    V1    V2    |   /   DET | V1    VO    V1 |
C.                  | V2    V1    VO    V1    |  /        | V2    V1    VO |
C.                  | 1     Z    Z**2 Z**3  | /
C.       WHERE A(Z) = Z**IP + ALF(1) * Z**(IP-1) + ... + ALF(IP).
C.       NOTE THAT THE COEFFICIENT OF Z**3 IS ALWAYS EQUAL TO 1.
C.     * GRAM-SCHMIDT ORTHOGONALIZATION OF A SEQUENCE, ( 1, Z, Z**2,
C.       Z**3, ... ,Z**(2N-1) ), ON THE UNIT CIRCLE, GIVING THEIR INNER
C.       PRODUCTS:
C.                              K     L
C.            V(K-L) = ( Z   , Z   ),    0 =< K,L =< IP.
C.       WHERE V(J) = COR(J), V(0) = 1.
C.       COEFFICIENTS OF IP-TH ORDER ORTHOGONAL POLYNOMIAL ARE OBTAINED
C.       THROUGH THIS SUBROUTINE. (ALF(1),...,ALF(IP))
C.     * COMPUTATION OF REFLECTION COEFFICIENTS REF(I) AT THE BOUNDARY
C.       OF THE I-TH SECTION AND (I+1)-TH SECTION IN ACOUSTIC TUBE
C.       MODELING OF VOCAL TRACT.
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       SOLUTION IS THAT TOEPLITZ MATRIX ( V(I-J) ), I,J=0,1,...
C.       BE POSITIVE DEFINITE.
C.
C.   CALLING SEQUENCE:
C.         --------------------------------
C.         CALL CORREF(IP,R,ALF,REF,RESID)
C.         --------------------------------
C.   IP       : INPUT.         INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   COR(.)   : INPUT.         REAL ARRAY : DIMENSION=IP
C.              AUTOCORRELATION COEFFICIENTS.
C.              COR(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   ALF(.)   : OUTPUT.        REAL ARRAY : DIMENSION=IP.
```

```
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.    REF(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.             PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.             ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.    RESID   : OUTPUT.       REAL.
C.             LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.             RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.             FILTER.
C.
C.    NOTE: * IF IP<0, IP IS REGARDED AS IP=0. THEN, RESID=1, AND
C.           ALF(.) AND REF(.) ARE NOT OBTAINED.
C.
```

```
C. --- COVCSM ---
C.
C.  DESCRIPTION:
C.    * CONVERSION OF "COV" INTO "CSM".
C.    * CSM ANALYSIS UNDER CONSTRAINT CONDITIONS:
C.                      M
C.        COV(I) = SUM ( SINT(J) * COS( PI * FREQ(J) ) )
C.                    J=1
C.      IF IP=ODD,  N=(IP+1)/2, M=N,     WITH NO CONSTRAINT.
C.      IF IP=EVEN, N=(IP+1)/2, M=N+1,  OMEGA(N+1)=PI.
C.    * LINE SPECTRUM REPRESENTATION OF LPC COEFFICIENTS UNDER A
C.      CONDITION,  K(IP+1) = -1. (GLOTTIS ENTIRELY OPEN)
C.    * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.      SOLUTION IS THAT CORRELATION FUNCTION MAKES A POSITIVE
C.      DEFINITE SEQUENCE. I.E., FOR ANY COMPLEX NUMBERS X(I),Y(J),
C.           IP
C.           SUM  X(I) * COV(I-J) * Y(J)  > 0
C.         I=1,J=1
C.      WHERE "COV" IS DEFINED AS COV(0:IP).
C.
C.  CALLING SEQUENCE:
C.         ----------------------------
C.         CALL COVCSM(IP,COV,FREQ,SINT)
C.         ----------------------------
C.  IP       : INPUT.        INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.  COV(.)   : INPUT.        REAL ARRAY : DIMENSION=IP+1.
C.             AUTOCORRELATION FUNCTION.
C.             COR(1) IS THE POWER (VARIANCE) OF THE SIGNAL.
C.  FREQ(.)  : OUTPUT.       REAL ARRAY : DIMENSION=N, N=[(IP+1)/2]
C.             CSM FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.             A SET OF ARCCOS(ROOT OF P(X;N))/PI.
C.             INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.  SINT(.)  : OUTPUT.       REAL ARRAY : DIMENSION=N, OR N+1.
C.             CSM INTENSITIES, 0 < SS(I) < 1, I=1,...,N;
C.             RESIDUALS IN LINE SPECTRUM REPRESENTATION OF LPC;
C.             CHRISTOFFEL NUMBERS.
C.             SS(I) CORRESPONDS TO FREQ(I).
C.             SS(N+1) CORRESPONDS TO FREQUENCY=PI, IF IP=EVEN.
C.
```

```
C. --- COVCSM ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COV" INTO "CSP".
C.     * CSM ANALYSIS UNDER CONSTRAINT CONDITIONS:
C.
C.         COV(I) = SUM ( SINT(J) * COS( PI * FREQ(J) ) )
C.                   J
C.       IF IP=ODD,  N=(IP-1)/2, J=0,1,.,N+1, OMEGA(0)=0,OMEGA(N+1)=PI.
C.       IF IP=EVEN, N=(IP+1)/2, J=0,1,..,N,  OMEGA(0)=0.
C.     * LINE SPECTRUM REPRESENTATION OF LPC COEFFICIENTS UNDER A
C.       CONDITION,  K(IP+1) = +1. (GLOTTIS ENTIRELY CLOSED)
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       SOLUTION IS THAT CORRELATION FUNCTION MAKES A POSITIVE
C.       DEFINITE SEQUENCE. I.E., FOR ANY COMPLEX NUMBERS X(I),Y(J),
C.           IP
C.           SUM  X(I) * COV(I-J) * Y(J)  > 0
C.         I=1,J=1
C.       WHERE "COV" IS DEFINED AS COV(0:IP).
C.
C.   CALLING SEQUENCE:
C.         -----------------------------
C.         CALL COVCSP(IP,COV,FREQ,SINT)
C.         -----------------------------
C.   IP      : INPUT.        INTEGER.  < 16.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   COV(.)  : INPUT.        REAL ARRAY : DIMENSION=IP+1.
C.             AUTOCORRELATION FUNCTION.
C.             COR(1) IS THE POWER (VARIANCE) OF THE SIGNAL.
C.   FREQ(.) : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.             CSM FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.             A SET OF ARCCOS(ROOT OF P(X;N))/PI.
C.             INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.   SINT(.) : OUTPUT.       REAL ARRAY : DIMENSION=IP+1-N.
C.             CSM INTENSITIES, 0 < SS(I) < 1, I=1,...,N;
C.             RESIDUALS IN LINE SPECTRUM REPRESENTATION OF LPC;
C.             CHRISTOFFEL NUMBERS.
C.             SS(1) CORRESPONDS TO FREQUENCY 0.
C.             SS(I+1) CORRESPONDS TO FREQ(I).
C.             SS(N+2) CORRESPONDS TO FREQUENCY=PI, IF IP=ODD.
C.
C.   NOTE: * MAXIMUM OF IP IS 15. TO INCREASE MAX OF IP, CHANGE THE
C.           DIMENSION OF UU(.) AND UUU(.).
C.
```

```
C. --- COVICF --- F77
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COV" INTO "ICF".
C.     * COMPUTATION OF INTERPOLATIVE CORRELATION FUNCTION "ICF"
C.       FROM AUTOCORRELATION FUNCTION "COV".
C.     * SUPPOSE S(F) IS A POSITIVE SYMMETRIC FUNCTION OF F. IF
C.                          PI
C.          COV(L-K) = INTEGRAL( COS( (L-K)*F ) * S(F) )
C.                         -PI
C.       IS GIVEN FOR (L-K) = 0,1,..,2*N-1,
C.                          PI         (L-K)
C.          U  (L-K) = INTEGRAL( COS        ( F ) * S(F) )
C.                         -PI
C.       IS COMPUTED THROUGH THIS ALGORITHM.
C.     * TCHEBYCHEFF EXPANSION OF AUTOCORRELATION FUNCTION "COV":
C.                       I
C.          COV(I) = SUM( T(I,J) * U(J) )
C.                      J=0
C.       WHERE T(I,J) DENOTES THE COEFFICIENT OF J-TH TERM IN THE
C.       I-TH ORDER TCHEBYCHEFF POLYNOMIAL.
C.
C.   CALLING SEQUENCE:
C.          --------------------
C.          CALL COVICF(N,COV,U)
C.          --------------------
C.   IP       : INPUT.        INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   COV(.)   : INPUT.        REAL ARRAY : DIMENSION=IP+1.
C.              AUTOCORRELATION FUNCTION.
C.              COR(1) IS THE POWER (VARIANCE) OF THE SIGNAL.
C.   U(.)     : OUTPUT.       REAL ARRAY : DIMENSION=IP+1
C.              INTERPOLATIVE CORRELATION FUNCTION.
C.              U(1) IS EQUAL TO COV(1) (POWER OR VARIANCE).
C.
```

```
C. --- COVLIP ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COV" INTO "LIP".
C.     * COMPUTATION OF LINE-SPECTRUM INTENSITY PAIR.
C.           (FROM COVARIANCE VIA PARCOR)
C.     * CSM ANALYSIS UNDER PAIR OF CONSTRAINT CONDITIONS:
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       SOLUTION IS THAT CORRELATION FUNCTION MAKES A POSITIVE
C.       DEFINITE SEQUENCE. I.E., FOR ANY COMPLEX NUMBERS X(I),Y(J),
C.            IP
C.            SUM  X(I) * COV(I-J) * Y(J)  >  0
C.          I=1,J=1
C.       WHERE "COV" IS DEFINED AS COV(0:IP).
C.
C.   CALLING SEQUENCE:
C.          -----------------------------
C.          CALL COVLIP(IP,COV,FREQ,SINT)
C.          -----------------------------
C.   IP       : INPUT.       INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   COV(.)   : INPUT.       REAL ARRAY : DIMENSION=IP+1.
C.              AUTOCORRELATION FUNCTION.
C.              COR(1) IS THE POWER (VARIANCE) OF THE SIGNAL.
C.   FREQ(.)  : OUTPUT.      REAL ARRAY : DIMENSION=IP
C.              CSM FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.              A SET OF ARCCOS(ROOT OF P(X;N))/PI.
C.              INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.   SINT(.)  : OUTPUT.      REAL ARRAY : DIMENSION=IP+2.
C.              CSM INTENSITIES, 0 < SS(I) < 1, I=1,...,N;
C.              RESIDUALS IN LINE SPECTRUM REPRESENTATION OF LPC;
C.              CHRISTOFFEL NUMBERS.
C.              SS(I+1) CORRESPONDS TO FREQ(I), FOR I=1,...,IP.
C.              SS(1) CORRESPONDS TO FREQUENCY=0.
C.              SS(IP+2) CORRESPONDS TO FREQUENCY=PI.
C.
```

