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NOISE ANALYSIS OF SINGLE CHANNEL DEGHOSTING FILTERS

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NOISE ANALYSIS OF SINGLE CHANNEL DEGHOSTING FILTERS

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ABSTRACT

Arrays of performance values showing the change in noise variance due to deghosting indicate significant sensitivity to both the deghosting method and pre-band pass filtering. As a specification for single channel deghosting, the apparent reflection coefficient used to derive the operator, should be constrained such that the noise amplification does not exceed a specified design criteria such as 1 db. Some typical results of such a test are given. The apparent reflection coefficient used to design the echo suppressor is observed as highly dependent on the echo time.

1. INTRODUCTION

Single channel deghosting is considered in the context of a modular approach to processing vertical array data for signal detection and measurement. The modules consist of:

(1) pre-set band pass filter designed to improve detection probability of nearly vertical p-waves for a fixed false alarm probability (eg 0.02 or expectation of less then one false alarm per minute)

(2) single channel deghosting operator for removal of echo distortion

(3) possible multi-channel wave number-frequency filter, fan filter, for estimating the p-pulse and suppressing the ambient and signal-coda noise

(4) in place of (3), possible use of signal correlation criteria for detecting and measuring the p-pulse.

Here, we are confined to evaluating the performance of single channel deghosting operators to determine the constraints required to prevent the deghosting operators from degrading the overall performance of the system.

2. NOISE DATA

The noise is obtained from a pseudo random number generating function, FORTRAN 63 RANF (-1). The alogorithm has been tested and shown statistically to provide a sequence of random uncorrelated numbers. The sequence will not repeat until millions of samples have been called. The pseudo random numbers are averaged nine times to produce a nearly Gaussian input of uncorrelated samples. They are filtered twice in series using RECFIL3, a recursive narrow-band filter. The low frequency noise component is obtained with the frequency set at to .2 cps and $Q = f_0/\Delta f = 3.5$, and the high frequency to 2.0 cps, $Q = 6$. A plot of the power spectral density of a sample of the synthetic noise is shown in figure 1.

3. PERFORMANCE ANALYSIS PARAMETERS

The purpose of applying a single channel inverse deghosting operator is to suppress the echo reflected at the earth's surface. For teleseismic signals, the incidence angle is approximately 15°, thus the down-going pulse could be modeled with a reflection coefficent of 0.9 and the up-going pulse with a reflection coefficient of 1.1. In practice however, reflection coefficients greater than 1.0 lead to unstable operators, so that single channel echo-suppression is feasible only if we attempt to only partially remove the echo in isolating the up-going and down-going pulses. In analysing the performance of our echo-suppression filters, we try different reflection coefficients from zero to .9 at intervals of approximately .1; further we sample two-way echo times from .05 to 1.2 seconds at intervals of 0.5 seconds. Four minute noise samples are filtered. For each sample specified by the arrays of echo times and reflection coefficients, the variance of the noise is computed before and after applying the deghosting operator. The performance of the filter is guaged in decibels as 10 log (variance after filtering/variance before filtering). Negative values indicate a reduction in noise; positive an amplification in noise due to applying the deghosting filter.

4. PRE-FILTERING AND DEGHOSTING MODELS

This analysis will demonstrate that the performance on ambient noise is very sensitive to the bandpass filter and also on the numerical method used to deghost. Two different deghosting methods, two different bandpass filters, and unfiltered data make up a total of five cases to be evaluated by performance arrays. To produce each element in the array we operate on four minutes of data: each array, 16 hours of data, and for all five cases, 80 hours of data. The fact that all of these performances figures were computed with less than 40 minutes of computer time attests to speed of the bandpass and deghosting operators.

The deghosting methods are described as method I and method II. Both are recursive filters which require only one multiplication per data point.

Method I.

$$Y_r = X_{r + m/2} - R \cdot X_{r-m/2}$$

$$F_{mi + j} = R \cdot F_{m(i-1)+j} + Y_{mi+j}$$

$$M < Mi < N$$

$$1 < j < M-1$$

X_r is the array of data containing the echo

R, reflection coefficient

F_r, deghosted data

m, echo-time measured in number of points

Method II.

$$Y_r = X_{r + m/2} - 0.9 \cdot X_{r-m/2}$$

$$F_{mi + j} = R \cdot F_{m(i-1)+j} + Y_{mi + j}$$

The results evaluated for two band-pass filters employ gapped finite difference which involves only several subtractions per data point.

