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DAFFT/PAFFT/DAQUAN (EAE)

DECUS Program Library Write-up — DECUS NO. 8-525

CHAPTER 1

Use of DAFFT overlay for DAQUAN (EAE)[1]

DAFFT (Data Acquisition and FFT) contains all functional aspects of DAQUAN except the following:

1. MODIFY function is removed.
2. SQUEEZE function is removed.
3. Number of points limited to 1024.
4. Window or boxcar averaging is not done due to its inherent destructive low frequency bandpass filtering.

It includes these added functions:

1. Performs complex FFT from single precision data to give complex single precision results.
2. Performs complex inverse FFT similarly.
3. Computes scaled power spectrum .
4. Allows temporary storage of 1024 values in a third buffer area.
5. Has option of 3 point or 11 point digital filtering in time domain and Hanning filtering in frequency domain.

DAFFT will allow signal averaging in the time domain (up to 1024 double precision points), FFT into frequency domain giving up to 1024 real and 1024 complex coefficients (half of which are in positive and half in negative frequency), computation of the power versus frequency spectrum as the scaled sum of the squares of those coefficients, input and/or output of any of these arrays using the teletype or high speed reader/punch, and will allow the ability to retain an extra 1024 point array in core for recall of data from a previous step.

The software package consists of the DAQUAN (EAE) and DAFFT OVERLAY binaries. DAQUAN (EAE) is equivalent to DAQUAN except that all floating point operations will make use of the KE8-E, extended arithmetic element, for higher computational speed. The DAFFT OVERLAY is a two-part binary, the first of which is a copy of DECUS NO. 8-144, J. W. Rothman's FFTS-C, and the second which contains the modifications and additions to DAQUAN (EAE). Also incorporated is the patch for FFTS-C to correct a roundoff error.

LOADING

Refer to Appendix A of DAQUAN for detailed loading procedure. Load DAQUAN (EAE) as described for DAQUAN. Then place DAFFT OVERLAY in reader and hit CONT switch. Insure

[1] Refers to the DAQUAN Users Manual - DEC-LB-U8OB-D

that AC is zero when reader stops. If not, repeat procedure as described in Appendix A of DAQUAN, Section 1.3. If AC was zero, hit CONT to load final section. Again, insure that AC is zero.

When the tapes are loaded, proceed with startup as described in Section 1.3 of Appendix A of DAQUAN. To use DAFFT under PS/8, proceed as follows:

```
.R ABSLDR ↲
*PTR:,,$                  (read three tapes from reader)
.SAVE SYS DAFFT Ø-7577,1ØØØØ-11577;ØØ2ØØ ↲
```

OPERATION

Notes

Since MODIFY and SQUEEZE are not available, requesting them will cause typeout of a question mark. Similarly, do not at any time request more than 1024 points. Also, any array upon which FFT and IFFT is to be done must be some power of two in length, i.e., 4, 8, 16, ... 256, 512, or 1024 points. If this rule is violated, the results are unpredictable. Also, any array to be transformed must reside in Channel 1.

Use of the CALCULATE command will require using the last 128 locations of field zero where the PS/8 monitor head resides. Therefore, after using CALCULATE, if PS/8 is to be recalled it must be bootstrapped back into core. Do not start at 7600'.

Relationship to Acquisition

The FFT of 2^N real or complex input points will yield 2^N complex coefficients, half of which are positive frequency and half are negative frequency. Most applications use only positive frequency, therefore, 2^{N-1} points result from the transform. For a desired final result of 0 - f max bandwidth, the input should be band limited at twice fmax and sample rate should equal twice fmax to prevent aliasing and to allow accurate frequency recovery.

In order to remove DC offset from the data, before computing the FFT the mean value of the array is subtracted from each datum. This "zero mean" correction forces the integral of the array to zero.

Command Description

The new commands are:

FT: Calculate FFT of complex time domain data. Real coefficients are in channel 1 and imaginary coefficients are in channel 2 before calling.

ZT: Calculate FFT of real valued time domain data. Real coefficients are in channel 1. Channel 2 is set to zero before transform.

IT: Calculate inverse FFT of complex frequency domain data. Real coefficients in channel 1 and imaginaries in channel 2.

PO: Compute power versus frequency spectrum as sum of squares of real and imaginary coefficients. Channel 1 contains real coefficients and channel 2 contains imaginary coefficients before calling.

SH: Shift to or from channel 1 and storage buffer.

SM: Perform Hanning, 3 point, or 11 point filtering.

FT and ZT will create arrays including both positive and negative frequencies. Zero frequency is set at left margin with increasing values to the most positive requency in center of the scope. The most negative frequency is adjacent to that and remainder of display is negative frequency going to zero again on right margin. The power display is analogous.

After data is entered (by AVERAGE or PAPER TAPE commands) insure that real coefficients are in channel 1 and imaginary (if any) are in channel 2. The real and imaginary coefficients are output or input as separate arrays.