```
C. --- COVREF ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COV" INTO "REF".
C.       "ALF" IS SIMULTANEOUSLY OBTAINED.
C.     * COMPUTATION OF PARCOR COEFFICIENTS "REF" OF AN ARBITRARY
C.       SIGNAL FROM ITS AUTOCORRELATION FUNCTION "COV".
C.     * COMPUTATION OF ORTHOGONAL POLYNOMIAL COEFFICIENTS FROM
C.       AUTOCORRELATION FUNCTION.
C.     * RECURSIVE ALGORITHM FOR SOLVING TOEPLITZ MATRIX EQUATION.
C.       EXAMPLE(IP=3):  SOLVE IN RESPECT TO A1, A2, AND A3.
C.           ( V0 V1 V2 )    ( A1 )      ( V1 )
C.           ( V1 V0 V1 ) * ( A2 ) = - ( V2 )
C.           ( V2 V1 V0 )    ( A3 )      ( V3 )
C.       WHERE VJ = COV(J+1), AJ = ALF(J).
C.     * RECURSIVE COMPUTATION OF COEFFICIENTS OF A POLYNOMIAL:(EX,IP=4)
C.                 | V0    V1    V2    V3    |     /        | V0    V1    V2 |
C.       A(Z)= DET | V1    V0    V1    V2    |    /    DET  | V1    V0    V1 |
C.                 | V2    V1    V0    V1    |   /          | V2    V1    V0 |
C.                 | 1     Z     Z**2  Z**3  |  /
C.           = Z**3 + ALF(1) * Z**2 + ALF(2) * Z + ALF(3).
C.     * GRAM-SCHMIDT ORTHOGONALIZATION OF A SEQUENCE, ( 1, Z, Z**2,
C.       Z**3, ... ,Z**(2N-1) ), ON THE UNIT CIRCLE, GIVING THEIR INNER
C.       PRODUCTS:
C.                            K     L
C.            V(K-L) = ( Z    , Z    ),     0 =< K,L =< IP.
C.       WHERE V(J) = COV(J+1).
C.       COEFFICIENTS OF IP-TH ORDER ORTHOGONAL POLYNOMIAL ARE OBTAINED
C.       THROUGH THIS SUBROUTINE. (ALF(1),...,ALF(IP))
C.     * COMPUTATION OF REFLECTION COEFFICIENTS REF(I) AT THE BOUNDARY
C.       OF THE I-TH SECTION AND (I+1)-TH SECTION IN ACOUSTIC TUBE
C.       MODELING OF VOCAL TRACT.
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT TOEPLITZ MATRIX ( V(I-J) ), I,J=0,1,...
C.       BE POSITIVE DEFINITE.
C.
C.   CALLING SEQUENCE:
C.          ---------------------------------
C.          CALL COVREF(IP,COV,ALF,REF,RESID)
C.          ---------------------------------
C.   IP       : INPUT.        INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   COV(.)   : INPUT.        REAL ARRAY : DIMENSION=IP+1
C.              AUTOCORRELATION FUNCTION.
C.              COR(1) IS THE POWER/VARIANCE OF THE SIGNAL.
C.   ALF(.)   : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
```

```
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.    REF(.)  : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.             PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.             ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.    RESID   : OUTPUT.        REAL.
C.             LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.             RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.             FILTER MULTIPLIED BY SIGNAL POWER.
C.             POWER OF SOURCE SIGNAL REQUIRED FOR GETTING SYNTHETIC
C.             SPEECH OF POWER EQUAL TO "COV(1)".
C.
```

```
C. --- CSMCOV ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "CSM" INTO "COV".
C.     * COMPUTATION OF AUTOCORRELATION FUNCTION FROM COMPOSITE
C.       SINUSOIDAL FREQUENCIES AND INTENSITIES.  ALGORITHM IS:
C.                         N
C.          COV(J) = SUM( SS(I) * COS( J * PI * FQ(I) )
C.                        I=1
C.       FOR J = 0, 1, ..., 2*N-1.
C.
C.   CALLING SEQUENCE:
C.          ------------------------
C.          CALL CSMCOV(N,FQ,SS,COV)
C.          ------------------------
C.   N        : INPUT.         INTEGER.
C.              THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.              THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.   FQ(.)    : INPUT.         REAL ARRAY : DIMENSION=N.
C.              CSM FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.              A SET OF ARCCOS(ROOT OF P(X;N))/PI.
C.              INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.   SS(.)    : INPUT.         REAL ARRAY : DIMENSION=N.
C.              CSM INTENSITIES, 0 < SS(I), I=1,...,N;
C.              RESIDUALS IN LINE SPECTRUM REPRESENTATION OF LPC;
C.              CHRISTOFFEL NUMBERS.
C.              SS(I) CORRESPONDS TO FREQ(I).
C.   COV(.)   : OUTPUT.        REAL ARRAY : DIMENSION=2*N.
C.              AUTOCORRELATION FUNCTION.
C.              COV(1) = SS(1) + SS(2) + ..... + SS(N).
C.
```

```
C. --- DARCCOS ---
C.
C.   DESCRIPTION:
C.     * FUNCTION TO COMPUTE ARC COSINE OF X DEFINED IN (-1,1).
C.
C.   CALLING SEQUENCE:
C.             ----------
C.             DARCCOS(X)
C.             ----------
C.   DARCCOS : OUTPUT.        DOUBLE PRECISION.
C.             ARC COSINE OF X.  0 =< ARCCOS =< PI.
C.   X       : INPUT.         DOUBLE PRECISION.
C.             COSINE VALUE.  -1 =< X =< 1.
C.
```

```
      SUBROUTINE DCOVCSM(IP,COV,FREQ,SINT)
C.
C.   ****** CSM ANALYSIS UNDER CONSTRAINT CONDITION ******
C.      IF IP=OD, NO CONSTRAINT.
C.      IF IP=EVEN, OMEGA(N+1)=PI.
C.           (BOTH ARE CONDITION K(IP+1)=-1)
```

```
      SUBROUTINE DCOVCSP(IP,COV,FREQ,SINT)
C.
C.    ****** CSM ANALYSIS UNDER CONSTRAINT CONDITION ******
C.       IF IP=ODD,  OMEGA=0 AND PI.
C.       IF IP=EVEN, OMEGA=0.
C.             (BOTH ARE CONDITION K(IP+1)=+1)
```

```
C. --- DCT ---
C.
C.   DESCRIPTION:
C.     * REAL NUMBER COSINE TRANSFORM.
C.     * FOURIER TRANSFORM OF SYMMETRICAL REAL NUMBER SEQUENCE.
C.       IF P(.) IS THE POWER SPECTRUM WHOSE VALUES ARE 0 OUTSIDE
C.       I>M, ITS COSINE TRANSFORM R(.) IS THE AUTOCORRELATION
C.       FUNCTION WHOSE VALUES ARE GIVEN FOR J=1,2,...,N.
C.
C.   CALLING SEQUENCE:
C.           -------------------------------
C.           CALL DCT(P,M,R,N,SINTBL,NN,INV)
C.           -------------------------------
C.
C.   P(.)     : INPUT.         REAL ARRAY : DIMENSION=M.
C.              INPUT DATA SEQUENCE SUCH THAT P(I)=0, I>M.
C.   M        : INPUT.         INTEGER.
C.              DIMENSION OF DATA SEQUENCE P(.).
C.   R(.)     : OUTPUT.        REAL ARRAY : DIMENSION=N.
C.              OUTPUT DATA SEQUENCE OF COSINE TRANSFORM OF P(.).
C.   N        : INPUT.         INTEGER.
C.              DIMENSION OF DATA SEQUENCE R(.). NUMBER OF
C.              REQUIRED OUTPUT POINTS.
C.   SINTBL(.) INPUT/OUTPUT. REAL ARRAY : DIMENSION=NN.
C.              SINE TABLE OF DIMENSION NN WHICH CONTAINS ALL THE
C.              VALUES AT NN POINTS: (PI*K)/(2*NN), K=1,...,NN.
C.   N        : INPUT.         INTEGER.
C.              DIMENSION OF SINE TABLE SINTBL(.).
C.   INV      : INPUT.         INTEGER.
C.              INV=0: ORDINARY TRANSFORM,  INV=1: INVERSE TRANSFORM.
```

```
      FUNCTION DDOT(XX,YY,N)
C************************************************
C      DDOT(XX,YY,N)=XX(1)*YY(1)+.....+XX(N)*YY(N)
C          XX : SINGLE PRECISION REAL ARRAY
C          YY : SINGLE PRECISION REAL ARRAY
C          DDOT : DOUBLE PRECISION FUNCTION
C************************************************
```

```
      SUBROUTINE DNEWTON(N,A,X,EPS,IND)
C
C     SOLVE N-TH ORDER EQUATION THROUGH NEWTON-RAPHSON METHOD.
C     A(1),A(3),...,A(N) : COEFICIENTS OF X**(N-I)
C     X(1),X(2),...,X(N) : SOLUTION(REAL)
C     EPS : ABSOLUTE CONVERGENCE CRITERION.  ABS(DELTA X ).LE.EPS-->END
C     IND : =0,ALL SOLUTIONS ARE NORMALLY OBTAINED.
C           =1,SOME ROOTS ARE COMPLEX(NOT OBTAINED),OR NOT OBTAINED IN
C             "MAX"-TIMES ITERATION(DEL IS NOT LESS THAN EPS)
```

```
      FUNCTION DOT(XX,YY,N)
C*****************************************************
C       DOT(XX,YY,N)=XX(1)*YY(1)+.....+XX(N)*YY(N)
C           XX : SINGLE PRECISION REAL ARRAY
C           YY : SINGLE PRECISION REAL ARRAY
C           DOT : SINGLE PRECISION FUNCTION
C*****************************************************
```

```
      SUBROUTINE DPASCAL(R,RW,LW,LMAX)
C
C************* LAG WINDOWING ****************************************
C
C      R(I),I=1,...,LMAX  : CORRELATION COEFICIENTS.
C      RW(I),I=1,...,LMAX : LAG WINDOWED CORRELATION.
C         R(0)=RW(0)=1.0 IS SURPOSED.
C      LW    : LAG WINDOW PARAMETER.  IF LW=0, LW IS TAKEN AS +INFINITY,
C                 AND THEN RW(I)=R(I),FOR ALL I.
C      LMAX : DIMENSION OF R(I) AND RW(I).
```

```
      SUBROUTINE DVDMOND(N,A,B,X)
C
C ********* VAN DER MONDE TYPE LINEAR EQUATIONS **********
C
C VAN DER MONDE TYPE EQUATION HAS  THE TYPE AS FOLLOWING:
C              (EXAMPLE OF N=4)
C      1      1      1      1        X  X1  =  B1
C      A1     A2     A3     A4          X2     B2
C      A1**2  A2**2  A3**2  A4**2       X3     B2
C      A1**3  A2**3  A3**3  A4**3       X4     B4
```

