Smoothed Spectra by Spectral Window—SWIN

The program SWIN (Smoothed Spectra by Parzen's **S**pectral **Win**dow) is a subroutine subprogram that performs smoothing on a spectrum that has already been computed in the frequency domain. Therefore, unlike the other program LWIN, the length of the spectrum to be treated, i.e., the number of spectral values, is arbitrary, and there are no restrictions related to powers of 2.

SWIN（Smoothed Spectra by **S**pectral **Win**dow）

【Purpose】

To smooth the given Fourier and power spectra in the frequency domain using Parzen's spectral window with the specified bandwidth.

【Usage】

（1） How to connect

CALL SWIN (NFOLD, F, G, ND, IND, DF, BAND)

Argument	Type	Parameter in calling program	Return Parameter
NFOLD	I	Total number of Fourier & Power Spectra	Unchanged
F	R 1-D array (ND)	Original Unsmoothed Fourier Spectrum if IND=010, no need to input here	Smoothed Fourier Spectrum
G	R 1-D array (ND)	Original Unsmoothed Power Spectrum if IND=010, no need to input here	Smoothed Power Spectrum
ND	I	Dimension size of F and G in calling program	Unchanged
IND	I	Index for given original spectra 100 : Fourier spectrum 010 : Power spectrum	Unchanged
DF	R	Frequency interval of Fourier & Power Spectra (Unit : Hz)	Unchanged
BAND	R	Band width (unit: Hz)	Unchanged

（2） Necessary subroutines and function subprograms

None

(3) Remarks

i) The arguments *IND* can be added together. Therefore, given both the original Fourier spectrum and the power spectrum, we can write *IND* = 110 (100 + 010). However, the result is the same with *IND* = 010.

ii) *BAND* /*DF* must be greater than 560/ 151 and less than the lesser of 14000/ 151 and 140(*NFOLD*-1)/ 151.

iii) If the argument *BAND* = 0.0 then no smoothing is performed.

【Calculation Method】

First, create a Parzen's spectral window according to the specified bandwidth as follows.

$$W(f)=\frac{3}{4}u\left(\frac{\sin\frac{\pi uf}{2}}{\frac{\pi uf}{2}}\right)^4$$

Next, we perform a moving average of the power spectrum numerically.

$$\overline{G}(f)=\int_{-\infty}^{\infty}G(g)W(f-g)\,\mathrm{d}g$$

The width of the window is truncated at $\pm f=2/u$ on the horizontal axis.

There are some restrictions on the bandwidth for smoothing that can be specified as arguments, as noted in the notes above. These are to prevent the window from being too wide compared to the length of the given spectrum, and for programming reasons, the shape of the window should be expressed as a number within 101. However, none of these restrictions are of any practical concern. If the bandwidth is specified as zero, the program returns to the calling program without smoothing.

When a window is applied to the spectrum, the width of the window will be out of the spectrum at both ends of the spectrum. In such a case, the values in the outliers are folded back into the spectrum by using the bending relation of the spectrum.

When the Fourier spectrum is given first, it is smoothed by converting it to a power spectrum, and finally the smoothed Fourier spectrum is obtained from the smoothed power spectrum. In this way, the smoothing is not done directly on the Fourier spectrum, but on the power spectrum, in order not to change the power of the original waveform.

