FILE.

INTERNAL DOCUMENT No 123

I.O.S.

PROPOSED CHANGES TO ROUTINE DIGITAL WAVE DATA COLLECTION FROM WAVERIDER BUOYS

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey GU8 5UB
(042-879-4141)

(Director: Dr. A. S. Laughton)

Bidston Observatory,
Birkenhead,
Merseyside L43 7RA
(051-653-8633)
(Assistant Director: Dr. D. E. Cartwright)

Crossway,
Taunton,
Somerset TA1 2DW
(0823-86211)
(Assistant Director: M. J. Tucker)

PROPOSED CHANGES TO ROUTINE DIGITAL WAVE DATA COLLECTION FROM WAVERIDER BUOYS

INTERNAL DOCUMENT NO 123

FEBRUARY 1981

R Gleason
Institute of Oceanographic Sciences
Crossway
Taunton
Somerset

CONTENTS

INTRODUCTION

It has been clear for some time that there is a need to change the sampling scheme used to record IOS digital wave data so that longer records can be taken as routine. There are two reasons for this:-

1. The random sampling errors associated with the present sampling and analysis scheme are very large. The normalised standard error of the resulting spectral estimates being about 32%.
2. The record length of 1024 seconds presently used is too short to provide adequately stable estimates of a number of time domain statistics. This is particularly so when considering the "groupiness" of waves.

The present note discusses the approaches which are available to meet this need both on the data processing and instrumentation sides. After considering the various options available, in particular from the point of view of cost effectiveness and practicability, a course of action is recommended which seems to be the best compromise available.

DATA REQUIREMENTS

1. Time series

For time series analysis it is generally agreed that a record length of 30 mins or more would be a suitable length to allow a variety of analyses to be undertaken. Pitt, Driver and Ewing (1978) pointed out that the mean error in estimating the height of the crest of a wave of period T whose profile is represented by discrete values separated by ΔT is a function of $T/\Delta T$ (Fig 1). The typical range of periods which could be expected in UK waters would lie within the range 5 to 14 seconds. This would give mean errors between 5 and 2 percent with $\Delta T = 1$ sec. However, for the IOS present sampling scheme $\Delta T = 0.5$s, therefore, $T/\Delta T$ is between 10 and 28 which gives errors less than 2 percent for all values. Further decreases in ΔT will improve these figures only slightly as can be seen from the shape of the curve.

To summarise, for time series analysis double length records (2048 s) sampled at 2 Hz is a minimum but acceptable requirement.

2. Spectral Analysis

Our present analysis scheme yields spectral estimates at intervals of approximately 0.01 Hz across the band 0.03 to 0.65 Hz. It can be argued that there is little practical need for those estimates above 0.5 Hz. It is also relevant to recall that the response of the waverider hull is no longer uniform above this frequency. Thus from the point of view of the calculation of spectra, a digitising interval of 1 second is probably adequate, although of course the bandwidth of the analogue signal must be suitably restricted to minimise aliasing

The estimates are spaced at equal intervals along the frequency axis and are defined with similar statistical confidence. However the practical applications of the spectrum are often more concerned with the amount of information per unit period change. It can be seen from the range of estimates and their spacing that there are very few with periods of more than 15 seconds whilst there are many with periods less than 5 seconds. The possibility does exist to present more estimates with lower statistical confidence more closely spaced at low frequencies. This option has not been examined at this stage, in view of the many complications which would be implied for subsequent processing and use of the spectral data.

As Tucker (1979) pointed out the sampling error of spectral estimates is inversely proportional to the square root of the number of adjacent harmonics used to calculate the estimate. With 10 values this is approximately 32%. For double length records estimates for the same frequencies would be formed by averaging 20 values thereby reducing the error to 22%. Triple length gives 18% and quadruple 16% (Fig 3). Clearly the longer the record the more values are averaged to find the estimate and the smaller the percentage error. However sampling for too long a period may cause problems as the statistical process being investigated is not stationary.