```
C. --- EXCHEB --- F77
C.
C.  DESCRIPTION:
C.     * EXPANSION OF LINEAR COMBINATION OF CHEBYCHEFF POLYNOMIALS
C.       INTO A POLYNOMIAL OF X.  SUPPOSE A LINEAR COMBINATION OF
C.       TCHEBYCHEFF(CHEBYSHEV) POLYNOMIALS:
C.
C.           S(X) = T(X,N) + A(1) * T(X,N-1) + .... + A(N) * T(X,0)
C.
C.       WHERE T(X,K) DENOTES K-TH TCHEBYCHEFF POLYNOMIAL OF X,
C.       THEN, EXPAND EACH CHEBYCHEFF POLYNOMIAL AND GET A POLYNOMIAL
C.       OF X:
C.                     N             N-1
C.           S(X) = X  + B(1) * X     + .... + B(N).
C.
C.     * THIS PROBLEM IS EQUIVALENT TO THE CONVERSION OF A LINEAR
C.                              K       K
C.       COMBINATION OF ( Z  + 1 / Z  ) INTO A POLYNOMIAL OF
C.       ( Z + 1/Z ).
C.     * THIS PROBLEM IS EQUIVALENT TO THE CONVERSION OF A LINEAR
C.       COMBINATION OF COS(K*X), K=1,...,N, INTO A POLYNOMIAL OF COS(X)C.
C.
C.  CALLING SEQUENCE:
C.          ------------------
C.          CALL EXCHEB(N,A,B)
C.          ------------------
C.  N       : INPUT.        INTEGER.   N =< 10.
C.  A(.)    : INPUT.        REAL ARRAY : DIMENSION=N.
C.  B(.)    : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.
C.  NOTE: (1) ARRAYS "A" AND "B" CAN BE IDENTICAL.
```

```
C. --- EXCHEB --- F77
C.
C.   DESCRIPTION:
C.     * EXPANSION OF LINEAR COMBINATION OF CHEBYCHEFF POLYNOMIALS
C.       INTO A POLYNOMIAL OF X.  SUPPOSE A LINEAR COMBINATION OF
C.       TCHEBYCHEFF(CHEBYSHEV) POLYNOMIALS:
C.
C.           S(X) = T(X,N) + A(1) * T(X,N-1) + .... + A(N) * T(X,0)
C.
C.       WHERE T(X,K) DENOTES K-TH TCHEBYCHEFF POLYNOMIAL OF X,
C.       THEN, EXPAND EACH CHEBYCHEFF POLYNOMIAL AND GET A POLYNOMIAL
C.       OF X:
C.                     N            N-1
C.           S(X) = X  + B(1) * X     + .... + B(N).
C.
C.     * THIS PROBLEM IS EQUIVALENT TO THE CONVERSION OF A LINEAR
C.                           K         K
C.       COMBINATION OF ( Z  + 1 / Z  ) INTO A POLYNOMIAL OF
C.       ( Z + 1/Z ).
C.     * THIS PROBLEM IS EQUIVALENT TO THE CONVERSION OF A LINEAR
C.       COMBINATION OF COS(K*X), K=1,...,N, INTO A POLYNOMIAL OF COS(X).
C.
C.   CALLING SEQUENCE:
C.          ------------------
C.          CALL EXCHEB(N,A,B)
C.          ------------------
C.   N       : INPUT.        INTEGER.   N =< 10.
C.   A(.)    : INPUT.        REAL ARRAY : DIMENSION=N.
C.   B(.)    : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.
C.   NOTE: (1) ARRAYS "A" AND "B" CAN BE IDENTICAL.
```

```
C. --- FFT ---
C.
C.   DESCRIPTION:
C.     * COMPLEX NUMBER FFT. ( FAST FOURIER TRANSFORM )
C.
C.   CALLING SEQUENCE:
C.          -----------------
C.          CALL FFT(XR,XI,M)
C.          -----------------
C.
C.   XR(.)    : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**M.
C.              REAL PART OF INPUT DATA/ OUTPUT DATA.
C.   XI(.)    : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**M.
C.              IMAGINARY  PART OF INPUT DATA/ OUTPUT DATA.
C.   M        : INPUT.        INTEGER.
C.              EXPONENT.  I.E., DIMENSION = 2**M.  (NONNEGATIVE)
C.
C.   NOTE:
C     THIS SUBROUTINE IS A MODIFICATION OF "CFFT".
```

```
C. --- GDELAY --- F77
C.
C.   DESCRIPTION:
C.     * GROUP DELAY CHARACTERISTICS OF ALL POLE FILTER.
C.       THE FILTER IS SPECIFIED BY ALF(1)---ALF(IP)
C.       IMPLICITLY ALF(0)=1.0
C.     * THE FUNCTION IS DEFINED BY THE DERIVED FUNCTION OF PHASE
C.       OF 1/A(1/Z) : Z=EXP(J*FREQUENCY) IN RESPECT TO FREQUENCY.
C.
C.   CALLING SEQUENCE:
C.             --------------------
C.             GDELAY(IP,ALF,OMEGA)
C.             --------------------
```

```
C. --- GOERTZ ---
C.
C.   DESCRIPTION:
C.     * GOERTZEL ALGORITHM FOR COMPUTATION OF DESCRETE FOURIER
C.       TRANSFORM.
C.     * POWER SPECTRUM COMPUTATION FOR ARBITRARY FREQUENCY FROM
C.       DATA SEQUENCE.
C.
C.   CALLING SEQUENCE:
C.             ----------------
C.             GOERTZ(X,N,COSZ)
C.             ----------------
C.
C.   GOERTZ  : REAL FUNCTION.
C.             SUM OF SQUARED REAL PART AND IMAGINARY PART OF FOURIER
C.             SERIES OF INPUT DATA.
C.   X(.)    : INPUT.      REAL ARRAY : DIMENSION=N.
C.             INPUT DATA SEQUENCE.
C.   N       : INPUT.      INTEGER.
C.             DIMENSION OF DATA SEQUENCE X(.).
C.   COSZ    : INPUT.      REAL.
C.             COSINE VALUE OF ARGUMENT OF Z, WHERE Z=EXP(J*OMEGA),
C.             AND OMEGA IS THE ANGULAR FREQUENCY AT WHICH DFT IS
C.             TO BE COMPUTED.
```

```
C. --- HAMWDW ---
C.
C.    DESCRIPTION:
C.      * HAMMING WINDOW GENERATION.
C.
C.    CALLING SEQUENCE:
C.           ---------------------
C.           CALL HAMWDW(WINDOW,N)
C.           ---------------------
C.    N          : INPUT.         INTEGER.
C.                 THE DIMENSION OF DATA; DATA LENGTH; WINDOW LENGTH.
C.    WINDOW(.): OUTPUT.        REAL ARRAY : DIMENSION=N.
C.                 HAMMING WINDOW DATA.
```

```
C. --- HANWDW ---
C.
C.  DESCRIPTION:
C.     * HANNING WINDOW GENERATION.
C.
C.  CALLING SEQUENCE:
C.           ---------------------
C.           CALL HANWDW(WINDOW,N)
C.           ---------------------
C
C.  N          : INPUT.          INTEGER.
C.               THE DIMENSION OF DATA; DATA LENGTH; WINDOW LENGTH.
C.  WINDOW(.): OUTPUT.          REAL ARRAY : DIMENSION=N.
C.               HANNING WINDOW DATA.
```

```
      SUBROUTINE ICCJAC(N,U,PH,PL,Q,R)
C.
C. ****** SOLVE HANKEL MATRIX EQUATION THROUGH RECURSIVE FORMULA ******
C. ****** OR.. CONVERSION OF INTERPOLATING CORRELATION INTO ORTHOGONAL
C.        POLYNOMIAL COEFFICIENT PAIR AND JACOBI COEFFICIENTS ******
C.
C.      N     : ORDER. THE NUMBER OF SINUSOIDAL COMPONENTS.
C.      U     : INTERPOLATING CORRELATION COEFFICIENTS. IMPLICITLY, U(0)=1.0.
C.      P1    : HIGHER ORDER ORTHOGONAL POLYNOMIAL COEFFICIENTS.
C.      P2    : LOWER ORDER ORTHOGONAL POLYNOMIAL COEFFICIENTS.
C.      Q     : JACOBI COEFFICIENTS (DIAGONAL ELEMENTS)
C.      R     : JACOBI COEFFICIENTS (BI-DIAGONAL ELEMENTS)
```

```
C. --- ICFFT ---
C.
C.   DESCRIPTION:
C.     * INVERSE DESCRETE FOURIER TRANSFORM OF COMPLEX DATA.
C.
C.   CALLING SEQUENCE:
C.            ---------------
C.            CALL ICFFT(X,L)
C.            ---------------
C.
C.   X(.)     : input/output. complex array : dimension=2**L.
C.              INPUT = DATA #1. X(1),...,X(2**L)
C.              OUTPUT= TRANSFORMED DATA.
C.   L        : INPUT.          INTEGER.
C.              EXPONENT.  I.E., DIMENSION = 2**L.  (NONNEGATIVE)
```

```
C. --- ICFJAC ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ICF" INTO "JAC".
C.       "PCP" IS SIMULTANEOUSLY OBTAINED.
C.     * COMPUTATION OF JACOBI COEFFICIENTS FROM INTERPOLATIVE COR-
C.       RELATION FUNCTION. ORTHOGONAL POLYNOMIAL COEFFICIENTS PAIR
C.       IS ALSO OBTAINED.
C.     * RECURSIVE ALGORITHM FOR SOLVING HANKEL MATRIX EQUATION.
C.       EXAMPLE(N=3):  SOLVE IN RESPECT TO X1, X2, AND X3.
C.           ( U1 U2 U3 )    ( X1 )       ( U4 )
C.           ( U2 U3 U4 ) *  ( X2 )  = -  ( U5 )
C.           ( U3 U4 U5 )    ( X3 )       ( U6 )
C.     * RECURSIVE COMPUTATION OF COEFFICIENTS OF A POLYNOMIAL:(EX,N=4)
C.                     | U1   U2   U3   U4   |    /      | U1   U2   U3 |
C.       P(X)= DET     | U2   U3   U4   U5   |   /   DET | U2   U3   U4 |
C.                     | U3   U4   U5   U6   |  /        | U3   U4   U5 |
C.                     | 1    X    X**2 X**3 | /
C.       NOTE THAT THE COEFFICIENT OF Z**4 IS ALWAYS EQUAL TO 1.
C.     * GRAM-SCHMIDT ORTHOGONALIZATION OF A SEQUENCE, ( 1, X, X**2,
C.       X**3, ... ,X**(2N-1) ) GIVING THEIR INNER PRODUCTS,
C.                                K     L
C.             U(K+L) = ( X   , X    ),     0 =< K,L =< 2*N-1.
C.       ( IN THIS CASE, U(I) STARTS FROM U(0). )
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT HANKEL MATRIX ( U(I+J) ), I,J=0,2,...
C.       BE POSITIVE DEFINITE.
C.
C.   CALLING SEQUENCE:
C.         ---------------------------
C.         CALL ICFJAC(N,U,PC1,PC2,Q,R)
C.         ---------------------------
C.   N        : INPUT.          INTEGER.
C.              THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.              THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.   U(.)     : INPUT.          REAL ARRAY : DIMENSION=2*N.
C.              INTERPOLATIVE CORRELATION FUNCTION.
C.              COMPONENTS OF A HANKEL MATRIX.
C.              U(I+J) = INNER PRODUCT OF X**I AND X**J.
C.              U(1) IS EQUAL TO COV(1) (POWER OR VARIANCE).
C.   PC1(.)   : OUTPUT.         REAL ARRAY : DIMENSION=N.
C.              COEFFICIENTS OF N-TH ORDER ORTHOGONAL POLYNOMIAL.
C.              SOLUTION OF A HANKEL MATRIX EQUATION OF DIMENSION N.
C.   PC2(.)   : OUTPUT.         REAL ARRAY : DIMENSION=N-1.
C.              COEFFICIENTS OF (N-1)-TH ORDER ORTHOGONAL POLYNOMIAL.
C.              SOLUTION OF A HANKEL MATRIX EQUATION OF DIMENSION N-1.
C.   Q(.)     : OUTPUT.         REAL ARRAY : DIMENSION=N.
C.              JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
```