Shift Command

Typing:

SH:

Will cause:

SAVE?

to be typed. Answer 'Y' if data in channel 1 is to be placed in storage buffer. Answer 'N' if data in storage buffer is to be loaded into channel 1. Hit RETURN after either response to continue execution.

Smooth Command

A choice of two time domain or a frequency domain filter is available. When:

SM:

is typed, the message

H,3,11(0,1,2):

is printed requesting a value of Ø to execute Hanning smoothing of the real and imaginary Fourier coefficients stored in channels 1 and 2, respectively. The expression used is:

$$Y_i = -1/4 \,.\, Y_i{-1} + 1/2 \,.\, Y_i - 1/4 \,.\, Y_{i+1}.$$

It is designed to remove fractional frequencies and to enhance resolution in the frequency domain.

A response of "1" will cause the data in the currently displayed channel to be smoothed with a three point filter defined as follows:

$$Y_i = 1/4 \cdot Y_{i-1} + 1/2 \cdot Y_i + 1/4 \cdot Y_{i+1}.$$

Responding with "2" executes the 11 point filter as described in Chapter 2 (2.13) of DAQUAN and Appendix E of DAQUAN.

Complete the desired response by hitting RETURN key.

FFT Commands

Typing FT:, IT:, or ZT: has the performance as described in section "Command Description." When the transform is completed, DAFFT will type out

FACTOR= XX

where XX is a power of two by which the stored values are to be multiplied in order to get the actual Fourier coefficients. All stored values were divided by that power of two in order to prevent overflow of the single precision format. The coefficients are inferred to be fractions between +1 and -1 but for all intents and purposes may be considered as integers between + and - 2048. Then the actual Fourier coefficient is found as

$$FC_i = (Y_i/2048) \cdot 2^{FACTOR}.$$

Since DAFFT, for purposes of display, assumes a number range of 0 to 1000, display of the transforms will show scope wraparound. This is allowed in order to retain maximum resolution of the data. If it is desired for plotting or whatever the arrays can be scaled down using the MULTIPLY command (Chapter 2.12) of DAQUAN with a MIN of 2000 (or 1000) and MPY of 0.25 (or 0.5). This should be done for both the real array in channel 1 and the imaginaries in channel 2. Use of the SCALE command is discouraged since that routine assumes a data range of + to - 1024 and the FFT and IFFT gives a range of + to - 2048. However, if the power spectrum is to be computed, it is recommended that no scaling be done. This then allows the full resolution to be used.

Power Command

To compute the power spectrum from the stored real and imaginary coefficients, type

PO:

DAFFT then requests

FACTOR=

Enter a value from 6-12 followed by RETURN. This is to allow scaling to the desired range. The larger the FACTOR the smaller the result. The power coefficient is computed as a 24-bit value then divided by 2^{FACTOR}. Use of a large FACTOR allows keeping all power coefficients on scale whereas a smaller FACTOR allows presentation of the weak power components. Only the low order 12 bits are retained.

The expression for computing power is

$$P_i = (Y_{1i}^2 + Y_{2i}^2) \cdot 2^{-FACTOR}$$

where Y_{1i} is the real coefficient (in channel 1) and Y_{2i} is the imaginary coefficient (in channel 2). The power array will replace the data in channel 1.

DAFFT EXAMPLE

```
DAQUAN LIVES!
TITLE: DAFFT DEMO ( ↑A)

OK, HIT ME!

AV:                              Acquire 10 scans of 1024 points at 1024Hz from channel
CHANNEL= 2                       2 with no prescan delay.

NO. POINTS= 1Ø24
SEC/SCAN=1
DELAY(SEC)=Ø
NO. SCANS= 1Ø

SH:                              Save time averaged data in storage buffer.
SAVE?Y                           Zero out complex coefficient array and compute FFT.
21ZT:                            Data was automatically divided by 16 (2^4).
FACTOR= 4                        Compute power spectrum with factor of 2^-9.
21PO:
FACTOR=  9
1SH:                             Shift storage buffer back to channel 1, i.e., restore time
SAVE?N                           averaged data.
1ZT:
FACTOR= 4                        Compute FFT as above.
SM:                              Apply Hanning filter.
H,3,11(Ø,1,2)=Ø
PO:                              Compute power spectrum as above.
FACTOR= 9
```

CHAPTER 2

Use of PAFFT overlay for DAQUAN (EAE)

PAFFT (Power Average by FFT) has all the features of DAFFT (Chapter 1) except the CALCULATE command and, instead of time domain averaging, frequency domain averaging of the power spectrum is done. This is accomplished by acquiring a synced sweep of data in time, resetting to a zero mean, doing the FFT, applying Hanning filtering, computing power, adding to the double precision power average, and returning to allow the next sweep. A 1024 average requires about 4 seconds dead time per sweep (set by FFT time).

OPERATION

The AVERAGE routine as described in Chapter 2.3 of DAQUAN was modified by inserting the FFT and power average computations after each sweep. Also, when the run is complete the number of points for display is halved. This will present only the positive frequency power spectrum.

