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FORTRAN PROGRAM FOR LINEAR PREDICTIVE SPECTRAL ANALYSIS OF UNIV--ETC(U)
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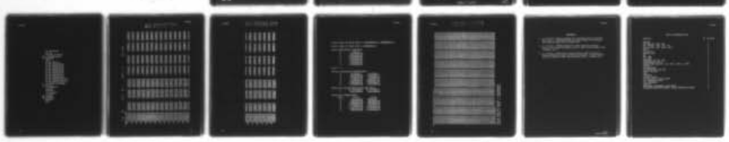

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NUSC Technical Document 5831

FORTRAN Program for Linear Predictive Spectral Analysis of Univariate Complex Data With Disjoint Equi-Sized Pieces

Albert H. Nuttall
Special Projects Department

12 December 1977

NUSC

NAVAL UNDERWATER SYSTEMS CENTER
Newport, Rhode Island • New London, Connecticut

PREFACE

This research was conducted under NUSC Project No. A-752-05, "Applications of Statistical Communication Theory to Acoustical Signal Processing," Principal Investigator, Dr. A. H. Nuttall (Code 313), Navy Subproject and Task No. ZR-00-001, Program Manager, J. H. Probus (MAT 035), Naval Material Command.

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REPORT DOCUMENTATION PAGE

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Linear Prediction
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Spectral Analysis
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Linear Predictive Beamforming

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A FORTRAN program for linear predictive spectral analysis of univariate complex data with disjoint equi-sized pieces is presented. This result has application to data taken with a device that periodically goes off-line, and to maximum entropy beamforming on a limited number of equi-spaced linear array elements.

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FORTRAN PROGRAM FOR LINEAR PREDICTIVE SPECTRAL ANALYSIS OF UNIVARIATE COMPLEX DATA WITH DISJOINT EQUI-SIZED PIECES

INTRODUCTION

In reference 1, the theoretical basis for estimating spectra via linear predictive techniques from univariate complex data with bad data points was presented. Also, a program was given there for spectral analysis of real data with gaps. Later, in reference 2, a program for complex data with no bad data points was presented. However, neither program is capable of handling complex data with gaps. This present document remedies this situation for the case where the disjoint pieces of complex data each have the same number of points.

Complex data can arise when a real process is complex-demodulated to zero frequency and sampled at a low rate for purposes of ease of processing and computation. Alternatively, if a real process is subjected to Fourier transformation into the frequency domain, complex coefficients result. Both of these examples are of frequent occurrences in practical applications.

Data segments of equal length can occur, for example, when a recording device is periodically taken off-line (for calibration purposes, perhaps), or if large periodic bursts of noise occur. An important frequency-domain application occurs for an equi-spaced line array of limited extent. Then the number of elements in the array is the maximum size of each disjoint piece of frequency coefficients. If, for a particular time segment of array outputs, we look at the Fourier coefficients at one frequency, we can attempt linear prediction in space; averaging the prediction error over time then yields the extrapolation effect inherent in maximum entropy processing (see reference 3). This will result in the array appearing to have a longer length than its true length, and thereby yield improved angular resolution of plane-wave arrivals. This approach is analogous to the improved frequency resolution obtainable from limited time data.

The input parameters to the program are fully explained in the comment statements. For a single piece of data, the number of disjoint pieces, ND, can be set equal to 1. A sample run is presented after the program. For application to linear predictive beamforming, delete the statement

```
X(I, J) = X(I, J) - AVE
```