```
C.              ALL OF Q(.) RANGE BETWEEN -1 AND 1.
C.   R(.)     : OUTPUT.        REAL ARRAY : DIMENSION=N-1.
C.              JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.              RATIO OF NORMS OF ORTHOGONAL POLYNOMIALS OF ORDERS I
C.              AND I-1.  I.E., R(I)=NORM( P(X;I) )/NORM( P(X;I-1) ).
C.              ALL OF R(.) RANGE BETWEEN 0 AND 1.
```

```
C. --- ICFPCP ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "ICF" INTO "PCP".
C.     * COMPUTATION OF ORTHOGONAL POLYNOMIAL COEFFICIENTS PAIR FROM
C.       INTERPOLATIVE CORRELATION FUNCTION.
C.     * RECURSIVE ALGORITHM FOR SOLVING HANKEL MATRIX EQUATION.
C.       EXAMPLE(N=3):  SOLVE IN RESPECT TO P1, P2, AND P3.
C.           ( U1 U2 U3 )   ( P1 )     ( U4 )
C.           ( U2 U3 U4 ) * ( P2 ) = - ( U5 )
C.           ( U3 U4 U5 )   ( P3 )     ( U6 )
C.     * RECURSIVE COMPUTATION OF COEFFICIENTS OF A POLYNOMIAL:(EX,N=4)
C.                     | U1    U2    U3    U4    |     /       | U1    U2    U3 |
C.       P(X)= DET | U2    U3    U4    U5    |    /   DET | U2    U3    U4 |
C.                     | U3    U4    U5    U6    |   /         | U3    U4    U5 |
C.                     | 1     X     X**2 X**3  |  /
C.       NOTE THAT THE COEFFICIENT OF Z**4 IS ALWAYS EQUAL TO 1.
C.     * GRAM-SCHMIDT ORTHOGONALIZATION OF A SEQUENCE, ( 1, X, X**2,
C.       X**3, ... ,X**(2N-1) ) GIVING THEIR INNER PRODUCTS,
C.                                K     L
C.            U(K+L) = ( X   , X   ),    0 =< K,L =< 2*N-1.
C.       ( IN THIS CASE, U(I) STARTS FROM U(0). )
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT HANKEL MATRIX ( U(I+J) ), I,J=0,1,...
C.       BE POSITIVE DEFINITE.
C.
C.   CALLING SEQUENCE:
C.            ------------------------
C.            CALL ICFPCP(N,U,PC1,PC2)
C.            ------------------------
C.   N        : INPUT.          INTEGER.
C.              THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.              THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.   U(.)     : INPUT.          REAL ARRAY : DIMENSION=IP+1
C.              INTERPOLATIVE CORRELATION FUNCTION.
C.              COMPONENTS OF A HANKEL MATRIX.
C.              U(I+J) = INNER PRODUCT OF X**I AND X**J.
C.              U(1) IS EQUAL TO COV(1) (POWER OR VARIANCE).
C.   PC1(.)   : OUTPUT.         REAL ARRAY : DIMENSION=N.
C.              COEFFICIENTS OF N-TH ORDER ORTHOGONAL POLYNOMIAL.
C.              SOLUTION OF A HANKEL MATRIX EQUATION OF DIMENSION N.
C.   PC2(.)   : OUTPUT.         REAL ARRAY : DIMENSION=N-1.
C.              COEFFICIENTS OF (N-1)-TH ORDER ORTHOGONAL POLYNOMIAL.
C.              SOLUTION OF A HANKEL MATRIX EQUATION OF DIMENSION N-1.
```

```
C. --- IFFT ---
C.
C.  DESCRIPTION:
C.    * INVERSE DESCRETE FOURIER TRANSFORM OF COMPLEX DATA.
C.
C.  CALLING SEQUENCE:
C.        ---------------
C.        CALL IFFT(X,Y,L)
C.        ---------------
C.
C.  X(.)     : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**L.
C.             INPUT = DATA #1. X(1),...,X(2**L)
C.             OUTPUT= TRANSFORMED DATA.
C.  Y(.)     : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**L.
C.             INPUT = DATA #1. X(1),...,X(2**L)
C.             OUTPUT= TRANSFORMED DATA.
C.  L        : INPUT.        INTEGER.
C.             EXPONENT.  I.E., DIMENSION = 2**L.  (NONNEGATIVE)
```

```
      SUBROUTINE ITCHEB(N,V,A,COEF)
C************* INVERSE TCHEBYCHEFF TRANSFORM *************************
C        A(I)=SUM OF C(I,J)*V(J-I) FOR J=0,1,..,I /2**I
C         WHERE C(I,J) IS BINOMIAL COEFFICIENT, WHICH IS EQUAL TO THE
C         COEFFICIENT OF X**J OF (1+X)**I.
C         AND WHERE V(I) AND A(I) ARE DEFINED FOR I=0,1,2,....
C         THEY ARE EXPRESSED AS V(1),V(2),... AND V(1),V(2),....
```

```
C. --- IXHAM --- F77
C.
      SUBROUTINE IXHAM(N,IDATA,WDATA)
C
C   *** HAMMING WINDOWING APPLIED TO INTEGER DATA ***
C                (REVISED VERSION OF "HAM")
C
C     N       : DIMENSION OF DATA "IDATA". (EVEN INTEGER)
C     IDATA   : INPUT DATA (INTEGER) OF DIMENSION N
C     WDATA   : WINDOWED DATA (FLOATING)
C
```

```
      SUBROUTINE IXHAN(N,IDATA,WDATA)
C
C    *** HANNING WINDOWING APPLIED TO INTEGER DATA ***
C                (REVISED VERSION OF "HAM")
C
C      N      : DIMENSION OF DATA "IDATA". (EVEN INTEGER)
C      IDATA  : INPUT DATA (INTEGER) OF DIMENSION N
C      WDATA  : WINDOWED DATA (FLOATING)
```

```
C. --- JACPCP ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "JAC" INTO "PCP".
C.     * COMPUTATION OF ORTHOGONAL POLYNOMIAL COEFFICIENTS PAIR FROM
C.       COEFFICIENTS IN RECURSIVE FORMULA (JACOBI COEFFICIENTS).
C.       WHERE ORTHOGONAL POLYNOMIAL IS DEFINED AS BELOW:(EX,N=4)
C.                  | U1   U2   U3   U4   |    /      | U1   U2   U3 |
C.       P(X)= DET  | U2   U3   U4   U5   |   /   DET | U2   U3   U4 |
C.                  | U3   U4   U5   U6   |  /        | U3   U4   U5 |
C.                  | 1    X    X**2 X**3 | /
C.       RECURSIVE FORMULA AMONG POLYNOMIALS OF 3 DIFFERENT ORDERS
C.       HOLDS:
C.           P(X;L) = ( X - Q(L) ) * P(X;L-1) - R(L-1) * P(X;L-2)
C.
C.   CALLING SEQUENCE:
C.          --------------------------
C.          CALL JACPCP(N,Q,R,PC1,PC2)
C.          --------------------------
C.   N       : INPUT.         INTEGER.
C.             THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.             THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.   Q(.)    : INPUT.         REAL ARRAY : DIMENSION=N.
C.             JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.             ALL OF Q(.) RANGE BETWEEN -1 AND 1.
C.   R(.)    : INPUT.         REAL ARRAY : DIMENSION=N-1.
C.             JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.             RATIO OF NORMS OF ORTHOGONAL POLYNOMIALS OF ORDERS I
C.             AND I-1.  I.E., R(I)=NORM( P(X;I) )/NORM( P(X;I-1) ).
C.             ALL OF R(.) RANGE BETWEEN 0 AND 1.
C.   PC1(.)  : OUTPUT.        REAL ARRAY : DIMENSION=N.
C.             COEFFICIENTS OF N-TH ORDER ORTHOGONAL POLYNOMIAL P(X;N).
C.   PC2(.)  : OUTPUT.        REAL ARRAY : DIMENSION=N-1.
C.             COEFFICIENTS OF (N-1)-TH ORDER ORTHOGONAL POLYNOMIAL
C.             P(X;N-1).
```

```
C. --- LAGWDW --- F77
C.
C.    DESCRIPTION:
C.      * LAG WINDOW (PASCAL) DATA GENERATION.
C.
C.    CALLING SEQUENCE:
C.            ------------------------
C.            CALL LAGWDW(WDATA,IP,HB)
C.            ------------------------
C.
C.    WDATA(.): OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.    IP      : INPUT.         INTEGER.
C.              DIMENSION OF WDATA(.).
C.    HB      : INPUT.         REAL.
C.               0.0 < HB < 1.0 .... IF HB=0, WDATA(I)=1.0 FOR ALL I.
C.              WINDOW HALF VALUE BAND WIDTH TO SAMPLING FREQUENCY RATIO.
C.              EXAMPLE: LAG WINDOW HALF VALUE BAND WIDTH = 100 Hz, AND
C.              SAMPLING FREQUENCY = 8 kHz, THEN HB = 100/8k = 1/80 =0.0125
```

```
C. --- LAGWIN ---
C.
C.   DESCRIPTION:
C.     * MAKES LAG WINDOW (PASCAL) DATA.
C.
C.   CALLING SEQUENCE:
C.           --------------------------
C.           CALL LAGWIN(WDATA,LW,IP)
C.           --------------------------
C
C.   WDATA(.): OUTPUT.         REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   LW      : INPUT.          INTEGER.
C.             LAG WINDOW PARAMETER.  IF LW=0, LW IS TAKEN AS +INFINITY,
C.   IP      : INPUT.          INTEGER.
C.             DIMENSION OF WDATA(.).
```

```
      SUBROUTINE LARREF(IP,ZR,REF)
C
C    *** CONVERSION OF LOG AREA RATIOS INTO PARCOR COEFFICIENTS ***
C    IP     : THE NUMBER OF POLES.
C    ZR(.) : LOG AREA RATIO.
C    REF(.) : PARCOR COEFFICIENT.
```

```
C. --- LEROUX ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "COR" INTO "REF".
C.     * COMPUTATION OF PARCOR COEFFICIENTS BY LE ROUX'S ALGORITHM.
C.
C.   CALLING SEQUENCE:
C.          ----------------------------
C.          CALL LEROUX(IP,COV1,REF,RES)
C.          ----------------------------
C.   IP      : INPUT.        INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   COV1(.) : INPUT.        REAL ARRAY : DIMENSION=IP+1
C.             AUTOCORRELATION FUNCTION.
C.             COR(1) IS THE POWER/VARIANCE OF THE SIGNAL.
C.   REF(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.             PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.             ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.   RES(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION / PARCOR RESIDUAL POWER OF
C.             EACH STAGE.  I.E., RES(I) IS THE RESIDUAL POWER
C.             OF I-TH PARCOR ANALYSIS STAGE.
```