Little information is available on the stationarity of wave processes but certainly the long term routine analysis of wave data by IOS shows that these processes can change rapidly between records separated by three hours , especially with storm arrivals. When analysing records taken every ninety minutes at South Uist during the Cloverleaf Buoy experiment in September 1980, it was found that on one occasion with slowly changing conditions the process appeared stationary and that the successive spectra were almost superimposable. Even so there is no concrete evidence on which a purely objective assessment can be made. However, there is a strong subjective belief that record lengths of an hour will almost certainly have stationarity problems with storm arrivals. If this is the case then records three times the standard length which would be fifty one minutes long, must be near the limit for stationarity.

In summary, double length records reduce the normalised standard error of the spectral estimates from 32% to 22% whilst treble and quadruple reduce this further to 18% and 16% respectively. However, quadruple length records are probably over the limit for statistical stationarity considerations.

INSTRUMENTATION

The length (in seconds) of a record is given by

$$T = N.\Delta T$$

where N is the number of points sampled and ΔT is the sampling interval. Thus we can increase T by increasing N or ΔT. The first consideration is to see whether there are any instrumental limits on such changes. There is now sufficient expertise in-house concerning the workings and modification of the Microdata logger electronics that changes in record length, sampling interval and the resultant adjustment in records logged per track and per cartridge are understood and easily accomplished. They are all inter related and can be altered by modifying one printed circuit board.

CHOICE OF SITE

The decision has already been taken that the Isles of Scilly installation should be used as a test site for any change in the routine sampling scheme. This site has a single channel Microdata logger, the Waverider is in an exposed situation and should record a considerable range of wave conditions, and the receiving equipment is readily accessible from the Taunton laboratory in the event of problems. This will be further improved when the receiver is linked by land line to the Taunton laboratory in late 1981. The Scilly Isles Microdata will be changed soon from logging digital voltage values to logging frequency counts summed over the sampling period (Hardcastle, 1976). It would be advantageous to make an early decision to allow any modifications to the sampling scheme to be made at the same time as the move to frequency logging.

Clearly it is important that any decision made must be easily implemented neither requiring major redesign of any of the Microdata logger PCB's nor affecting the high valid data return from the routine data collection programme. The latter has been running at better than a 90% valid data return since the change from 27 MHz to 29 MHz for the telemetry link between the buoy and recieving site.

OPERATIONAL PROCEDURES

Most of our receiving sites are isolated and as a result we rely on the services of non-IOS personnel such as members of the armed forces, coastguard services or lighthouse keepers. At the Isles of Scilly the receiver and logger are in the St Mary's coastguard tower and the cartridges are changed and mailed to IOS fortnightly by the Officer on watch. As the coastguards operate shift working it is not necessarily the same person on duty at each tape change. The tape changes could quite easily be altered to weekly, probably with no real inconvenience to those on site. However, tape changes at intervals of less than a week begin to impose on the staff and takes away the regularity associated with weekly or specific date changes eg every Monday or the first of every month. We rely heavily on the goodwill of these non-IOS personnel to keep our data returning regularly. Extra length cartridges could facilitate an increase to treble length records sampled at 2 Hz as compared to double length for a standard cartridge if weekly changes were chosen.

DATA ANALYSIS

Now that the new read and validation system removes previous constraints on record length associated with PDP 11/20 core size our next important consideration is the extra cost of the computer time required to process longer records.

As far as the spectral analysis of the time series is concerned there are two options available either carry out a Fast Fourier Transform on the full series or apply an anti-aliasing digital filter to the original time series then take every alternate sample point, effectively redigitising at 1 Hz and FFT the reduced series. Pitt has considered two filters and concluded that the one derived from the Hilow computer program written by Cartwright was the better.

This filter function is shown in figure 2 and its documentation as appendix I. Comparisons were carried out on a double length (4096 data points) digital wave record sampled at 2 Hz to obtain running costs for:

(i) a digital anti-aliasing filter applied to the original 4096 point record to produce a record which was then resampled at 1 Hz (2048 points).

(ii) a FFT on the 1 Hz sampled record (2048 points)

(iii) a FFT on the original full record sampled at 2 Hz (4096 points).

The costings showed that within two or three percent the filter plus FFT [(i) + (ii)] cost the same as a full FFT (iii). The digital filter (i) cost approximately the same as the FFT (ii) cost. From these results we can infer that the cost of the FFT and hence the full spectral analysis costs are proportional to the length of time series analysed.