【Program List】

```
C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *    SWIN   1
C     SUBROUTINE FOR SMOOTHED SPECTRA BY PARZEN'S SPECTRAL WINDOW         SWIN   2
C  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *    SWIN   3
C                                                                          SWIN   4
C                                                CODED BY Y.OHSAKI         SWIN   5
C                                                                          SWIN   6
C     PURPOSE                                                              SWIN   7
C       TO SMOOTH FOURIER AND POWER SPECTRA BY APPLICATION OF              SWIN   8
C       PARZEN'S SPECTRAL WINDOW WITH THE SPECIFIED BANDWIDTH              SWIN   9
C       IN FREQUENCY DOMAIN                                                SWIN  10
C                                                                          SWIN  11
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C     USAGE                                                          SWIN  12
C       CALL SWIN(NFOLD,F,G,ND,IND,DF,BAND)                          SWIN  13
C                                                                    SWIN  14
C     DESCRIPTION OF ARGUMENTS                                       SWIN  15
C       NFOLD - TOTAL NUMBER OF THE GIVEN SPECTRAL VALUES            SWIN  16
C       F(ND) - THE ORIGINAL/SMOOTHED FOURIER SPECTRUM AT CALL/RETURN SWIN  17
C       G(ND) - THE ORIGINAL/SMOOTHED POWER SPECTRUM AT CALL/RETURN  SWIN  18
C       IND   - 100 WHEN FOURIER SPECTRUM IS ORIGINALLY GIVEN        SWIN  19
C               010 WHEN POWER SPECTRUM IS ORIGINALLY GIVEN          SWIN  20
C       DF    - FREQUENCY INCREMENT IN THE SPECTRUM IN HZ            SWIN  21
C       BAND  - THE SPECIFIED BANDWIDTH IN HZ                        SWIN  22
C                                                                    SWIN  23
C     REMARKS                                                        SWIN  24
C       THE RATIO BAND/DF MUST BE LARGER THAN 560/151, AND LESS THAN SWIN  25
C       14000/151 OR 140(NFOLD-1)/151 WHICHEVER SMALLER              SWIN  26
C                                                                    SWIN  27
C     SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                  SWIN  28
C       NONE                                                         SWIN  29
C                                                                    SWIN  30
      SUBROUTINE SWIN(NFOLD,F,G,ND,IND,DF,BAND)                      SWIN  31
C                                                                    SWIN  32
      DIMENSION F(ND),G(ND),W(101),G1(4497),G2(4497)                 SWIN  33
C                                                                    SWIN  34
C     INITIALIZATION                                                 SWIN  35
C                                                                    SWIN  36
      T=1./DF                                                        SWIN  37
      IF(BAND.EQ.0.) GO TO 120                                       SWIN  38
      UDF=1.854305/BAND*DF                                           SWIN  39
      IF(UDF.GT.0.5) GO TO 230                                       SWIN  40
      LMAX=IFIX(2./UDF)+1                                            SWIN  41
      IF(LMAX.GT.101) GO TO 240                                      SWIN  42
C                                                                    SWIN  43
C     SPECTRAL WINDOW                                                SWIN  44
C                                                                    SWIN  45
      W(1)=0.75*UDF                                                  SWIN  46
      DO 110 L=2,LMAX                                                SWIN  47
      DIF=1.570796*REAL(L-1)*UDF                                     SWIN  48
      W(L)=W(1)*(SIN(DIF)/DIF)**4                                    SWIN  49
  110 CONTINUE                                                       SWIN  50
C                                                                    SWIN  51
C     CONVERSION FROM FOURIER TO POWER SPECTRUM                      SWIN  52
C                                                                    SWIN  53
  120 IF(IND.NE.100) GO TO 140                                       SWIN  54
      G(1)=F(1)**2/T                                                 SWIN  55
      DO 130 K=2,NFOLD-1                                             SWIN  56
      G(K)=2.*F(K)**2/T                                              SWIN  57
  130 CONTINUE                                                       SWIN  58
      G(NFOLD)=F(NFOLD)**2/T                                         SWIN  59
C                                                                    SWIN  60
C     SMOOTHING OF POWER SPECTRUM                                    SWIN  61
C                                                                    SWIN  62
  140 IF(BAND.EQ.0.) GO TO 210                                       SWIN  63
      LL=LMAX*2-1                                                    SWIN  64
```

```
      LN=LL-1+NFOLD                                                    SWIN  65
      LT=(LL-1)*2+NFOLD                                                SWIN  66
      LE=LT-LMAX+1                                                     SWIN  67
      DO 150 K=1,LT                                                    SWIN  68
      G1(K)=0.                                                         SWIN  69
  150 CONTINUE                                                         SWIN  70
      DO 160 K=1,NFOLD                                                 SWIN  71
      G1(LL-1+K)=G(K)                                                  SWIN  72
  160 CONTINUE                                                         SWIN  73
      DO 180 K=LMAX,LE                                                 SWIN  74
      S=W(1)*G1(K)                                                     SWIN  75
      DO 170 L=2,LMAX                                                  SWIN  76
      S=S+W(L)*(G1(K-L+1)+G1(K+L-1))                                   SWIN  77
  170 CONTINUE                                                         SWIN  78
      G2(K)=S                                                          SWIN  79
  180 CONTINUE                                                         SWIN  80
      DO 190 L=2,LMAX                                                  SWIN  81
      G2(LL+L-1)=G2(LL+L-1)+G2(LL-L+1)                                 SWIN  82
      G2(LN-L+1)=G2(LN-L+1)+G2(LN+L-1)                                 SWIN  83
  190 CONTINUE                                                         SWIN  84
      DO 200 K=1,NFOLD                                                 SWIN  85
      G(K)=G2(LL-1+K)                                                  SWIN  86
  200 CONTINUE                                                         SWIN  87
C                                                                      SWIN  88
C     SMOOTHED FOURIER SPECTRUM                                        SWIN  89
C                                                                      SWIN  90
  210 F(1)=SQRT(G(1)*T)                                                SWIN  91
      DO 220 K=2,NFOLD-1                                               SWIN  92
      F(K)=SQRT(G(K)*T/2.)                                             SWIN  93
  220 CONTINUE                                                         SWIN  94
      F(NFOLD)=SQRT(G(NFOLD)*T)                                        SWIN  95
      RETURN                                                           SWIN  96
C                                                                      SWIN  97
  230 WRITE(6,601)                                                     SWIN  98
      STOP                                                             SWIN  99
  240 WRITE(6,602)                                                     SWIN 100
      STOP                                                             SWIN 101
C                                                                      SWIN 102
C     FORMAT STATEMENTS                                                SWIN 103
C                                                                      SWIN 104
  601 FORMAT('BANDWIDTH IS TOO NARROW')                                SWIN 105
  602 FORMAT('BANDWIDTH IS TOO WIDE')                                  SWIN 106
      END                                                              SWIN 107
```