```
C. --- LSPALF --- F77
C.
C.   DESCRIPTION:
C.
C.     * CONVERSION OF "LSP" INTO "ALF".
C.
C.     * RETRIEVAL OF A POLYNOMIAL A(Z) GIVING NORMALIZED ARGUMENTS OF
C.       ROOTS OF POLYNOMIALS OF X:
C.
C.       IN CASE IP=EVEN,
C.                                 IP                       (IP+1)
C            QM(X) = (  Z * A(Z) + Z   * A(1/Z)  ) / ( Z + 1 ) / 2
C.                                 IP                       (IP+1)
C.           QP(X) = (  Z * A(Z) - Z   * A(1/Z)  ) / ( Z - 1 ) / 2
C.
C.       IN CASE IP=ODD,
C.                                 IP              (IP+2)
C.           QM(X) = (  Z * A(Z) + Z   * A(1/Z)  ) / 2
C.                                 IP                  2          IP
C.           QP(X) = (  Z * A(Z) - Z   * A(1/Z)  ) / ( Z  - 1 ) / 2
C.
C.       WHERE
C.                      IP            IP-1
C.           A(Z) = Z   + A(1) * Z     + .... + A(IP)
C.                  2
C.           X = ( Z  + 1 ) / 2.
C.
C.   CALLING SEQUENCE:
C.
C.          ---------------------------
C.          CALL LSPALF(IP,FREQ,ALF)
C.          ---------------------------
C.
C.   IP       : INPUT.        INTEGER.     IP =< 20.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   FREQ(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.              LSP FREQUENCIES RANGING BETWEEN 0.0 AND 1.0,
C.              INCREMENTALLY ORDERED, I.E., FREQ(1)<FREQ(2)<...<FREQ(IP).
C.   ALF(.)   : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.              LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.              ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.
C.   NOTE: (1) SUBROUTINE CALL: "MPQUAD"(MULTIPLY QUADRATIC FACTORS)
C.         (2) "IP" MUST NOT BE GREATER THAN 40. (LIMIT OF ARRAY SIZE)
```

```
C. --- LSPPOP ---
C.
C.  DESCRIPTION:
C.    * CONVERSION OF "LSP" INTO "POP".
C.    * COMPUTATION OF COEFFICIENTS OF POLYNOMIALS:
C.
C.     QM(X) = ( X - COS(PI*FREQ(1)) ) * ( X - COS(PI*FREQ(3)) ) * ...
C.     QP(X) = ( X - COS(PI*FREQ(2)) ) * ( X - COS(PI*FREQ(4)) ) * ...
C.
C.  CALLING SEQUENCE:
C.          ----------------------------
C.          CALL LSPPOP(IP,FREQ,OPM,OPP)
C.          ----------------------------
C.  IP       : INPUT.        INTEGER.     2 =< IP =< 14.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.  FREQ(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.             LSP FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.             CSM FREQUENCIES UNDER TWO DIFERRENT CONDITIONS,
C.               IP=EVEN:   FREQ(0)=0,ORDER=N / FREQ(N+1)=1,ORDER=N
C.               IP=ODD:    ORDER=N / FREQ(0)=0,FREQ(N+1)=1,ORDER=N-1,
C.             WHERE N=[(IP+1)/2].
C.             INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.  OPM(.)   : OUTPUT.       REAL ARRAY : DIMENSION=[(IP+1)/2]
C.             COEFFICIENTS OF ORTHOGONAL POLYNOMIAL.
C.             IMPLICITLY, OPM(0)=1.
C.  OPP(.)   : OUTPUT.       REAL ARRAY : DIMENSION=[IP/2]
C.             COEFFICIENTS OF ORTHOGONAL POLYNOMIAL.
C.             IMPLICITLY, OPP(0)=1.
```

```
C*********************************************************************
C*                                                                   *
C*      SUBROUTINE MCORR(V,VM,A,MINDEL,MAXDEL,M)                     *
C*      ---------------------------------------                      *
C*      MODIFIED AUTOCORRELATION FOR PITCH EXTRACTION                *
C*                                                                   *
C*      INPUT    V(I)........AUTOCORRELATION COEFF.                  *
C*      -----------                                                  *
C*           FUNCTION DOT(X,Y,M)                                     *
C*           FUNCTION DOTR(X,Y,M)                                    *
C*                                                                   *
C*      !!!!!THIS PROGRAM CAN BE USED TO OBTAIN MOVING AVERAGE OF    *
C*           ARRAY V(I). IN THIS CASE, AVERAGING WEIGHTING IS SET    *
C*           TO A(I).                                                *
C*                                                                   *
C*********************************************************************
```

```
C. --- MPQUAD ---
C.
C.  DESCRIPTION:
C.    * MULTIPLY A RECIPROCAL POLYNOMIAL:
C.                  N        N-1                                   N-1     N
C.          S(X) = Z + P(1)*Z    + ... + P(N) + ... + P(1)/Z    + 1/Z
C.
C.      BY A RECIPROCAL QUADRATIC FACTOR:
C.
C.          Q(Z) = Z + A + 1/Z.
C.
C.  CALLING SEQUENCE:
C.          ------------------
C.          CALL MPQUAD(P,N,A)
C.          ------------------
C.  P(.)    : INPUT/OUTPUT. REAL ARRAY : DIMENSION=N.
C.            COEFFICIENTS OF S(X). P(0)=1.0 IMPLICITLY.
C.            P(1),...,P(N) ARE GIVEN.
C.  N       : INPUT/OUTPUT. INTEGER.     N <-- N+1.
C.            DIMENSION OF THE ARRAY "P", WHICH IS AUTOMATICALLY
C.            INCREMENTED BY 1 AFTER CALLING THIS ROUTINE.
C.  A       : INPUT.         REAL.
C.            THE CONSTANT TERM IN QUADRATIC FACTOR.
```

```
      SUBROUTINE MULIR(IX,YY,ZZ,N)
C
C    *** MULTIPLY INTEGER ARRAY BY REAL ARRAY ***
C
C    IX(.) : INTEGER ARRAY.
C    YY(.) : REAL ARRAY.
C    ZZ(.) : REAL ARRAY. ZZ(I)=IX(I)*YY(I)
C    N     : DIMENSION OF ARRAYS.
```

```
C. --- MULIRR ---
C.
C.   DESCRIPTION:
C.      * ARRAY ARITHMETIC :  IX * YY = ZZ
C.        I.E. ZZ(I)=IX(I)*YY(I) FOR I=1,N
C.
C.   CALLING SEQUENCE:
C.           -----------------------
C.           CALL MULIRR(N,IX,YY,ZZ)
C.           -----------------------
C
C.    N      : DIMENSION OF DATA
C.    IX(.)  : INPUT DATA ARRAY (INTEGER)
C.    YY(.)  : INPUT DATA ARRAY (FLOATING)
C.    ZZ(.)  : OUTPUT DATA ARRAY (FLOATING)
C.
C.   NOTE: * IX(*) is an array of integer*2.
```

```
C. --- MULRRR ---
C.
C.   DESCRIPTION:
C.     * ARRAY ARITHMETIC :  XX * YY = ZZ
C.       I.E. ZZ(I)=XX(I)*YY(I) FOR I=1,N
C.
C.   CALLING SEQUENCE:
C.           -----------------------
C.           CALL MULRRR(N,XX,YY,ZZ)
C.           -----------------------
C
C.    N      : DIMENSION OF DATA
C.    XX(.)  : INPUT DATA ARRAY (FLOATING)
C.    YY(.)  : INPUT DATA ARRAY (FLOATING)
C.    ZZ(.)  : OUTPUT DATA ARRAY (FLOATING)
```

```
C. --- NEWTON ---
C.
C.   DESCRIPTION:
C.     * SOLVE AN ALGEBRAIC EQUATION,
C.                    N           N-1
C.         F(X) = X  + A(1) * X    + ... + A(N)
C.       TROUGH NEWTON-RAPHSON ITERATION.
C.
C.   CALLING SEQUENCE:
C.          --------------------------
C.          CALL NEWTON(N,A,X,EPS,IND)
C.          --------------------------
C.   N        : INPUT.        INTEGER.
C.              THE ORDER OF REAL COEFFICIENT ALGEBRAIC EQUATION.
C.   A(.)     : INPUT.        REAL ARRAY : DIMENSION=N.
C.              COEFFICIENTS OF N-TH ORDER POLYNOMIAL.
C.              A(0) IS IMPLICITLY ASSUMED TO BE 1.
C.   X(.)     : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.              ROOTS OF N-TH ORDER POLYNOMIAL.
C.              SOLUTION OF A HANKEL MATRIX EQUATION OF DIMENSION N-1.
C.   EPS      : INPUT.        REAL.
C.              CONVERGENCE CRITERION IN NEWTON-RAPHSON ITERATION.
C.   IND      : OUTPUT.       INTEGER.
C.              IF IND = 0, ALL SOLUTIONS ARE NORMALLY OBTAINED.
C.              IF IND = 1, THE EQUATION HAS COMPLEX ROOTS
C.               OR NOT CONVERGED IN "MAX"-TIMES ITERATION.
C.              THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.
C.   NOTE: * INITIAL VALUE IS -1. SO, IF ALL THE ROOTS OF THE EQUATION
C.           ARE REAL, DIFFERENT EACH OTHER, AND GREATER THAN -1,
C.           THE SOLUTION IS DECREASINGLY ORDERED:
C.                 X(1) > X(2) > ... > X(N) > -1.
```

```
C. --- NRSTEP ---
C.
C.   DESCRIPTION:
C.     * APPLY A SINGLE STEP OF NEWTON-RAPHSON ITERATION TO AN
C.       ALGEBRAIC EQUATION AND DIVIDE IT BY ( X - ROOT ).
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT ALL THE ROOTS OF POLYNOMIAL A(Z) LIE
C.       INSIDE THE UNIT CIRCLE.
C.
C.   CALLING SEQUENCE:
C.          ---------------------
C.          CALL NRSTEP(COEF,N,X)
C.          ---------------------
C.   COEF(.) : INPUT/OUTPUT. REAL ARRAY : DIMENSION=N.
C.             COEFFICIENTS OF THE N-TH ORDER POLYNOMIAL (INPUT).
C.             COEFFICIENTS OF NEW (N-1)-TH ORDER POLYNOMIAL (OUTPUT).
C.             NEW POLYNOMIAL(X) = GIVEN POLYNOMIAL(X)/(X-ROOT).
C.             COEF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   N       : INPUT.        INTEGER.
C.             THE ORDER OF THE POLYNOMIAL (N>0).
C.   X       : INPUT/OUTPUT. REAL.
C.             INITIAL VALUE OF THE ITERATION (INPUT),
C.             THE ROOT (OUTPUT).
C.
C.   NOTE: * ORIGINALLY CODED BY F.ITAKURA (ORIGINAL NAME WAS "NEWTON"),
C.           RENAMED AND REVISED BY S.SAGAYAMA,  1981.11.14.
C.         * EFFECTIVE DIMENSION OF "COEF" CHANGES INTO (N-1) AFTER
C.           CALLING THIS SUBROUTINE.  COEF(N) IS MEANINGLESS.
```