in loop 3 of SUBROUTINE CXDISJ.

```
C  LINEAR PREDICTIVE SPECTRAL ANALYSIS FOR UNIVARIATE
C       COMPLEX DATA WITH DISJOINT EQUI-SIZED PIECES
C  EQUATION REFERENCES ARE TO NUTTALL, NUSC TR 5303, 26 MARCH 1976
C  USER: CHANGE LINES 26 AND 40, AND REPLACE SUBROUTINE DATA
C  N = NUMBER OF COMPLEX DATA POINTS IN EACH PIECE; INTEGER INPUT
C  ND = NUMBER OF DISJOINT PIECES; INTEGER INPUT
C  X(1,1)...X(N,1),...,X(1,ND)...X(N,ND) = COMPLEX INPUT DATA;
C       ALTERED ON OUTPUT
C  PMAX = MAXIMUM ORDER OF FILTER; PMAX.LT.N; INTEGER INPUT
C  NF = SIZE OF FFT (MUST BE A POWER OF 2 TO USE MKLFFT); INTEGER INPUT
C  AVE = COMPLEX SAMPLE MEAN OF INPUT DATA; OUTPUT
C  P0 = SAMPLE POWER OF INPUT DATA; OUTPUT
C  AIC = AKAIKE'S INFORMATION CRITERION; OUTPUT
C  PBEST = BEST ORDER OF FILTER; INTEGER OUTPUT
C  SPBEST = (EQ H-7)/NF  FOR P=PBEST; OUTPUT
C  SPMAX = (EQ H-7)/NF  FOR P=PMAX; OUTPUT
C  A(1),...,A(PBEST) = COMPLEX PREDICTIVE FILTER COEFFICIENTS =
C       A(1;PBEST),...,A(PBEST;PBEST); OUTPUT
C  RHO(1),...,RHO(PMAX) = COMPLEX NORMALIZED CORRELATIONS; OUTPUT
C  XX(1),...,XX(NF) = SCALED SPECTRUM, WHOSE SUM = SAMPLE POWER; OUTPUT
C  COSI(1),...,COSI(NF/4+1) = QUARTER COSINE TABLE FOR FFT PURPOSES
C  Y(N,ND) IS A REQUIRED COMPLEX AUXILIARY ARRAY
C  YY(NF) IS A REQUIRED AUXILIARY ARRAY
C  ON OUTPUT, X(1,1),...,X(PMAX,1) = A(1;PMAX),...,A(PMAX;PMAX)
C  ON OUTPUT, Y(1,1),...,Y(PMAX,1) = A(1;1),...,A(PMAX;PMAX)
      PARAMETER N =  10, ND = 20, PMAX =  6, NF = 512, NF41=NF/4+1
      INTEGER PBEST,P
      REAL SPBEST,T1,T2
      COMPLEX X(N,ND),Y(N,ND),A(PMAX),RHO(PMAX),AVE,G,T
      DIMENSION XX(NF),YY(NF),COSI(NF41),AIC(PMAX),AIC0(2)
      EQUIVALENCE (AIC(1),AIC0(2))
C  PRINT OUT VALUES OF PARAMETERS
      I=N
      J=ND
      K=PMAX
      L=NF
```

```
      PRINT 1, I,J,K,L
1     FORMAT(1H1,' N =',I6,10X,'ND =',I6,10X,'PMAX =',I4,10X,'NF =',I5)
C  COMPLEX INPUT DATA IN X(1,1)...X(N,1),...,X(1,ND)...X(N,ND)
      CALL DATA
      PRINT 2
2     FORMAT(/' COMPLEX INPUT DATA:')
      DO 3 J=1,ND
      PRINT 34, J
34    FORMAT('    PIECE NUMBER',I3)
3     PRINT 4, (X(I,J), I=1,N)
4     FORMAT(4(E18.8,E15.8))
C  EVALUATE FILTER COEFFICIENTS
      CALL CXDISJ
      PRINT 5, AVE
5     FORMAT(/' COMPLEX MEAN OF INPUT DATA = (',E13.8,',',E13.8,')')
      PRINT 6, P0
6     FORMAT(/' SAMPLE POWER OF INPUT DATA =',E13.8)
      PRINT 7
7     FORMAT(/' AKAIKE INFORMATION CRITERION:'/9X,'P',11X,'AIC(P)')
      PRINT 8, (P,AIC(P), P=0,IA)
8     FORMAT(I10,E20.8)
      PRINT 9, PBEST
9     FORMAT(/' PBEST =',I3)
      PRINT 10
10    FORMAT(/' PARTIAL CORRELATION COEFFICIENTS:'/
     $9X,'P',9X,'RE A(P;P)',7X,'IM A(P;P)')
      PRINT 11, (P,Y(P,1), P=1,IA)
11    FORMAT(I10,E20.8,E16.8)
      IF(PBEST.EQ.0) GO TO 12
      PRINT 13
13    FORMAT(/' PREDICTIVE FILTER COEFFICIENTS FOR PBEST:'/
     $9X,'K',7X,'RE A(K;PBEST)',3X,'IM A(K;PBEST)')
      PRINT 11, (P,A(P), P=1,PBEST)