5. GAPPED FINITE DIFFERENCE FILTER

The gapped difference operator is given as $\{1, o,o. . .o, -k\}$, where $k \leq 1$, and the gap is specified by the number of points between 1 and k. Here we are given by k = 1. The spectrum of the operator is given by

$$D(f) = i \sin\left(\frac{\pi}{2}\frac{f}{fo}\right)$$

where the frequency of the first peak of the filter is related to the number of points in the gap, L.

$$L = \frac{S.R}{2\, f_o}$$ S. R., the sampling rate.

Note that series application of D(f) can be used to generate higher differences

$$D^{(m)}\ (fo) = (i^2)^{\frac{m}{2}} = (-1)^N = D^{2n}\ (f_o)$$

where n = 1,2,3, ... specifies the 2nd difference, 4th difference, etc. Taken as a filter we observe that for n = odd, the sign of the filter is reversed. The response of the filter is

$$D^{(2n)}\ (f) = (-1)^n \sin^{2n}\left(\frac{\pi}{2}\frac{f}{fo}\right)$$

The gap, L, is determined by setting the first peak to the desired frequency. Nulls occur at integer multiples of twice the frequency of the first peak, and additional peaks occur at frequencies between the null's. Suppose at frequencies greater than the first null in the spectrum, for example at f=2, the signal and noise power are expected to attenuate rapidly with increasing frequency. These high frequency peaks will in this case produce negligible effects in the filtered output. If, however, we wish to insure attenuation of high frequency peaks in the noise spectrum we may apply in series with the filter a low pass smoothing operator $\{1, o, o, \ldots, o, +k\}$ where $k \leq 1$. The spectrum of the operator is given by S(f).

$$S(f) = \cos\left(\frac{\pi}{2}\frac{f}{fo}\right)$$

Repeated application of the smoothing operator leads to the operator

$$S^{(m)}\ (f) = \cos^{m}\left(\frac{\pi}{2}\frac{f}{fo}\right)$$

where, for example, fo may be taken at the folding frequency.

For k = 1 there are no multiplications in either the smoothing or difference operator, so that the above digital operators are exceedingly fast. For k = 1 only an approximate inverse can be obtained. These are, in fact, simply deghosting operators. For $k \leq 1$, exact inverses can be obtained. The inverse can be designed as recursive filters with n multiplications per point where n is the number of series applications of $D^{(n)}$ or $S^{(n)}$.

Smoothed gapped finite difference filters can be described spectrally as

$$F(f) = D^{(2n)}(f)\, S^{(m)}(f)$$

$$= (-1)^n \sin^{2n}\left(\frac{\pi f}{fo}\right) \cos^m\left(\frac{\pi f}{2f_1}\right)$$

The two models evaluated were

1) Smoothed second difference filter

$n = 1$ $f_o = 1.1$ cps $m = 4$ $f_1 = 10$ cps

2) Smoothed fourth difference filter

$n = 2$ $f_o = 1.1$ cps $m = 4$ $f_1 = 10$ cps

6. RESULTS

Figure one shows the power spectrum of the noise data used in the evaluation of combined bandpass filters and deghosting operators. Table I through Table V, for different values of the reflection coefficient and the echo time (sum of up-hole and down-hole time), show the effect of the deghosting on the noise. Table I is for unfiltered data, on the other tables the noise is bandpass filtered. The performances figures in decibels show the effect of deghosting by comparing variance of the filtered noise after deghosting to the variance of filtered noise before deghosting. Examination of the performance figures show that both the bandpass filter and the deghosting method significantly affect the performance of single channel deghosting operators.

7. CONCLUSIONS

For unfiltered data and echo times between .2 sec and 0.35 seconds, and greater than 0.6 seconds the assumed reflection coefficient should not exceed 0.75 which is adequate for removal of 85% of the echo. For data prefiltered by smoothed second difference operators, the best performance is obtained with deghosting method I.

For echo times greater than 0.3 seconds, the reflection coefficient should not exceed 0.4 for removal of slightly less than half of the echo amplitude.