```
      SUBROUTINE PASCAL(R,RW,LW,LMAX)
C************* LAG WINDOWING ****************************************
C      R(I),I=1,...,LMAX  : CORRELATION COEFICIENTS.
C      RW(I),I=1,...,LMAX : LAG WINDOWED CORRELATION.
C         R(0)=RW(0)=1.0 IS SURPOSED.
C      LW     : LAG WINDOW PARAMETER.  IF LW=0, LW IS TAKEN AS +INFINITY,
C                   AND THEN RW(I)=R(I),FOR ALL I.
C      LMAX : DIMENSION OF R(I) AND RW(I).
```

```
C. --- PCPCSM ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "PCP" INTO "CSM".
C.     * COMPUTATION OF COMPOSITE SINUSOIDAL PARAMETERS FROM
C.       ORTHOGONAL POLYNOMIAL COEFFICIENTS PAIR.
C.
C.   CALLING SEQUENCE:
C.            ----------------------------
C.            CALL PCPCSM(N,PC1,PC2,FQ,SS)
C.            ----------------------------
C.   N        : INPUT.        INTEGER.
C.              THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.              THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.   PC1(.)   : INPUT.        REAL ARRAY : DIMENSION=N.
C.              COEFFICIENTS OF N-TH ORDER ORTHOGONAL POLYNOMIAL P(X;N).
C.   PC2(.)   : INPUT.        REAL ARRAY : DIMENSION=N-1.
C.              COEFFICIENTS OF (N-1)-TH ORDER ORTHOGONAL POLYNOMIAL
C.              P(X;N-1).
C.   FQ(.)    : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.              CSM FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.              A SET OF ARCCOS(ROOT OF P(X;N))/PI.
C.              INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.   SS(.)    : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.              CSM INTENSITIES, 0 < SS(I) < 1, I=1,...,N;
C.              RESIDUALS IN LINE SPECTRUM REPRESENTATION OF LPC;
C.              CHRISTOFFEL NUMBERS.
C.              NORMALIZED THAT  SS(1)+SS(2)+...+SS(N)=1  HOLDS.
C.              SS(I) CORRESPONDS TO FREQ(I).
```

```
C. --- PCPJAC ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "PCP" INTO "JAC".
C.     * COMPUTATION OF COEFFICIENTS IN RECURSIVE FORMULA FROM
C.       ORTHOGONAL POLYNOMIAL COEFFICIENTS PAIR,
C.       WHERE ORTHOGONAL POLYNOMIAL IS DEFINED AS BELOW:(EX,N=4)
C.                 | U1   U2   U3   U4   |    /       | U1   U2   U3 |
C.       P(X)= DET | U2   U3   U4   U5   |   /    DET | U2   U3   U4 |
C.                 | U3   U4   U5   U6   |  /         | U3   U4   U5 |
C.                 | 1    X    X**2 X**3 | /
C.       RECURSIVE FORMULA AMONG POLYNOMIALS OF 3 DIFFERENT ORDERS
C.       HOLDS:
C.           P(X;L) = ( X - Q(L) ) * P(X;L-1) - R(L-1) * P(X;L-2)
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT ALL THE ROOTS OF P(X;N) AND THOSE OF
C.       P(X;N-1) ALTERNATE BETWEEN -1 AND 1.
C.
C.   CALLING SEQUENCE:
C.           --------------------------
C.           CALL PCPJAC(N,PC1,PC2,Q,R)
C.           --------------------------
C.   N        : INPUT.        INTEGER.
C.              THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.              THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.   PC1(.)   : INPUT.        REAL ARRAY : DIMENSION=N.
C.              COEFFICIENTS OF N-TH ORDER ORTHOGONAL POLYNOMIAL P(X;N).
C.   PC2(.)   : INPUT.        REAL ARRAY : DIMENSION=N-1.
C.              COEFFICIENTS OF (N-1)-TH ORDER ORTHOGONAL POLYNOMIAL
C.              P(X;N-1).
C.   Q(.)     : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.              JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.              ALL OF Q(.) RANGE BETWEEN -1 AND 1.
C.   R(.)     : OUTPUT.       REAL ARRAY : DIMENSION=N-1.
C.              JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.              RATIO OF NORMS OF ORTHOGONAL POLYNOMIALS OF ORDERS I
C.              AND I-1.  I.E., R(I)=NORM( P(X;I) )/NORM( P(X;I-1) ).
C.              ALL OF R(.) RANGE BETWEEN 0 AND 1.
```

```
C*********************************************************************
C*                                                                   *
C*    SUBROUTINE PITCH(MAXT,COVMAX,VM,AAA,MINDEL,MAXDEL)             *
C*    -------------------------------------------------              *
C*    PITCH EXTRACTION BY MODIFIED AUTOCORRELATION                   *
C*                                                                   *
C*    INPUT    VM(I).......MODIFIED AUTOCORRELATION                  *
C*             AAA.........PREDICTION RESIDUAL                       *
C*             MINDEL......MINIMUM DELAY TO EXTRACT PITCH            *
C*             MAXDEL......MAXIMUM DELAY TO EXTRACT PITCH            *
C*                                                                   *
C*    OUTPUT   MAXT........PITCH PERIOD (SAMPLES)                    *
C*             COVMAX......MAXIMUM OF VM(I)                          *
C*                                                                   *
C*********************************************************************
```

```
C*********************************************************************
C*                                                                   *
C*     SUBROUTINE PITCH2(MAXT,COVMAX,VM,AAA,MINDEL,MAXDEL)           *
C*     ---------------------------------------------------           *
C*     PITCH EXTRACTION BY MODIFIED AUTOCORRELATION                  *
C*                                                                   *
C*     INPUT    VM(I).......MODIFIED AUTOCORRELATION                 *
C*              AAA.........PREDICTION RESIDUAL                      *
C*              MINDEL......MINIMUM DELAY TO EXTRACT PITCH           *
C*              MAXDEL......MAXIMUM DELAY TO EXTRACT PITCH           *
C*                                                                   *
C*     OUTPUT   MAXT........PITCH PERIOD (SAMPLES)                   *
C*              COVMAX......MAXIMUM OF VM(I)                         *
C*                                                                   *
C*********************************************************************
```

```
C. --- POLALF ---
C.
C.    DESCRIPTION:
C.      * CONVERSION OF "POL" INTO "ALF".
C.        "POL" IS A COMBINATION OF "FREQ" AND "BW".
C.      * COMPUTATION OF LINEAR PREDICTION COEFFICIENTS FROM LPC POLES
C.        REPRESENTED BY THEIR FREQUENCIES AND BAND WIDTHS.
C.
C.    CALLING SEQUENCE:
C.           ------------------------------
C.           CALL POLALF(IP,FREQ,BW,FS,ALF)
C.           ------------------------------
C.    IP       : INPUT.          INTEGER.
C.               THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.    FREQ(.)  : INPUT.          REAL ARRAY : DIMENSION=IP.
C.               POLE FREQUENCIES. RANGING BETWEEN 0 AND FS.
C.               INCREASINGLY ORDERED.  FREQ(1)=<FREQ(2)=<....
C.    BW(.)    : INPUT.          REAL ARRAY : DIMENSION=IP.
C.               POLE BAND WIDTHS.
C.               BW(I) CORRESPONDS TO FREQ(I).
C.    FS       : INPUT.          REAL.
C.               SAMPLING FREQUENCY; OR FREQUENCY NORMALIZATION CONSTANT.
C.               ( 0.0   =OR<   FREQ(.)   =OR<  FS )
C.    ALF(.)   : OUTPUT.         REAL ARRAY : DIMENSION=IP.
C.               LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.               ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.
C.    NOTE: * ALF(.) IS ASSUMED TO BE REAL.  SO, TOTAL DEGREE OF
C.            "FREQ" AND "BW" SHOULD BE IP.  THAT MEANS ONLY REAL
C.            POLES AND HALF OF COMPLEX POLES WHOSE FREQUENCIS ARE
C.            BETWEEN 0 AND FS/2 ARE NEEDED.  CONJUGATE POLES WHOSE
C.            FREQUENCIES LAY ABOVE FS/2 ARE NOT NEEDED TO BE GIVEN.
```

```
C. --- POLCEP ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "POL" INTO "CEP".
C.     * COMPUTATION OF LPC CEPSTRUM FROM LPC POLES:
C.                       1      IP                  M
C.             CEP(M)= --- * SUM ( (LPC POLE(I))  ).
C.                       M     I=1
C.
C.   CALLING SEQUENCE:
C.           --------------------------------
C.           CALL POLCEP(IP,FREQ,BW,FS,CEP,N)
C.           --------------------------------
C.   IP       : INPUT.        INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   FREQ(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.              POLE FREQUENCIES. RANGING BETWEEN 0 AND FS.
C.              INCREASINGLY ORDERED.  FREQ(1)=<FREQ(2)=<.....
C.   BW(.)    : INPUT.        REAL ARRAY : DIMENSION=IP.
C.              POLE BAND WIDTHS.
C.              BW(I) CORRESPONDS TO FREQ(I).
C.   FS       : INPUT.        REAL.
C.              SAMPLING FREQUENCY; OR FREQUENCY NORMALIZATION CONSTANT.
C.              ( 0.0   =OR<   FREQ(.)   =OR<  FS )
C.   CEP(.)   : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.              LPC (ALL-POLE MODELED) CEPSTRUM.
C.              CEP(0) IS IMPLICITLY ASSUMED TO BE ALOG(RESID/PI),
C.              WHERE "RESID" IS RESIDUAL POWER OF LPC/PARCOR.
C.   N        : INPUT.        INTEGER.
C.              THE NUMBER OF REQUIRED POINTS OF AUTOCORRELATION.
C.              NOTE THAT THE DEGREE OF FREEDOM REMAINS IP.
C.
C.   NOTE: * CEP(.) IS ASSUMED TO BE REAL.  SO, TOTAL DEGREE OF
C.           "FREQ" AND "BW" SHOULD BE IP.  THAT MEANS ONLY REAL
C.           POLES AND HALF OF COMPLEX POLES WHOSE FREQUENCIS ARE
C.           BETWEEN 0 AND FS/2 ARE NEEDED.  CONJUGATE POLES WHOSE
C.           FREQUENCIES LAY ABOVE FS/2 ARE NOT NEEDED TO BE GIVEN.
```

```
C.     ***** POLRT2 ******************************
      SUBROUTINE POLRT2(POLM,POLP,M,XM,XP,IER)
C.       XM(I) : ROOTS OF POLM=0
C.       XP(I) : ROOTS OF POLP=0
C.    ASSUMPTION :
C.       1.0>XM(1)>XP(1)>XM(2)> --- >XM(M)>XP(M)>-1.0
```