```

```
12     PRINT 14
14     FORMAT(/' NORMALIZED CORRELATIONS:'/
      $7X,'DELAY',9X,'RE RHO',10X,'IM RHO')
       P=0
       T=(1.,0.)
       PRINT 11, P,T
       PRINT 11, (P,RHO(P), P=1,IA)
C   EVALUATE SPECTRAL ESTIMATE
       CALL SPECT
       PRINT 15
15     FORMAT(/' POWER SPECTRUM, STARTING FROM ZERO FREQUENCY (BIN 1):')
       PRINT 16, (XX(I), I=1,NF)
16     FORMAT(2X,10E13.8)
       PRINT 17, SUM
17     FORMAT(/' SUM OF SPECTRUM VALUES =',E13.8)
       PRINT 18, P0
18     FORMAT(' SAMPLE POWER OF INPUT  =',E13.8)
C
       SUBROUTINE DATA
C   THIS SUBROUTINE GENERATES COMPLEX DATA
       DEFINE IRAND=I*5**15+((1-SIGN(1,I*5**15))/2)*34359738367
       DEFINE RAND=FLOAT(I)/34359738367.
       I=5281
       G=(.65,.65)
       DO 1 J=1,ND
       T=(0.,0.)
       DO 2 K=1,200      @ WILL DISCARD THESE INITIAL POINTS
       I=IRAND
       T1=RAND-.5
       I=IRAND
       T2=RAND-.5
2      T=G*T+CMPLX(T1,T2)
       DO 3 K=1,N
       I=IRAND
       T1=RAND-.5
       I=IRAND
```

```
      T2=RAND-.5
      T=G*T+CMPLX(T1,T2)
3     X(K,J)=T
1     CONTINUE
      RETURN
C
      SUBROUTINE CXDISJ
C   THIS SUBROUTINE COMPUTES AIC, PBEST, ALL THE FILTER
C   COEFFICIENTS, AND THE NORMALIZED CORRELATIONS
      DOUBLE PRECISION SAR,SAI,SB
      I=N
      K=PMAX
      IA=N-1
      IF(PMAX.GE.N) PRINT 1, K,I,IA
1     FORMAT(/' PMAX =',I4,' IS TOO LARGE FOR NUMBER OF DATA',
     $' POINTS N =',I5,';  SEARCH LIMITED TO P =',I4)
      IA=MIN(IA,PMAX)
      FAC=4./(N*ND)     @ FAC=0. WOULD FORCE PBEST EQUAL TO IA
C   COMPUTE SAMPLE MEAN
      AVE=(0.,0.)
      DO 2 J=1,ND
      DO 2 I=1,N
2     AVE=AVE+X(I,J)
      AVE=CMPLX(REAL(AVE)/(N*ND),AIMAG(AVE)/(N*ND))
C   SUBTRACT SAMPLE MEAN AND COMPUTE SAMPLE POWER
      P0=0.
      DO 3 J=1,ND
      DO 3 I=1,N
      X(I,J)=X(I,J)-AVE     @ TO KEEP SAMPLE MEAN, DELETE THIS CARD
      Y(I,J)=X(I,J)
3     P0=P0+REAL(X(I,J))**2+AIMAG(X(I,J))**2
      P0=P0/(N*ND)
C   BEGIN RECURSION
      AIC(0)=LOG(P0)
      AICMIN=AIC(0)
      PBEST=0
```

```
      SPMAX=P0/NF
      SPBEST=SPMAX
      DO 4 P=1,IA
C   CALCULATE CROSS-GAIN; EQ 155
      SAR=0.D0
      SAI=0.D0
      SB=0.D0
      L=P+1
      DO 5 J=1,ND
      DO 5 I=L,N
      T1=REAL(X(I,J))
      T2=AIMAG(X(I,J))
      T3=REAL(Y(I-1,J))
      T4=AIMAG(Y(I-1,J))
      SAR=SAR+T1*T3+T2*T4
      SAI=SAI+T2*T3-T1*T4
5     SB=SB+T1**2+T2**2+T3**2+T4**2
      T1=2.*SAR/SB
      T2=2.*SAI/SB
      G=CMPLX(T1,T2)
C   CALCULATE FILTER COEFFICIENTS; EQS 160&148. STORE IN X(1,1)...X(P,1)
      X(P,1)=G
      IF(P.EQ.1) GO TO 6
      L=P/2
      DO 7 I=1,L
      T=X(I,1)-G*CONJG(X(P-I,1))
      X(P-I,1)=X(P-I,1)-G*CONJG(X(I,1))
7     X(I,1)=T
C   CALCULATE NORMALIZED CORRELATION; EQ 149
6     T=X(P,1)
      IF(P.EQ.1) GO TO 8
      L=P-1
      DO 9 I=1,L
9     T=T+X(I,1)*RHO(P-I)
8     RHO(P)=T
```

```
C   CALCULATE AKAIKÉ'S INFORMATION CRITERION