For data prefiltered by fourth difference operators, the best performance was obtained using deghosting method I. For echo times exceeding 0.3 seconds and less than 0.75 seconds, the reflection coefficient should not exceed 0.2 seconds. For echo times greater than 0.75 but less than 0.9 seconds, the reflection coefficient should not exceed 0.45; for echo times equal or greater than 0.9 seconds the reflection coefficient should not exceed 0.75. The fourth difference filter appears most suited as the bandpass filter. Due to deghosting, there will be little if any compromise of the expected 9 db gain obtained by applying the bandpass filter. Any residual echo distortion must be removed by multichannel filtering.

For display purposes, an adequate job of deghosting can be done on all channels in the absence of bandpass filtering. Provided that the assumed reflection coefficient does not exceed .75, less than 1 db total noise amplification is assured.

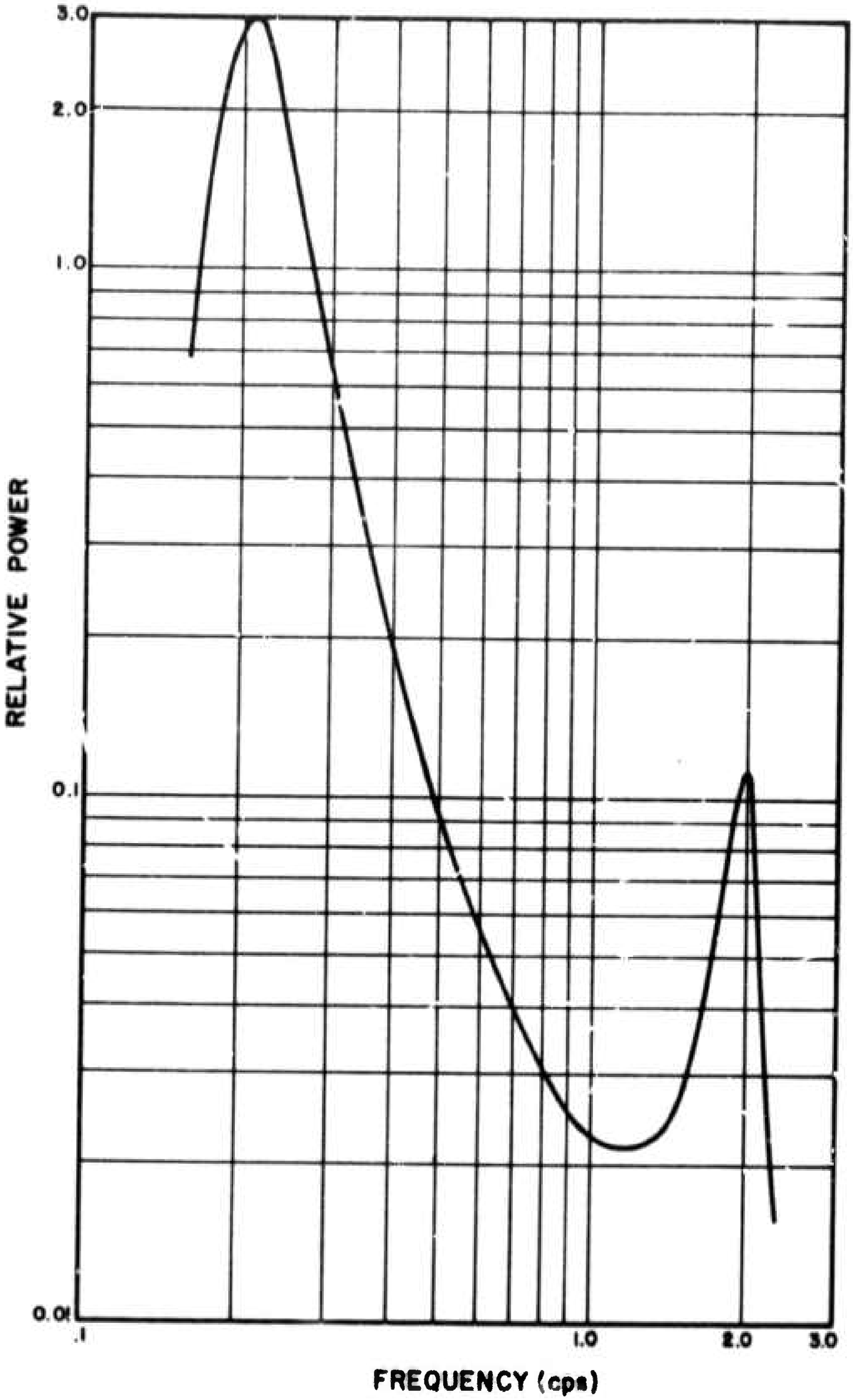

Figure 1. Noise Power Spectrum

PERFORMANCE OF DEGHOSTING FILTER IN DECIBELS

10 LOG $_{10}$(VARIANCE AFTER DEGHOSTING/VARIANCE BEFORE DEGHOSTING)

Reflection Coefficient →

Echo-Time (sec) ↓	0	.09	.18	.27	.36	.45	.54	.63	.72	.81	.90
.05	0	-.8	-1.5	-2.3	-3.1	-3.9	-4.7	-5.5	-6.3	-7.0	-7.6