```
C. --- POPALF ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "POP" INTO "ALF".
C.     * RETRIEVAL OF A POLYNOMIAL A(Z) FROM POLYNOMIALS QM(X) AND QP(X):
C.       IN CASE IP=EVEN,
C.                                    IP                          (IP+1)
C.           QM(X) = (  Z * A(Z) + Z    * A(1/Z)  ) / ( Z + 1 ) / 2
C.                                    IP                          (IP+1)
C.           QP(X) = (  Z * A(Z) - Z    * A(1/Z)  ) / ( Z - 1 ) / 2
C.
C.       IN CASE IP=ODD,
C.                                    IP                (IP+2)
C.           QM(X) = (  Z * A(Z) + Z    * A(1/Z)  ) / 2
C.                                    IP                  2          IP
C.           QP(X) = (  Z * A(Z) - Z    * A(1/Z)  ) / ( Z   - 1 ) / 2
C.
C.       WHERE
C.                        IP             IP-1
C.           A(Z) = Z   + A(1) * Z      + .... + A(IP).
C.                    2
C.           X = ( Z  + 1 ) / 2
C.
C.   CALLING SEQUENCE:
C.           --------------------------
C.           CALL POPALF(IP,OPM,OPP,ALF)
C.           --------------------------
C.   IP      : INPUT.         INTEGER.      IP =< 20.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   OPM(.)  : INPUT..        REAL ARRAY : DIMENSION=[(IP+1)/2].
C.             CSM ORTHOGONAL POLYNOMIAL COEFFICIENTS OF ASSUMED SPECTRUM,
C.             (1+COSW)S(W) (IP=EVEN) OR S(W) (IP=ODD).
C.   OPP(.)  : INPUT.         REAL ARRAY : DIMENSION=[IP/2].
C.             CSM ORTHOGONAL POLYNOMIAL COEFFICIENTS OF ASSUMED SPECTRUM,
C.             (1-COSW)S(W) (IP=EVEN) OR (1-COSW)(1+COSW)S(W) (IP=ODD).
C.             WHERE W=(OMEGA) ANGULAR FREQUENCY, S(W)=POWER SPECTRUM.
C.   ALF(.)  : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.
C.             OPM(.) AND OPP(.) ARE RELATED TO CSM ANALYSIS UNDER
C.             CONSTRAINT CONDITIONS SUCH AS,
C.               IP=EVEN:    FREQ(0)=0,ORDER=N / FREQ(N+1)=1,ORDER=N
C.               IP=ODD:     ORDER=N / FREQ(0)=0,FREQ(N+1)=1,ORDER=N-1,
C.             WHERE N=[(IP+1)/2].
```

```
C. --- POPLSP --- F77
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "POP" INTO "LSP".
C.     * COMPUTATION OF LINE SPECTRUM PAIR FREQUENCIES FROM PAIR OF
C.       ORTHOGONAL POLYNOMIALS RESPECTING TO DIFFERENT CSM CONSTRAINT
C.       CONDITIONS.
C.     * COMPUTATION OF ROOTS OF QM(X) AND QP(X), AND THEIR ARCCOSINE
C.       CONVERSION.
C.       THEIR ROOTS MUST BE ALTERNATE IN AN INTERVAL (-1,1); THE NEAREST
C.       TO 1 SHOULD BE ONE OF "QM".
C.
C.   CALLING SEQUENCE:
C.          ------------------------
C.          CALL POPLSP(IP,OPM,OPP,FREQ)
C.          ------------------------
C.   IP       : INPUT.         INTEGER.      2 =< IP =< 14.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.   OPM(.)   : INPUT.         REAL ARRAY : DIMENSION=[(IP+1)/2].
C.              ORTHOGONAL POLYNOMIAL COEFFICIENTS.
C.              OPM(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   OPP(.)   : INPUT.         REAL ARRAY : DIMENSION=IP/2.
C.              ORTHOGONAL POLYNOMIAL COEFFICIENTS.
C.              OPP(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   FREQ(.)  : OUTPUT.        REAL ARRAY : DIMENSION=IP.
C.              LSP FREQUENCIES, RANGING BETWEEN 0 AND 1;
C.              CSM FREQUENCIES UNDER TWO DIFERRENT CONDITIONS,
C.                IP=EVEN:   FREQ(0)=0,ORDER=N / FREQ(N+1)=1,ORDER=N
C.                IP=ODD:    ORDER=N / FREQ(0)=0,FREQ(N+1)=1,ORDER=N-1,
C.              WHERE N=[(IP+1)/2].
C.              INCREASINGLY ORDERED.  FQ(1)=<FQ(2)=<.....
C.
C.     * NOTE: (1) CONTENTS OF ARRAYS "OPM" AND "OPP" ARE NOT SAVED.
C.             (2) SUBROUTINE CALL: NRSTEP.
```

```
C. --- PSPEC ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "REF" INTO "COR".
C.       "ALF" IS SIMULTANEOUSLY OBTAINED.
C.     * COMPUTATION OF AUTOCORRELATION COEFFICIENTS "COR"
C.       OF AN AR-PROCESS SPECIFIED BY "REF" (PARCOR).
C.
C.   CALLING SEQUENCE:
C.          ---------------
C.          CALL PSPEC(X,L)
C.          ---------------
C.
C.   X(.)     : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**(L+2)
C.              WAVEFORM (SIGNAL) AND WORK AREA.
C.   L        : EXPONENT.  I.E.,THE NUMBER OF THE POINTS OF THE DATA IS
C               2**L.
```

```
C. --- R1FFT ---
C.
C.   DESCRIPTION:
C.     * DESCRETE FOURIER TRANSFORM OF A SET OF REAL DATA.
C.       THE ALGORITHM IS SUGGESTED BY J.W.COOLEY, P.A.W.LEWIS, P.D.WELCH.
C.
C.   CALLING SEQUENCE:
C.          ---------------
C.          CALL R1FFT(X,L)
C.          ---------------
C.
C.   X(.)     : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**L.
C               REAL TYPE DATA ARRAY OF DIMENSION (2**L). (AS INPUT)
C               COMPLEX TYPE TRANSFORMED DATA OF DIMENSION (2**(L-1)+1).(OUT)
C.   L        : INPUT.         INTEGER.
C.              EXPONENT.  I.E., DIMENSION = 2**L.  (NONNEGATIVE)
C               THE DFT OF "X" IS STORED IN X(1),....,X(2**L+2),AS A COMPLEX
C               ARRAY. (2**L+2) POINTS ARE CALCULATED.
```

```
C. --- R2FFT ---
C.
C.  DESCRIPTION:
C.    * DESCRETE FOURIER TRANSFORM OF TWO SETS OF REAL DATA (X AND Y).
C.
C.  CALLING SEQUENCE:
C.          -----------------
C.          CALL R2FFT(X,Y,M)
C.          -----------------
C.
C.  X(.)    : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**M.
C.            INPUT = DATA #1. X(1),...,X(2**M)
C.            OUTPUT= TRANSFORMED DATA. DATA STRUCTURE IS LIKE BELOW:
C.  XI(.)   : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**M.
C.            INPUT = DATA #2. Y(1),...,Y(2**M)
C.            OUTPUT= TRANSFORMED DATA. DATA STRUCTURE IS LIKE BELOW:
C.  M       : INPUT.        INTEGER.
C.            EXPONENT.  I.E., DIMENSION = 2**M.  (NONNEGATIVE)
C.
C.  NOTE:
C    TRANSFORMED DATA ARE STORED IN THE FORM :
C    X(1),...,X(N/2+1) --- (N/2+1) REAL PARTS, I.E.,R(0),...,R(N/2)
C    X(N/2+2),...,X(N) --- (N/2-1) IMAGINARY PARTS,
C                          I.E., I(1),...,I(N/2-1)
C    DATA STRUCTURE OF "Y(.)" IS THE SAME TO THAT OF "X(.)".
```

```
C. --- REFALF ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "REF" INTO "ALF".
C.     * ARBITRARY MINIMUM PHASE SEQUENCE OF LENGTH "IP"
C.       BY GIVING ARBITRARY "REF" WHICH RANGE BETWEEN -1 AND 1.
C.
C.   CALLING SEQUENCE:
C.          -----------------------
C.          CALL REFALF(IP,REF,ALF)
C.          -----------------------
C.   IP      : INPUT.        INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   REF(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.             PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.             ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.   ALF(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.
C.   NOTE: * ARRAYS "REF" AND "ALF" CAN BE IDENTICAL.
```

```
C. --- REFCOR ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "REF" INTO "COR".
C.       "ALF" IS SIMULTANEOUSLY OBTAINED.
C.     * COMPUTATION OF AUTOCORRELATION COEFFICIENTS "COR"
C.       OF AN AR-PROCESS SPECIFIED BY "REF" (PARCOR).
C.
C.   CALLING SEQUENCE:
C.          -----------------------------------
C.          CALL REFCOR(IP,REF,ALF,COR,N,RESID)
C.          -----------------------------------
C.   IP      : INPUT.        INTEGER.
C.             THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.             THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   REF(.)  : INPUT.        REAL ARRAY : DIMENSION=IP.
C.             PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.             ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.   ALF(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP.
C.             LINEAR PREDICTION COEFFICIENTS; AR PARAMETERS.
C.             ALF(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   COR(.)  : OUTPUT.       REAL ARRAY : DIMENSION=IP
C.             AUTOCORRELATION COEFFICIENTS.
C.             COR(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.   N       : INPUT.        INTEGER.
C.             THE NUMBER OF REQUIRED POINTS OF AUTOCORRELATION.
C.             NOTE THAT THE DEGREE OF FREEDOM REMAINS IP.
C.   RESID   : OUTPUT.       REAL.
C.             LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.             RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.             FILTER.
```

```
C. --- REFJAC ---
C.
C.    DESCRIPTION:
C.      * CONVERSION OF "REF" INTO "JAC".
C.      * CONVERSION OF COEFFICIENTS OF RECURSIVE FORMULAE IN
C.        GRAM-SCHMIDT ORTHOGONALIZATION ON THE UNIT CIRCLE INTO
C.        THOSE ON THE REAL AXIS.
C.
C.    CALLING SEQUENCE:
C.           ----------------------
C.           CALL REFJAC(N,REF,Q,R)
C.           ----------------------
C.    N        : INPUT.         INTEGER.
C.               THE ORDER OF COMPOSITE SINUSOIDAL MODELING (CSM).
C.               THE NUMBER OF SINUSOIDAL COMPONENTS IN CSM.
C.    REF(.)   : INPUT.         REAL ARRAY : DIMENSION=2*N-1.
C.               PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.               ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.    Q(.)     : OUTPUT.        REAL ARRAY : DIMENSION=N.
C.               JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.               ALL OF Q(.) RANGE BETWEEN -1 AND 1.
C.    R(.)     : OUTPUT.        REAL ARRAY : DIMENSION=N-1.
C.               JACOBI COEFFICIENTS; ORTHOGONALIZATION COEFFICIENTS.
C.               ALL OF R(.) RANGE BETWEEN 0 AND 1.
```

```
      SUBROUTINE REFLAR(IP,REF,ZR)
C   REF(I) : PARCOR COEFFICIENTS.
C   ZR(I)  : LOGARITHMIC AREA RATIO. (IMPEDANCE RATIO)
```