        T1=1.D0-4.D0*(SAR**2+SAI**2)/SB**2
        SPMAX=SPMAX*T1
        AIC(P)=LOG(SPMAX)+FAC*P
        IF(AIC(P).GE.AICMIN) GO TO 10
        AICMIN=AIC(P)
        PBEST=P
        SPBEST=SPMAX
        DO 11 I=1,P
11      A(I)=X(I,1)
10      IF(P.EQ.IA) GO TO 12
C   UPDATE FORWARD AND BACKWARD SEQUENCES; EQ 153
        L=P+1
        DO 13 J=1,ND
        DO 13 I=N,L,-1
        T=X(I,J)-G*Y(I-1,J)
        Y(I,J)=Y(I-1,J)-CONJG(G)*X(I,J)
13      X(I,J)=T
4       Y(P,1)=G
12      Y(IA,1)=G
        IF(PBEST.EQ.IA) GO TO 14
C   COMPUTE EXTRAPOLATED NORMALIZED CORRELATION
C   COEFFICIENTS FROM PBEST+1 TO PMAX; EQ 165
        L=PBEST+1
        DO 15 P=L,IA
        A(P)=(0.,0.)
        T=(0.,0.)
        DO 16 I=1,PBEST
16      T=T+A(I)*RHO(P-I)
15      RHO(P)=T
14      RETURN
C
```

```
      SUBROUTINE SPECT
C   THIS SUBROUTINE COMPUTES THE POWER SPECTRUM FOR PBEST; IT IS SCALED
C   SUCH THAT THE SUM OF VALUES COMPUTED SHOULD EQUAL THE SAMPLE POWER
      XX(1)=1.
      YY(1)=0.
      IF(PBEST.EQ.0) GO TO 1
      DO 2 I=1,PBEST
      XX(I+1)=-REAL(A(I))
2     YY(I+1)=-AIMAG(A(I))
1     L=PBEST+2
      DO 3 I=L,NF
      XX(I)=0.
3     YY(I)=0.
      CALL QTRCOS(COSI,NF)
      L=1.4427*LOG(NF)+.5     @ LOG2(NF)
      CALL MKLFFT(XX,YY,COSI,L,-1)
      SUM=0.
      DO 4 I=1,NF
      XX(I)=SPBEST/(XX(I)**2+YY(I)**2)
4     SUM=SUM+XX(I)
      RETURN
      END

      SUBROUTINE QTRCOS(C,N)
      DIMENSION C(1)
      N41=N/4+1
      SCL=6.283185307/N
      DO 1 I=1,N41
1     C(I)=COS((I-1)*SCL)
      RETURN
      END
```

```
      SUBROUTINE MKLFFT(X,Y,CC,M,ISN)
      DIMENSION X(1),Y(1),CC(1),L(12)
      EQUIVALENCE (L12,L(1)),(L11,L(2)),(L10,L(3)),(L9,L(4)),(L8,L(5)),
     1(L7,L(6)),(L6,L(7)),(L5,L(8)),(L4,L(9)),(L3,L(10)),(L2,L(11)),
     2(L1,L(12))
      N=2**M
      ND4=N/4
      ND4P1=ND4+1
      ND4P2=ND4P1+1
      ND2P2=ND4+ND4P2
      DO 8 LO=1,M
      LMX=2**(M-LO)
      LIX=2*LMX
      ISCL=N/LIX
      DO 8 LM=1,LMX
      IARG=(LM-1)*ISCL+1
      IF(IARG.LE.ND4P1) GO TO 4
      C=-CC(ND2P2-IARG)
      S=ISN*CC(IARG-ND4)
      GO TO 6
    4 C=CC(IARG)
      S=ISN*CC(ND4P2-IARG)
    6 DO 8 LI=LIX,N,LIX
      J1=LI-LIX+LM
      J2=J1+LMX
      T1=X(J1)-X(J2)
      T2=Y(J1)-Y(J2)
      X(J1)=X(J1)+X(J2)
      Y(J1)=Y(J1)+Y(J2)
      X(J2)=C*T1-S*T2
      Y(J2)=C*T2+S*T1
    8 CONTINUE
```

```
      DO 40 J=1,12
      L(J)=1
      IF(J-M) 31,31,40
31    L(J)=2**(M+1-J)
40    CONTINUE
      JN=1
      DO 60 J1=1,L1
      DO 60 J2=J1,L2,L1
      DO 60 J3=J2,L3,L2
      DO 60 J4=J3,L4,L3
      DO 60 J5=J4,L5,L4
      DO 60 J6=J5,L6,L5
      DO 60 J7=J6,L7,L6
      DO 60 J8=J7,L8,L7
      DO 60 J9=J8,L9,L8
      DO 60 J10=J9,L10,L9
      DO 60 J11=J10,L11,L10
      DO 60 JR=J11,L12,L11
      IF(JN-JR) 51,51,52
51    R=X(JN)
      X(JN)=X(JR)
      X(JR)=R
      FI=Y(JN)
      Y(JN)=Y(JR)
      Y(JR)=FI
52    JN=JN+1
60    CONTINUE
      RETURN
      END
```