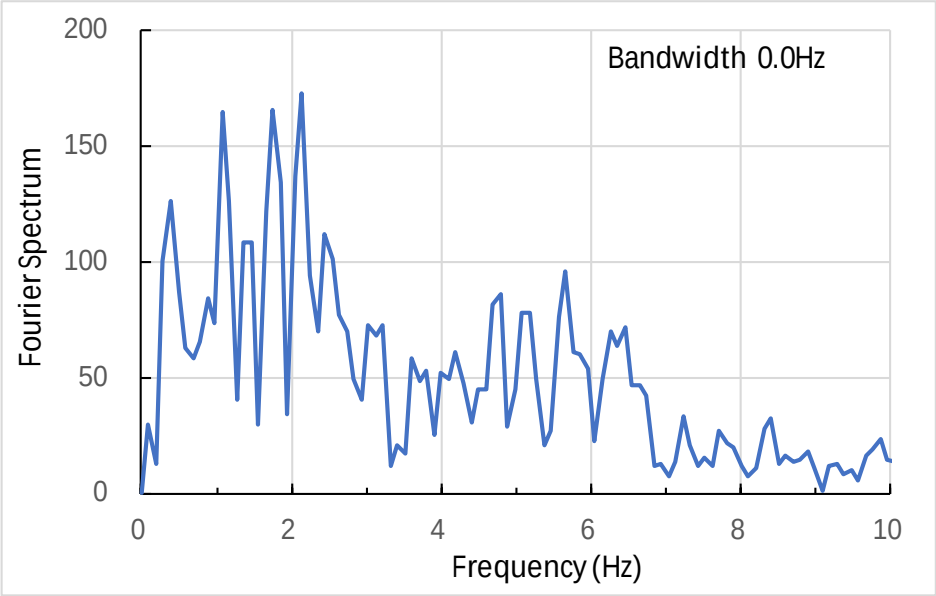
【Example】

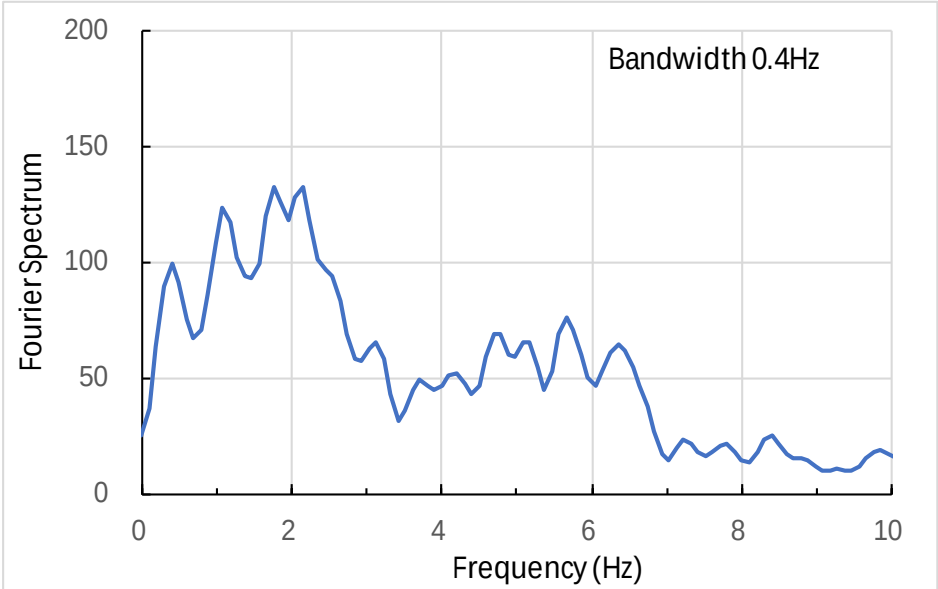
From the file EQ.01, read the time interval, number of the earthquake motion data, and digital data, and draw the Fourier spectrum by changing the bandwidth from 1.2 to 0.8 to 0.4 Hz..