```
C. --- REFNRP ---
C.
C.    DESCRIPTION:
C.      * COMPUTE NORMALIZED RESIDUAL POWER
C.        IN BOTH CASES OF VOICED AND UNVOICED
C.        FROM PARCOR COEFFICIENTS PARAMETERS AND PITCH PERIOD.
C.
C.    CALLING SEQUENCE:
C.           --------------------------------
C.           CALL REFNRP(IP,REF,LPITCH,RESID)
C.           --------------------------------
C.
C.    IP       : INPUT.        INTEGER.
C.               THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.               THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.    REF(.)   : INPUT.        REAL ARRAY : DIMENSION=IP.
C.               PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.               ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.    LPITCH   : INPUT.        INTEGER.
C.               PITCH PERIOD. IF LPITCH = 0, IT MEANS UNVOICED SOUND.
C.    RESID    : OUTPUT.       REAL.
C.               LINEAR PREDICTION / PARCOR RESIDUAL POWER;
C.               RECIPROCAL OF POWER GAIN OF PARCOR/LPC/LSP ALL-POLE
C.               FILTER MULTIPLIED BY SIGNAL POWER.
C.               POWER OF SOURCE SIGNAL REQUIRED FOR GETTING SYNTHETIC
C.               SPEECH OF POWER EQUAL TO "COV(1)".
```

```
      SUBROUTINE REFRES(IP,REF,RES)
C    *** CONVERSION OF REFLECTION COEFICIENTS INTO RESIDUAL SEQUENCE **
C         IP         : ORDER OF AR MODEL. (NUMBER OF POLES)
C         REF(I)     : PARCOR PARAMETERS.(ORDER=IP)
C         THE ALGORITHM IS QUITE SIMPLE.
C        CALCULATE THE PRODUCT OF (1.0-REF(I)**2), I=1,...,IP.
C         RES(I)     : NORMALIZED RESIDUAL POWER OF I'TH STAGE.
```

```
C. --- REFSIG ---
C.
C.   DESCRIPTION:
C.     * CONVERSION OF "REF" INTO "SIG".
C.     * SPEECH SYNTHESIZER FILTER WHOSE COEFFICIENTS ARE "REF".
C.     * PARCOR ALL-POLE FILTER.
C.
C.   CALLING SEQUENCE:
C.              ------------------------
C.              REFSIG(IP,CEP,STATE,XIN)
C.              ------------------------
C.   REFSIG   : OUTPUT.        REAL FUNCTION.
C.              SAMPLE OUTPUT OF PARCOR ALL-POLE FILTER.
C.   IP       : INPUT.         INTEGER.
C.              THE ORDER OF ANALYSIS; THE NUMBER OF POLES IN LPC;
C.              THE DEGREE OF FREEDOM OF THE MODEL - 1.
C.   REF(.)   : INPUT.         REAL ARRAY : DIMENSION=IP.
C.              PARCOR COEFFICIENTS; REFLECTION COEFFICIENTS.
C.              ALL OF REF(.) RANGE BETWEEN -1 AND 1.
C.   STATE(.): INPUT/OUTPUT. REAL ARRAY : DIMENSION=IP.
C.              INNER STATE IN THE CEPSTRUM FILTER. LET BE ALL 0
C.              FOR INITIALIZATION.
C.   XIN      : INPUT.         REAL.
C.              FILTER INPUT SAMPLE.
```

```
C********* REORDER BY MAGNITUDE *************
      SUBROUTINE REORD(N,X,Y)
C   X(1),.....,X(N), AND Y(1),.....,Y(N) ARE REORDERED SO THAT
C       X(1)<=X(2)=<X(3)=<.........=<X(N).   ( Y'S ACOMPANY )
```

```
C. --- RFFT ---
C.
C.   DESCRIPTION:
C.     * DESCRETE FOURIER TRANSFORM OF A SET OF REAL DATA.
C.       THE ALGORITHM IS SUGGESTED BY J.W.COOLEY, P.A.W.LEWIS, P.D.WELCH.
C.
C.   CALLING SEQUENCE:
C.          ---------------
C.          CALL RFFT(X,L)
C.          ---------------
C.
C.   X(.)     : INPUT/OUTPUT. REAL ARRAY : DIMENSION=2**L.
C              REAL TYPE DATA ARRAY OF DIMENSION (2**L). (AS INPUT)
C              COMPLEX TYPE TRANSFORMED DATA OF DIMENSION (2**(L-1)+1).(OUT)
C.   L        : INPUT.         INTEGER.
C.             EXPONENT.  I.E., DIMENSION = 2**L.  (NONNEGATIVE)
C              THE DFT OF "X" IS STORED IN X(1),....,X(2**L+2),AS A COMPLEX
C              ARRAY. (2**L+2) POINTS ARE CALCULATED.
```

```
C. --- RRCMX ---
C.
C.   DESCRIPTION:
C.     * TRANSFORM REAL-REAL TO COMPLEX. DATA TYPE CONVERSION.
C.       X ,X ,X ,X ,...,X    ---> X ,X ,X ,X   ,...,X   ,X  .
C.        1  2  3  4      2N        1  N  2  N+1      N-1  2N
C.
C.   CALLING SEQUENCE:
C.           ---------------
C.           CALL RRCMX(X,L)
C.           ---------------
C.
C.   X(.)     : INPUT/OUTPUT. COMPLEX ARRAY: DIMENSION=2**M.
C               INPUT = TWO REAL DATA ARRAYS OF DIMENSION (2**L).
C               OUTPUT= COMPLEX DATA OF DIMENSION (2**L).
C.   L        : INPUT.         INTEGER.
C.              EXPONENT.  I.E., DIMENSION = 2**L.  (NONNEGATIVE)
```

```
C. --- SIGCOR ---
C.
C.    DESCRIPTION:
C.      * CONVERSION OF "SIG" INTO "COR".
C.      * COMPUTATION OF AUTOCORRELATION COEFFICIENTS "COR" FROM
C.        SIGNAL SAMPLES.
C.
C.    CALLING SEQUENCE:
C.            ------------------------------
C.            CALL SIGCOR(N,SIG,VO,COR,LMAX)
C.            ------------------------------
C.    N        : INPUT.        INTEGER.
C                LENGTH OF SAMPLE SEQUENCE.
C.    SIG(.)   : INPUT.        REAL ARRAY : DIMENSION=N.
C.               SIGNAL SAMPLE SEQUENCE.
C.    VO       : OUTPUT.       REAL.
C                POWER. (AVERAGE ENERGY PER SAMPLE).
C.    COR(.)   : OUTPUT.       REAL ARRAY : DIMENSION=LMAX
C.               AUTOCORRELATION COEFFICIENTS.
C.               COR(0) IS IMPLICITLY ASSUMED TO BE 1.0.
C.    LMAX     : INPUT.        INTEGER.
C.               THE NUMBER OF AUTOCORRELATION POINTS REQUIRED.
```

```
      SUBROUTINE SIGDCOR(N,SIG,POW,RHO,LMAX)
C
C        N      : LENGTH OF SAMPLE SEQUENCE.
C        SIG    : SAMPLE SEQUENCE.
C        POW    : POWER. (AVERAGE ENERGY PER SAMPLE).
C        RHO    : AUTOCORRELATION COEFFICIENTS.
C        LMAX   : THE NUMBER OF "RHO" POINTS.
```

```
C. --- VDMOND ---
C.
C.   DESCRIPTION:
C.     * SOLVE VANDER MONDE TYPE LINEAR EQUATIONS.
C.       ALGORITHM DEVELOPED AND CODED BY S.SAGAYAMA.
C.       VAN DER MONDE TYPE EQUATION HAS  THE TYPE AS FOLLOWING:
C        (EXAMPLE, N=4)
C.          ( 1     1     1     1     ) X  ( X1 ) = ( B1 )
C.          ( A1    A2    A3    A4    )    ( X2 )   ( B2 )
C.          ( A1**2 A2**2 A3**2 A4**2 )    ( X3 )   ( B3 )
C.          ( A1**3 A2**3 A3**3 A4**3 )    ( X4 )   ( B4 )
C.     * THE NECESARY AND SUFFICIENT CONDITION FOR EXISTENCE OF
C.       THE SOLUTION IS THAT ALL THE ELEMENTS IN "A(.)" DEFFER
C.       EACH OTHER.
C.
C.   CALLING SEQUENCE:
C.          --------------------
C.          CALL VDMOND(N,A,B,X)
C.          --------------------
C.   N        : INPUT.        INTEGER.
C.              THE DIMENSION OF VAN DER MONDE MATRIX.
C.   A(.)     : INPUT.        REAL ARRAY : DIMENSION=N.
C.              ELEMENTS OF VAN DER MONDE MATRIX.
C.   B(.)     : INPUT.        REAL ARRAY : DIMENSION=N.
C.              ELEMENTS OF RIGHT HAND VECTER.
C.   X(.)     : OUTPUT.       REAL ARRAY : DIMENSION=N.
C.              SOLUTION.
```

```
      SUBROUTINE WINDOW(N,X,W,Y)
C    ***** WINDOWING *****
C     Y(I)=X(I)*W(I), FOR I=1,...,N
C
C    X(.) : ORIGINAL DATA. (REAL)
C    W(.) : WINDOW DATA. (REAL)
C    Y(.) : WINDOWED DATA. (REAL)
```

```
C*************************************************
C     COMPUTE AUTOCORRELATION FROM SAMPLE SEQUENCE.
C*************************************************
      SUBROUTINE XXCOR(N,XX,VO,RHO,LMAX)
C
C      N      : LENGTH OF SAMPLE SEQUENCE.
C      XX     : SAMPLE SEQUENCE.
C      VO     : POWER. (AVERAGE ENERGY PER SAMPLE).
C      RHO    : AUTOCORRELATION COEFFICIENTS.
C      LMAX   : THE NUMBER OF "RHO" POINTS.
```

編集
ＡＴＲ視聴覚機構研究所
赤木　正人
（ｅｘ．６４７）

```c
/*--------------------------------------------------*/
/*      test program for libana_c.a                 */
/*              programed by M. Akagi, 1987.3.30    */
/*                                                  */
/* This program is a test program which obtains the */
/* LPC-cepstrum from wave signal.                   */
/*--------------------------------------------------*/

#include <stdio.h>
#include <math.h>
#include "/usr/lib/io.h"

main()
{
       int    _n=0;

       FILE  *ftpi , *ftpo , *fopen();

       int   m=10,n=256,nfast=8;
       short       ixb[256];
       double      x[256],alf[12],cor[12],cep[12],xi[256],
             vr,res;
       double      wdata[256];
       char  sname[80],fname[80];
       int   iframe,i,er;

       HAMWDW(_n,wdata,&n);

       printf("Input data name   \n");
       gets( sname );
       printf("output data name   \n");
       gets( fname );

       ftpi = fopen(sname,"r");
       ftpo = fopen(fname,"w");

       for( iframe = 0 ; iframe < 30000 ; iframe++) {
             er = ex_getsig(ftpi,iframe,n,nfast,ixb);
             if ( er == 0 ) exit();
             for(i=0;i<n;i++)
                   x[i] = wdata[i] * (float)ixb[i];
             SIGCOR(_n,&n,x,&vr,cor,&m);
             CORALF(_n,&m,cor,alf,&res);
             ALFCEP(_n,&m,alf,cep,&m);
             for(i=0;i<m-1;i++)
                   fprintf(ftpo,"%18.4f",cep[i]);
             fprintf(ftpo,"%18.4f\n",cep[m-1]);
       }
}
```