Costings to read, validate and spectrally analyse four weeks wave data are

Read 2 Microdata tapes	- £60	(PDP 11)
Transfer to Honeywell	- £40	
Validate	- £110	
Total read and validation	= £210	

Spectral analysis with full four weeks data = £70

(NB These costs do not allow for time sharing sessions or for reruns of any part of the routine.)

From the above costings it can be seen that the remaining cost of the total digital wave data analysis package is made up of the field tape translation and validation. This cost is also charged at a rate directly proportional to the record length.

It is clear from this information that double length records will cost twice as much to analyse as present day records and that any further increase in record length will incur costs pro rata.

CONCLUSIONS

The cost of carrying out an FFT on an increased record length sampled at 2 Hz is no different from that of applying an anti-aliasing digital filter before resampling at 1 Hz and then carrying out an FFT. As the characteristics of any such filter are not ideal it would be better to FFT the full time series, this would allow us to present the same spectral estimates as at present and to cut off the spectra above a particular frequency if required. There will be no more aliasing in the spectrum than at present.

Accepting that improvements have to be made we are left with two main options, one of which has two alternatives:

1. Increase records to twice their present length and sample at 2 Hz. Carry out analysis on the double length records to provide exactly the same information as at present.

Advantages are:-

(i) we have minimum disruption to our program and routine analysis
(ii) this particular option has been implemented briefly for the South Uist Deepwater Waverider
(iii) tapes can be changed weekly on a specific day
(iv) if the same estimates as at present are calculated the errors are improved from 32% to 22%
(v) the criteria for time series analysis are met
(vi) the statistical processes are also probably stationary for virtually all conditions.

The disadvantage is that the cost is nearly doubled.

2.(a) Increase the record to three times its present length but sample still at 2 Hz. Carry out analysis exactly as at present.

Advantages are:-

(i) with extended play cartridges we can change tapes weekly
(ii) spectral estimates are improved from 32% to 18%
(iii) the criteria for time series analysis are met.

The disadvantages are:-

(i) we have never used extended play cartridges and we do not know if they have any specific problems

(ii) under rapidly changing wave conditions the total record length must be approaching the level where the lack of stationarity begins to increase the error of any spectral estimates calculated

(iii) the computer costs will virtually treble those at present.

2.(b) This third option which would be the same as 2.(a) except that the estimates would be grouped over fifteen adjacent harmonics, this will give the added advantage of improved resolution at low frequencies although the error will only be reduced from 32% to 26%. Otherwise the advantages and disadvantages will be as in 2.(a).

In conclusion it seems that the primary factor which will decide which method is used is the cost of computer analysis compared to the improvement in the errors of the spectral estimates. As a result the author recommends double length records analysed as at present as the option to choose.

REFERENCES

Hardcastle, P J (October 1979). Wave data logging. Note circulated within IOS Taunton for discussion.

Pitt, E G, Driver, J S and Ewing, J A (1978). Some inter comparisons between wave recorders. IOS Report No 43.

Tucker, M J (1979). The analysis and interpretation of records of sea waves. Part 2. The spectral analysis of one dimensional records. IOS Internal Document No 50.

APPENDIX I

Program: HILOW (available on NCS Honeywell as US/IOS08/NIO/PROGS/HILOW)

The program produces the right hand half of a symmetrical filter of <u>half length N</u>. That is, it produces a set of multipliers.

$$F_r, r = 0(1)N$$

for intended use with a data series $x(t)$ in the form

$$x_0(t) = F_0 x(t) + \sum_{r=1}^{N} F_r (x(t+r) - x(t-r))$$

$x_0(t)$ is the filtered version of $x(t)$, with certain parts of its spectrum suppressed according to the filter characteristics, but no alteration in phase.

When operating as a low pass filter

$$F_0 = (M + 0.5)/N$$

$$F_r = \cos^2 \tfrac{1}{2}\Omega r . \sin(M + \tfrac{1}{2})\Omega r / 2N \sin \tfrac{1}{2}\Omega r , \quad \Omega = \{\Pi/N\}$$

and $F_N = 0.$

M is one of the parameters usedto determine the cut off frequencies of the filter.