Also, when AVERAGE is requested and after NO. POINTS is specified, PAFFT requests

```
          FACTOR=
```

The response is a value of 6-12 followed by RETURN. This FACTOR is analogous to that described in Chapter 4.3.4 of DAQUAN.

PAFFT requires using channel 1 for the sweep acquisition, both channels1 and 2 for the Fourier coefficients, and the storage buffer to retain the double precision power average. Therefore, no other arrays, preceding data, etc., can be contained in core when a power average is being computed.

When the average is terminated the double precision power average is divided by the number of sweeps taken, truncated to the limits of + to - 2047, and stored in channel 1.

PAFFT EXAMPLE

```
DAQUAN LIVES!
TITLE:  PAFFT DEMO ( ↑A)

OK, HIT ME!

AV:
CHANNEL=Ø

NO. POINTS= 1Ø24
FACTOR= 8
SEC/SCAN= 3
DELAY(SEC)= Ø
NO. SCANS= 1Ø
```

Acquire 1024 point power average with scale factor of 8 and 10 scans maximum. Final array is 512 points with 0 - 170 Hz bandwidth (1024/3÷2)

```
NO. SCANS= 4                  Average stopped at four scans.

SC:                           Scale data to size for plotting.

MIN= Ø
MAX= 2Ø47
MPY= 0.489
SM:                           Apply 3 point filter.
H,3,11(Ø.1.2):1

PL:
LINE PLOT?Y                   Make a line plot of data.
G
PLOTTER OFF?Y
AV:
CHANNEL= 2                    Acquire power average with scale factor of 9 to give
                              512 points with bandwidth of 0 - 512 Hz.

NO. POINTS= 1Ø24
FACTOR= 9
SEC/SCAN= 1
DELAY(SEC)= Ø
NO. SCANS= 1Ø
```

APPENDIX A

Core map of DAQUAN

Field Ø

Page	Contents
Ø	Constants, subroutine links, temp. storage
1 (200)	Main display loop, fix and float subroutines
2 (400)	MODIFY*, TTY subroutines
3 (600)	F. P. input, output subroutines, plot axis marker
4 (1000)	Plotter calibration, answer subroutine, delay, A/D, DAC, relay subroutines
5 (1200)	Leader-trailer subr, X display increment setup, PAPERTAPE input, X-Y analog PLOT setup, Y-INVERT
6 (1400)	OUTPUT, SCALE, increment x coordinate subroutine
7 (1600)	Analog plotter driver, message output subroutine
8 (2000)	Keyboard command decoder, command dispatch table
9 (2200)	CALCULATE, COPY, ALTER, SUBTRACT routines
10 (2400)	Calculates drives, parameter dump
11 (2600)	Exponentiation subroutine, more calculate routines
12 (3000)	SWAP, SMOOTH, ADD, CURSOR routines, clockdriver
13 (3200)	Cursor decoder, STRIP
14 (3400)	INTEGRATE
15 (3600)	More calculate routines, array initializer, DERIVATIVES, SQUEEZE
16 (4000)	AVERAGE setup, TIME calibration, LIST cursors
17 (4200)	Average acquisition routine, output setup for PEAKREPORT
18 (4400)	Intersweep average display, X-INVERT, MULTIPLY
19 (4600)	Output routine for PEAK REPORT
20 (5000)	PEAK REPORT peak detector
5131-5377	6-bit packed ASCII messages
5400-7577	Floating Point Package #2 with modifications

*MODIFY overwritten by parameters when CALCULATE is used.

Field 1

Ø-3777	channel 1 data
4000-7777	channel 2 data

Field 1 Utilization

A. AVERAGE requires 2N locations starting from base of the channel where N is the number of points. Hence, a 1024 point average into channel 1 just fits. More than 1024 points will overrun into the other channel.

B. PEAK REPORT requires N + 9p locations where N is the number of points and p is the number of peaks detected. The peak parameters are stored immediately after the data array.

APPENDIX B

Core Map for DAFFT

(Only the major departures from DAQUAN core map (APPENDIX A) are presented here)

Field Ø

Page	Contents
2	Field 1 dispatcher, POWER, SHIFT, SMOOTH dispatcher overlay MODIFY
15 (3731-3756)	SQUEEZE overlayed by message text and FACTOR output from FFT's.
31(7600)	Parameter storage buffer for CALCULATE
Field 1	
Ø	Constants, storage for FFTS-C
1 (200)	FFT drivers, Hanning filter, zero mean routine
400-1577	FFTS-C
1600-3577	Channel 1 data
3600-5577	Channel 2 data
5600-7577	Storage buffer

APPENDIX C

Core Map for PAFFT

The departures from core map of DAQUAN (APPENDIX A and DAFFT (APPENDIX B) are shown below:

Field Ø

Page	Contents
9 (2200)	Mods to AVERAGE overlay CALCULATE routine
Field 1	
Ø	Hanning filter, zero mean subroutine
1 (200)	FFT drivers, power average subroutine