N = 10 ND = 20 PMAX = 6 NF = 512

COMPLEX INPUT DATA:

PIECE NUMBER 1							
.78179665+00	-.13473221+00	.91175924+00	.79477704+00	-.73324665-01	.12844565+01	-.11577945+01	.11171143+01
-.14566336+01	.12610591+00	-.13632712+01	-.43609920+00	-.10733597+01	-.11784904+01	.29585904+00	-.19085833+01
.13352177+01	-.79239590+00	.12376685+01	.64721197+00				
PIECE NUMBER 2							
.11332010+01	-.26430399+00	.55259556+00	.72106371+00	-.81438374-01	.12167038+01	-.10167439+01	.71039209+00
-.15673967+01	.43117464-01	-.82297912+00	-.77447465+00	.40224393+00	-.65631546+00	.45461970+00	-.54474910+00
.91660022+00	-.21089549+00	.54640821+00	.32481581-01				
PIECE NUMBER 3							
-.20974729+00	.19422616+01	-.17387798+01	.90273482+00	-.18141863+01	-.94451893+00	-.30581551+00	-.20339620+01
.12562732+01	-.11315998+01	.15128666+01	-.88509582-01	.86614962+00	.79080727+00	.10246997+00	.12318436+01
-.10378185+01	.48266359+00	-.71595875+00	-.54196951+00				
PIECE NUMBER 4							
.29159645+00	-.60064784+00	.19514039+00	.63291796-01	.13063908+00	.42878218+00	.20501007+00	.12341607+00
-.28323410+00	.78512141-01	-.39688541+00	.24598397+00	-.79453560+00	.10550434+00	-.23329240+00	-.85472570+00
.22314303+00	-.62218527+00	.24806003+00	.10142199+00				
PIECE NUMBER 5							
-.20801926+00	-.30662629+00	-.35465565+00	-.83007358-01	-.66927405-01	-.40945193+00	-.20179069+00	-.42154290-01
-.57830662-02	-.68790219-01	-.94798762-01	.29153705+00	-.80773551-01	-.79856379-01	-.44806718+00	-.29088007+00
-.13452530-01	-.93537965+00	.40488669+00	-.95540518+00				
PIECE NUMBER 6							
.17218950+00	-.65974023-01	-.79014245-02	.25015209-01	.21804274+00	.51157535-02	-.96013829-01	.26044519+00
-.71103991+00	-.33209670+00	-.49981873+00	-.11481491+01	.62641018+00	-.83327153+00	.14140112+01	.21704614-01
.62734874+00	.79922871+00	.27666922+00	.78669868+00				
PIECE NUMBER 7							
.11510527+01	.54276705-01	.58140152+00	.93847227+00	-.66690786+00	.86015029+00	-.73086809+00	-.86459746+00
-.64370962+00	-.58570363+00	-.27047141+00	-.52534746+00	.58597321+00	-.86707368-01	.93955625-01	-.15504469+00
.14438601-01	.44340446+00	-.34400214+00	.63906249+00				
PIECE NUMBER 8							
.13496244+00	-.75098439+00	.10333682+01	-.86444205+00	.97059333+00	.52011482+00	.59472539+00	.49431938+00
-.36497236+00	.10547157+01	-.93945137+00	.10380917+00	-.91379473+00	-.42669432+00	-.18722379+00	-.37276956+00
-.11195991-01	-.88680071+00	.49649345+00	-.36528616+00				
PIECE NUMBER 9							
-.10065941+01	.94296839+00	-.15696406+01	-.11302456+00	-.72370524+00	-.74474177+00	-.47985520+00	-.11506315+01
.88369716+00	-.12251202+01	.97190903+00	.95030881-01	.94605697+00	.69624466+00	-.86198591-01	.10959104+01
-.12552212+01	.52010719+00	-.78070377+00	-.76042433+00				
PIECE NUMBER 10							
.59747136+00	-.66081142+00	.76821736+00	.18528160-01	.86270748+00	.94292811+00	.46636887-01	.88803598+00
-.50259961+00	.74973759+00	-.92177460+00	-.16890464+00	-.86968745+00	-.11060396+01	.13223359+00	-.15106595+01
.64260341+00	-.12179394+01	.93757443+00	-.75322718+00				
PIECE NUMBER 11							
-.38820872+00	-.11217043+01	.13663010+00	-.14151449+01	.13502169+01	-.99899189+00	.16654283+01	.58600654+00
.95771126+00	.10737971+01	-.33872129+00	.12169289+01	-.69117308+00	.71234285+00	-.88052989+00	.37664675+00
-.47986308+00	-.47591610+00	-.66614524-03	-.61115903+00				
PIECE NUMBER 12							
-.32393172+00	.33630645-02	-.20067292-01	-.22192607-01	.16409889+00	-.11897600+00	.30094717+00	-.44780656+00
.30075851+00	.13835477+00	.59532265+00	.70466849+00	-.14434419+00	.80802769+00	-.30029416+00	.17949965+00
-.60836662+00	-.17663715+00	.17912702+00	-.81162749+00				
PIECE NUMBER 13							
-.69681304+00	.58895409-01	-.36490205+00	-.31849011+00	.17428869+00	-.79803237+00	.77483299+00	-.37703039+00
.10067036+01	.66035509+00	.50991943+00	.15263156+01	-.70256947+00	.13391371+01	-.18118857+01	.27550454+00
-.11277604+01	-.11400890+01	-.31837910-01	-.16151142+01				
PIECE NUMBER 14							
-.14113171+01	.70875198+00	-.11824463+01	-.89490756+00	-.54543891+00	-.11191288+01	.86943594+00	-.12755366+01