For the filter in fig2 M = 4 and N = 7.

Giving multipliers

F_0	= 0.64285716	F_3	= 0.01558259	F_6	= 0.00157404
F_1	= 0.27488807	F_4	= 0.03462502	F_7	= 0.0
F_2	= 0.10447956	F_5	= 0.00930547		

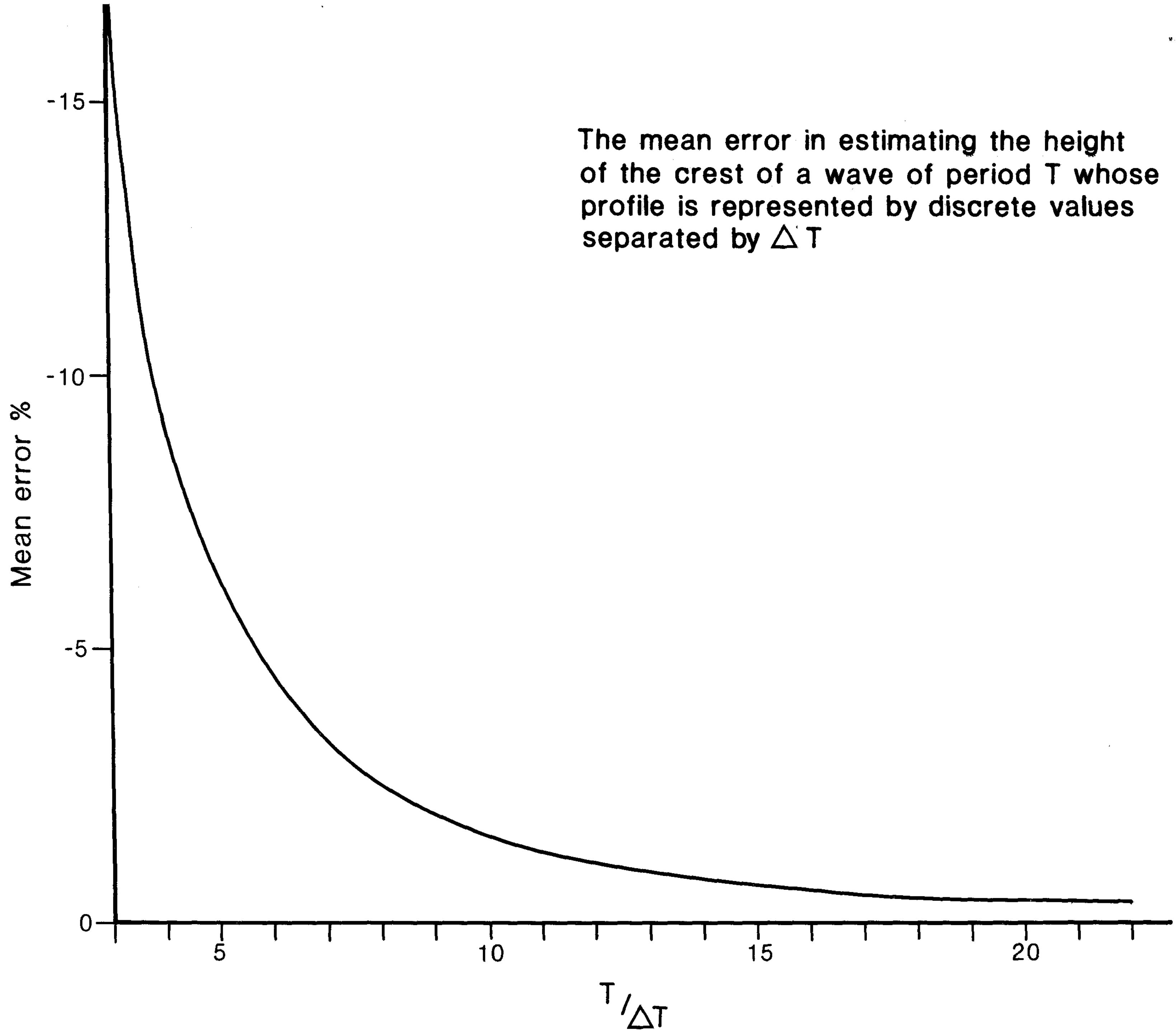
-15
-10
-5
0
Mean error %
The mean error in estimating the height of the crest of a wave of period T whose profile is represented by discrete values separated by ΔT
5
10
15
20
$T/\Delta T$