.10	-.0	-.7	-1.3	-2.0	-2.6	-3.2	-3.7	-4.3	-4.8	-5.2	-5.6
.15	-.0	-.6	-1.1	-1.6	-2.1	-2.6	-3.0	-3.4	-3.7	-4.0	-4.2
.20	-.0	-.5	-.9	-1.2	-1.5	-1.7	-1.6	-1.9	-1.9	-1.8	-1.4
.25	-.3	-.4	-.7	-.9	-.9	-.8	-.4	.3	1.4	3.2	6.3
.30	-.0	-.4	-.7	-.9	-.9	-.8	-.5	-.0	.8	2.1	4.6
.35	-.0	-.4	-.8	-1.0	-1.2	-1.3	-1.3	-1.2	-.9	-.3	1.0
.40	-.0	-.4	-.8	-1.2	-1.5	-1.7	-1.8	-1.8	-1.6	-.9	1.0
.45	-.0	-.5	-.9	-1.3	-1.6	-1.8	-2.0	-2.1	-2.0	-1.7	-.8
.50	-.0	-.5	-.9	-1.3	-1.6	-1.9	-2.0	-2.1	-2.0	-1.5	-.3
.55	-.0	-.5	-.8	-1.2	-1.5	-1.7	-1.9	-1.9	-1.7	-1.2	.1
.60	-.0	-.4	-.8	-1.1	-1.3	-1.5	-1.6	-1.6	-1.3	-.7	1.0
.65	-.0	-.3	-.6	-.9	-1.1	-1.2	-1.3	-1.2	-.9	-.1	1.7
.70	-.0	-.3	-.5	-.6	-.7	-.7	-.7	-.5	-.1	.7	2.2
.75	-.0	-.2	-.3	-.4	-.4	-.3	-.0	.4	1.1	2.3	4.6
.80	-.0	-.1	-.2	-.3	-.2	-.1	.2	.6	1.3	2.5	4.6
.85	-.0	-.1	-.2	-.2	-.2	-.1	.1	.5	1.2	2.3	4.7
.90	-.0	-.1	-.2	-.3	-.3	-.2	-.0	.3	.9	1.9	4.2
.95	-.0	-.1	-.2	-.3	-.3	-.3	-.2	.1	.5	1.3	3.1
1.00	-.0	-.1	-.2	-.3	.3	-.3	-.2	.0	.4	1.2	2.8
1.05	-.0	-.1	-.2	-.2	-.2	-.2	-.1	.1	.5	1.1	2.7
1.10	-.0	-.1	-.1	-.1	-.1	-.0	.1	.3	.7	1.5	3.1
1.15	-.0	-.0	.0	.0	.1	.2	.4	.7	1.2	2.2	4.4
1.20	-.0	.0	.1	.2	.3	.5	.7	1.1	1.7	2.7	4.8

Table 1. Data Unfiltered, Deghosting Method I.

PERFORMANCE OF DEGHOSTING FILTER IN DECIBELS

$10 \log_{10}$(VARIANCE AFTER DEGHOSTING/VARIANCE BEFORE DEGHOSTING)