.16469397+01	-.23764174+00	.95826184+00	.13901152+01	-.57977370+00	.16310306+01	-.10939529+01	.11660108+01
-.18861564+01	.38543141+00	-.18858373+01	-.49560507+00				
PIECE NUMBER 15							
.60163277+00	-.42241290+00	.31770632+00	.23912543+00	.39765580+00	.68361654+00	-.21587892+00	.81494974+00
-.11472579+01	.14176743+00	-.67330626+00	-.20529961+00	-.53543907+00	-.83429800+00	-.95036000-01	-.11436281+01
.21277203+00	-.96330317+00	.65743535+00	-.79990137-01				
PIECE NUMBER 16							
.10566945+01	.27903251+00	.99693389+00	.60340144+00	.41527621+00	.76089010+00	-.20181691+00	.11310237+01
-.10549279+01	.67854162+00	-.87676667+00	.21613240-01	-.83969749+00	-.55853747-01	-.10052471+01	-.53561554+00
-.15467420-01	-.65551642+00	.59143156-02	-.57087187+00				
PIECE NUMBER 17							
.10493477+01	-.19437459+01	.15066916+01	-.22291129+00	.12641892+01	.10802875+01	.56007403+00	.17893214+01
-.52240155+00	.18195128+01	-.14016637+01	.11676370+01	-.19123484+01	-.10352052+00	-.12321000+01	-.10844272+01
-.36243496+00	-.11228506+01	.84842874+00	-.53706481+00				
PIECE NUMBER 18							
.45137654+00	.41741937+00	.20048324+00	.16854444+00	.67059243-01	.41747948-01	-.23516455+00	-.17003797-01
-.26300296+00	.23306390+00	-.52246249+00	-.19265532+00	.26383080+00	-.57428315+00	.58749575+00	-.14744150+00
.30005418-01	.21482679+00	-.33733936+00	-.20330464+00				
PIECE NUMBER 19							
.51305314+00	-.22316602+00	.16167243+00	.42525277+00	-.34921423+00	-.67448094-02	.10779265+00	-.37363409+00
-.33143267-01	-.11117243+00	-.93226558-01	.15622764+00	-.54321118+00	.33674223+00	-.23450789+00	-.66812098-02
-.61086610-01	-.60886294+00	.72194413+00	.23158181-01				
PIECE NUMBER 20							
-.14456953+01	-.34647398+00	-.10941341+01	-.77361000+00	-.51200870+00	-.12565580+01	.85522581+00	-.10987851+01
.94514240+00	-.47585902+00	.13064936+01	.35008654+00	.30477042+00	.84845689+00	-.68216474+00	.11969178+01
-.10259822+01	.69469662+00	-.12542500+01	-.21400730+00				

COMPLEX MEAN OF INPUT DATA = (-.66319221-01,-.40282205-01)

SAMPLE POWER OF INPUT DATA = .12248106+01

AKAIKE INFORMATION CRITERION:

P	AIC(P)
0	.20278620+00
1	-.80169810+01
2	-.80072850+01
3	-.79875959+01
4	-.79702957+01
5	-.79654503+01
6	-.79519050+01

PBEST = 1

PARTIAL CORRELATION COEFFICIENTS:

P	RE A(P;P)	IM A(P;P)
1	.65607898+00	.65910558+00
2	.71265785-01	.71918564-01
3	.11103264-01	.13693754-01
4	.44373563-01	-.26964517-01
5	-.73896198-01	-.97876096-01
6	.20138093-03	.80211493-01

PREDICTIVE FILTER COEFFICIENTS FOR PBEST:

K	RE A(K;PBEST)	IM A(K;PBEST)
1	.65607898+00	.65910558+00

NORMALIZED CORRELATIONS:

DELAY	RE RHO	IM RHO
0	.10000000+01	.00000000
1	.65607898+00	.65910558+00
2	-.39805360-02	.86485063+00
3	-.57263941+00	.56478672+00
4	-.74795075+00	-.68851300-02
5	-.48617674+00	-.49749569+00
6	.89318492-02	-.64683826+00

POWER SPECTRUM, STARTING FROM ZERO FREQUENCY (BIN 1):