Figure 1

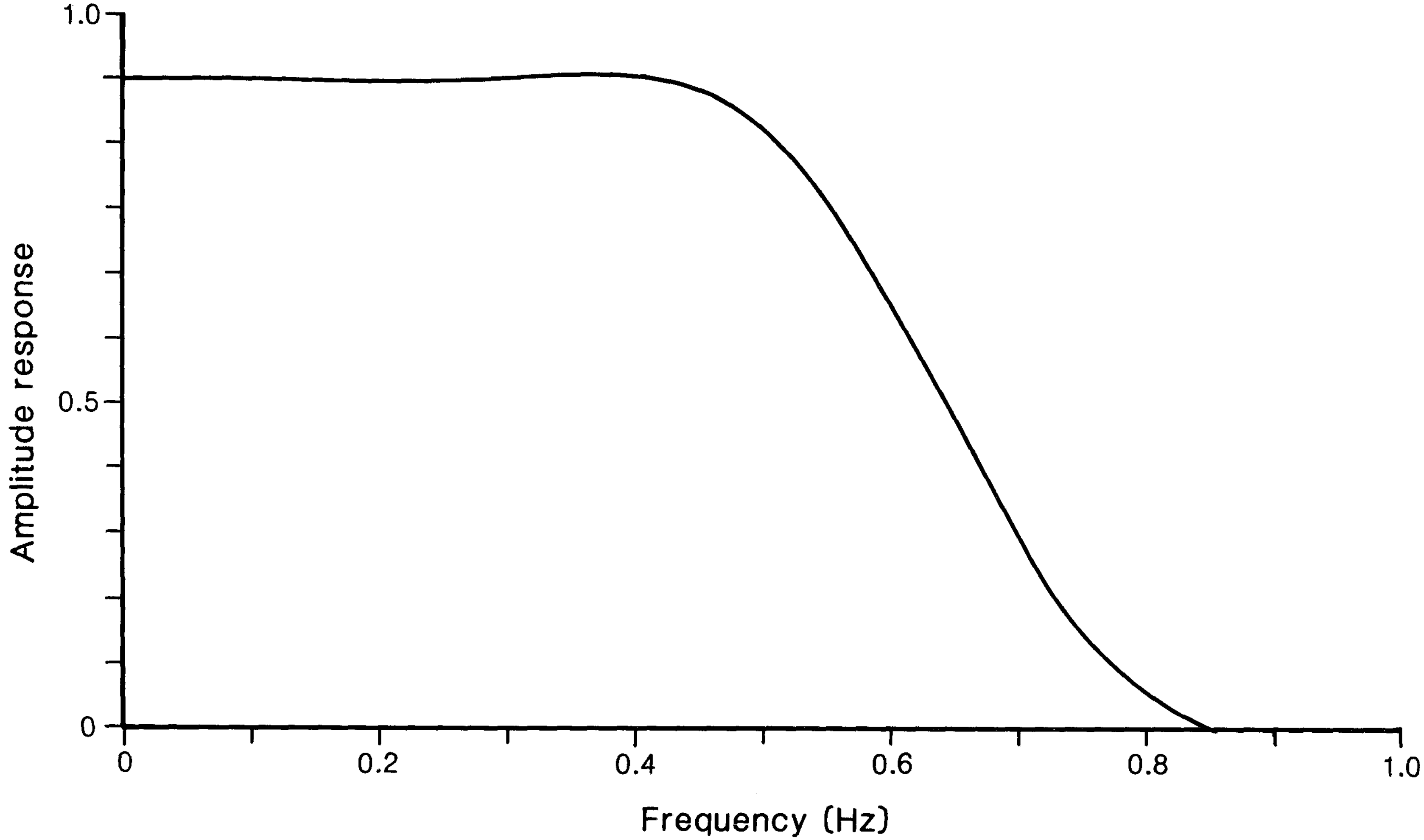

Figure 2

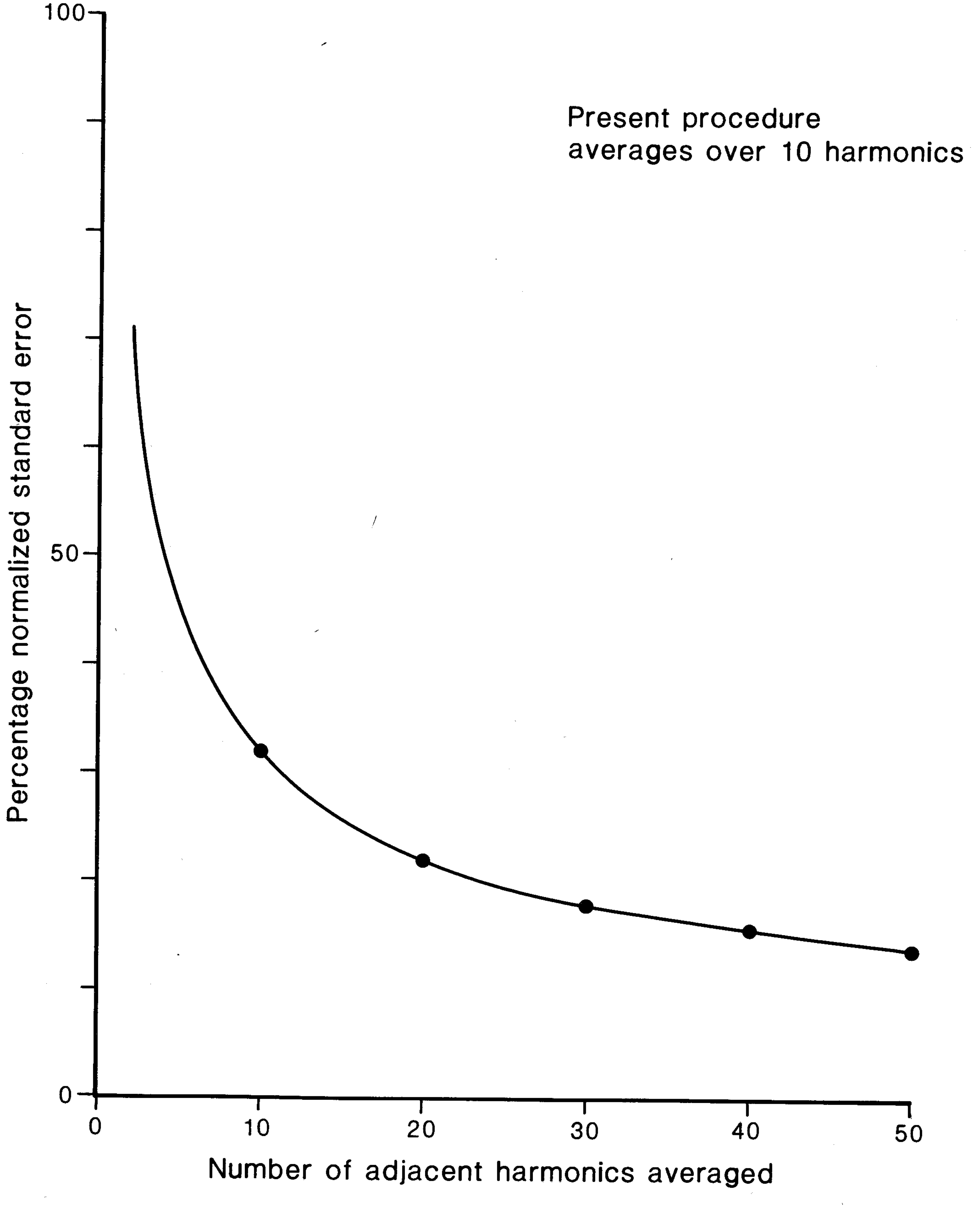
100
50
0
Percentage normalized standard error
Present procedure
averages over 10 harmonics
0
10
20
30
40
50
Number of adjacent harmonics averaged

Figure 3