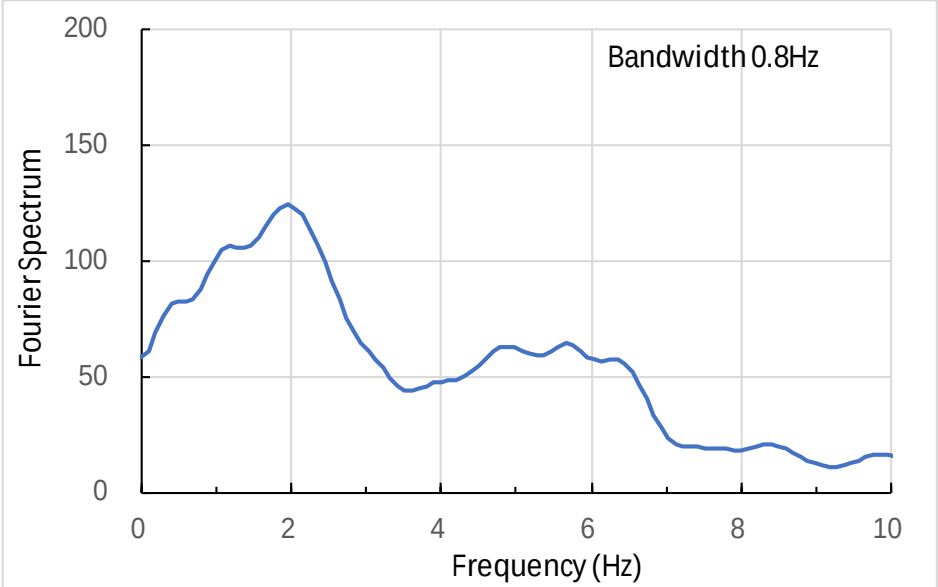
```
C
      DIMENSION DATA(800),F(513),G(513),F1(513),FF(513,4)
C
      READ(5,501) DT,NN,(DATA(M),M=1,NN)
      CALL FPAC(NN,DATA,800,DT,100,F,G,G,513,NFOLD,DF)
      DO 130 IBAND=1,4
      BAND=REAL(4-IBAND)*0.4
      IF(IBAND.EQ.1) BAND=0.0
      DO 110 K=1,NFOLD
      F1(K)=F(K)
  110 CONTINUE
C
      CALL SWIN(NFOLD,F1,G,513,100,DF,BAND)
C
      DO 120 K=1,NFOLD
      FF(K,IBAND)=F1(K)
  120 CONTINUE
  130 CONTINUE
C
      STOP
  501 FORMAT(T51,F10.0,I10/(8F10.0))
      END
```

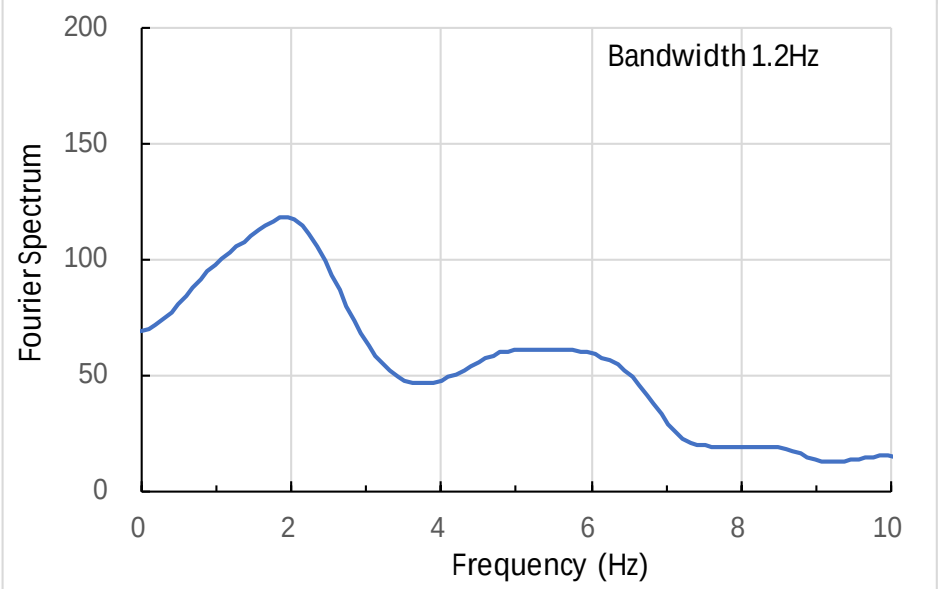
Output：

The smoothed Fourier spectrum is stored in the array *FF* for each bandwidth, as shown in the following figures.




Bandwidth 0.4Hz
Fourier Spectrum
Frequency (Hz)
0
50
100
150
200
0
2
4
6
8
10


Bandwidth 0.8Hz
Fourier Spectrum
Frequency (Hz)
0
50
100
150
200
0
2
4
6
8
10


Bandwidth 1.2Hz
Fourier Spectrum
Frequency (Hz)
0
50
100
150
200
0
2
4
6
8
10