.56491481-03	.60243930-03	.62080778-03	.64007498-03	.66030012-03	.68154740-03	.70388649-03	.72739300-03	.75214927-03	.77824492-03
.80577780-03	.83485474-03	.86559274-03	.89611995-03	.93257718-03	.96911917-03	.10079164-02	.10491573-02	.10930500-02	.11398251-02
.11897391-02	.12430769-02	.13001568-02	.13613342-02	.14270078-02	.14976053-02	.15735013-02	.16557756-02	.17445241-02	.18406704-02
.19450512-02	.20586234-02	.21824849-02	.23179007-02	.24663340-02	.26294820-02	.28093250-02	.30081804-02	.32287751-02	.34743310-02
.37486775-02	.40563864-02	.44029484-02	.47649959-02	.52405895-02	.57495792-02	.63340942-02	.70091470-02	.77934490-02	.87108623-02
.97097668-02	.11068329-01	.12595216-01	.14429301-01	.16647274-01	.19343543-01	.22633087-01	.26643766-01	.31501595-01	.37288840-01
.43934124-01	.51105299-01	.58006966-01	.63382289-01	.65869310-01	.64715214-01	.60279295-01	.53784291-01	.46593983-01	.39687610-01
.33561046-01	.28360482-01	.24045614-01	.20501311-01	.17596808-01	.15211498-01	.13243308-01	.11609779-01	.10243758-01	.90084131-02
.81203794-02	.72893508-02	.65757459-02	.59592134-02	.54234592-02	.49553538-02	.45442558-02	.41814812-02	.38598299-02	.35736221-02
.33177534-02	.30882048-02	.28815402-02	.26949587-02	.25256980-02	.23719590-02	.22318443-02	.21038074-02	.19865133-02	.18788046-02
.17796740-02	.16882422-02	.16037385-02	.15254861-02	.14528874-02	.13854150-02	.13226006-02	.12640278-02	.12093257-02	.11581624-02
.11102419-02	.10652964-02	.10230866-02	.98339590-03	.94602897-03	.91080085-03	.87757500-03	.84618166-03	.81649600-03	.78839708-03
.76177431-03	.73652663-03	.71256144-03	.68979372-03	.66814543-03	.64754476-03	.62792550-03	.60922660-03	.59139173-03	.57436872-03
.55810929-03	.54256873-03	.52770550-03	.51348106-03	.49985949-03	.48680746-03	.47429381-03	.46228958-03	.45076763-03	.43970268-03
.42907101-03	.41865051-03	.40902036-03	.39956114-03	.39045454-03	.38168343-03	.37323166-03	.36508407-03	.35722636-03	.34964511-03
.34232762-03	.33526193-03	.32843674-03	.32184143-03	.31546598-03	.30930058-03	.30333650-03	.29756512-03	.29197833-03	.28656847-03
.28132827-03	.27625083-03	.27132959-03	.26655833-03	.26193113-03	.25744237-03	.25308669-03	.24885900-03	.24475443-03	.24076838-03
.23689643-03	.23313437-03	.22947821-03	.22592411-03	.22246841-03	.21910763-03	.21583843-03	.21265761-03	.20956214-03	.20654909-03
.20361566-03	.20075918-03	.19797710-03	.19526694-03	.19262636-03	.19005312-03	.18754503-03	.18510003-03	.18271611-03	.18039137-03
.17812397-03	.17591214-03	.17375418-03	.17164848-03	.16959344-03	.16758758-03	.16562942-03	.16371759-03	.16185072-03	.16002753-03
.15824677-03	.15650724-03	.15480778-03	.15314727-03	.15152463-03	.14993884-03	.14838888-03	.14687379-03	.14539263-03	.14394452-03
.14252657-03	.14114395-03	.13978985-03	.13846548-03	.13717009-03	.13590294-03	.13466333-03	.13345058-03	.13226402-03	.13110301-03
.12996694-03	.12885520-03	.12776722-03	.12670243-03	.12566029-03	.12464028-03	.12364189-03	.12266462-03	.12170799-03	.12077155-03
.11985484-03	.11895742-03	.11807889-03	.11721882-03	.11637683-03	.11555253-03	.11474554-03	.11395551-03	.11318208-03	.11242492-03
.11168369-03	.11095808-03	.11024777-03	.10955247-03	.10887198-03	.10820572-03	.10755371-03	.10691559-03	.10629108-03	.10567996-03
.10508197-03	.10449686-03	.10392442-03	.10336442-03	.10281664-03	.10228087-03	.10175690-03	.10124454-03	.10074360-03	.10025390-03
.99775197-04	.99307387-04	.98850272-04	.98403685-04	.97967463-04	.97541456-04	.97125505-04	.96719465-04	.96323190-04	.95936542-04
.95559391-04	.95191598-04	.94833040-04	.94483595-04	.94143144-04	.93811568-04	.93488758-04	.93174604-04	.92869001-04	.92571848-04
.92283046-04	.92002500-04	.91730118-04	.91465809-04	.91209489-04	.90961076-04	.90720489-04	.90487648-04	.90262479-04	.90044913-04
.89834860-04	.89632314-04	.89437148-04	.89249321-04	.89068779-04	.88895459-04	.88729310-04	.88570280-04	.88418321-04	.88273385-04
.88135425-04	.88004402-04	.87880275-04	.87763004-04	.87652553-04	.87548890-04	.87451985-04	.87361806-04	.87278325-04	.87201517-04
.87131361-04	.87067835-04	.87010919-04	.86960594-04	.86916848-04	.86879667-04	.86849038-04	.86824954-04	.86807408-04	.86796393-04
.86791903-04	.86793942-04	.86802508-04	.86817607-04	.86839237-04	.86867411-04	.86902134-04	.86943417-04	.86991271-04	.87045714-04
.87106760-04	.87174428-04	.87248737-04	.87329712-04	.87417377-04	.87511758-04	.87612881-04	.87720780-04	.87835480-04	.87957043-04
.88085475-04	.88220827-04	.88363143-04	.88512465-04	.88668835-04	.88832308-04	.89002933-04	.89180759-04	.89365848-04	.89558253-04
.89758039-04	.89965265-04	.90179996-04	.90402303-04	.90632258-04	.90869931-04	.91115400-04	.91368744-04	.91630040-04	.91899391-04
.92176865-04	.92462561-04	.92756571-04	.93058992-04	.93369927-04	.93689478-04	.94017755-04	.94354866-04	.94700921-04	.95056047-04
.95420361-04	.95793988-04	.96177058-04	.96569705-04	.96972068-04	.97384285-04	.97806595-04	.98238876-04	.98681558-04	.99134704-04
.99598483-04	.10007307-03	.10055862-03	.10105534-03	.10156339-03	.10208298-03	.10261431-03	.10315756-03	.10371295-03	.10428070-03
.10486103-03	.10545416-03	.10606033-03	.10667978-03	.10731277-03	.10795954-03	.10862036-03	.10929550-03	.10998526-03	.11068990-03
.11140974-03	.11214507-03	.11289622-03	.11366351-03	.11444727-03	.11524786-03	.11606562-03	.11690094-03	.11775419-03	.11862574-03
.11951603-03	.12042545-03	.12135444-03	.12230344-03	.12327292-03	.12426333-03	.12527518-03	.12630805-03	.12736518-03	.12844480-03
.12954716-03	.13067404-03	.13182563-03	.13300253-03	.13420538-03	.13543484-03	.13669158-03	.13797629-03	.13928970-03	.14063256-03
.14200565-03	.14340975-03	.14484570-03	.14631436-03	.14781662-03	.14935339-03	.15092562-03	.15253432-03	.15418050-03	.15586523-03
.15756960-03	.15935476-03	.16116189-03	.16301222-03	.16490704-03	.16684766-03	.16883547-03	.17087189-03	.17295841-03	.17509657-03
.17726601-03	.17953436-03	.18183738-03	.18419889-03	.18662075-03	.18910495-03	.19165351-03	.19426857-03	.19695236-03	.19970718-03
.20253547-03	.20543972-03	.20842260-03	.21148683-03	.21463528-03	.21787097-03	.22119792-03	.22461672-03	.22813349-03	.23175004-03
.23547262-03	.23930308-03	.24324563-03	.24730542-03	.25148638-03	.25579347-03	.26023171-03	.26480634-03	.26952290-03	.27438717-03
.27940527-03	.28458364-03	.28992904-03	.29544859-03	.30114982-03	.30704065-03	.31312047-03	.31942506-03	.32593681-03	.33267456-03
.33964076-03	.34687046-03	.35435134-03	.36210382-03	.37014198-03	.37847705-03	.38712655-03	.39610536-03	.40543126-03	.41511907-03
.42519081-03	.43566574-03	.44656550-03	.45791319-03	.46973349-03	.48205278-03	.49489035-03	.50830354-03	.52229780-03	.53691708-03
.55219692-03	.56818368-03								

SUM OF SPECTRUM VALUES = .12248068+01
SAMPLE POWER OF INPUT = .12248106+01

REFERENCES

1. A. H. Nuttall, "Spectral Analysis of a Univariate Process with Bad Data Points, via Maximum Entropy and Linear Predictive Techniques," NUSC Technical Report 5303, 26 March 1976.

2. A. H. Nuttall, "FORTRAN Program for Linear Predictive Spectral Analysis of a Complex Univariate Process," NUSC Technical Report 5505, 3 December 1976.

3. A. H. Nuttall, "Multivariate Linear Predictive Spectral Analysis, Employing Weighted Forward and Backward Averaging: A Generalization of Burg's Algorithm," NUSC Technical Report 5501, 13 October 1976.

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