Echo-Time (sec)	Reflection Coefficient: 0	.09	.18	.27	.36	.45	.54	.63	.72	.81	.90
.05	0	-.8	-1.5	-2.3	-3.1	-3.9	-4.7	-5.5	-6.3	-7.0	-7.5
.10	.0	-.7	-1.3	-2.0	-2.6	-3.2	-3.7	-4.3	-4.8	-5.2	-5.5
.15	.0	-.6	-1.1	-1.7	-2.2	-2.6	-3.1	-3.5	-3.9	-4.2	-4.5
.20	-.0	-.4	-.9	-1.3	-1.7	-2.1	-2.4	-2.8	-3.1	-3.3	-3.3
.25	-.0	-.3	-.6	-.8	-1.1	-1.3	-1.5	-1.7	-1.9	-2.1	-2.2
.30	.0	-.1	-.2	-.3	-.4	-.4	-.4	-.3	-.0	.4	1.7
.35	.0	.0	.1	.1	.3	.5	.8	1.2	1.8	2.7	4.3
.40	.0	.1	.3	.5	.8	1.1	1.6	2.3	3.2	4.7	7.5
.45	.0	.2	.5	.8	1.1	1.6	2.1	2.8	3.7	4.8	6.7
.50	-.0	.3	.6	.9	1.4	1.9	2.5	3.2	4.2	5.7	8.1
.55	-.0	.3	.6	1.0	1.5	2.1	2.7	3.6	4.7	6.2	8.7
.60	-.0	.3	.6	1.0	1.5	2.1	2.8	3.8	5.0	6.7	9.5
.65	-.0	.3	.6	1.0	1.5	2.1	2.8	3.7	4.9	6.7	9.0
.70	-.0	.2	.6	.9	1.4	1.9	2.6	3.4	4.4	5.9	8.0
.75	-.0	.2	.5	.8	1.2	1.7	2.3	3.1	4.1	5.5	8.1
.80	-.0	.2	.4	.7	1.1	1.6	2.1	2.9	3.8	5.3	7.8
.85	-.0	.2	.4	.6	1.0	1.4	2.0	2.7	3.8	5.2	7.6
.90	-.0	.1	.3	.6	.9	1.3	1.9	2.6	3.7	5.3	8.2
.95	-.0	.1	.3	.5	.8	1.2	1.8	2.5	3.5	4.9	7.5
1.00	-.0	.1	.3	.5	.8	1.2	1.7	2.3	3.3	4.6	6.8
1.05	-.0	.1	.2	.5	.7	1.1	1.6	2.2	3.0	4.2	6.3
1.10	-.0	.1	.2	.4	.7	1.1	1.6	2.2	3.1	4.3	6.4
1.15	-.0	.1	.2	.4	.7	1.1	1.6	2.3	3.3	4.7	7.5
1.20	-.0	.1	.2	.4	.7	1.1	1.7	2.4	3.4	4.9	7.7

Table 2. Smoothed Second Difference Filter, Deghosting Method I.

PERFORMANCE OF DEGHOSTING FILTER IN DECIBELS

10 $\log_{10}$(VARIANCE AFTER DEGHOSTING/VARIANCE BEFORE DEGHOSTING)

↓ Echo-Time (sec)	Reflection Coefficient → 0	.09	.18	.27	.36	.45	.54	.63	.72	.81	.90
.05	0	-.8	-1.5	-2.3	-3.1	-3.9	-4.6	-5.4	-6.2	-6.8	-7.3
.10	.0	-.6	-1.3	-1.9	-2.5	-3.1	-3.6	-4.1	-4.5	-4.9	-5.2
.15	.0	-.5	-1.0	-1.5	-2.0	-2.4	-2.9	-3.3	-3.6	-3.9	-4.1
.20	.0	-.3	-.7	-1.1	-1.4	-1.8	-2.1	-2.4	-2.7	-2.9	-3.2
.25	.0	-.1	-.3	-.5	-.7	-.9	-1.2	-1.4	-1.7	-1.9	-2.2
.30	.0	.1	.1	.1	.1	.1	-.0	-.1	-.2	-.4	-.5
.35	.0	.3	.5	.8	1.0	1.2	1.4	1.7	1.9	2.3	2.6
.40	.0	.4	.9	1.3	1.8	2.3	2.9	3.5	4.4	5.8	8.3
.45	.0	.6	1.2	1.8	2.4	3.1	3.9	4.8	5.9	7.3	9.3
.50	.0	.6	1.3	2.0	2.8	3.7	4.6	5.8	7.1	9.3	11.8
.55	.0	.7	1.4	2.1	2.9	3.8	4.9	6.0	7.5	9.3	12.1
.60	.0	.6	1.3	2.0	2.8	3.7	4.7	5.9	7.4	9.3	12.4
.65	.0	.6	1.1	1.8	2.5	3.3	4.2	5.4	6.8	8.8	11.9
.70	.0	.4	.9	1.5	2.0	2.7	3.5	4.4	5.6	7.1	9.2
.75	.0	.3	.7	1.1	1.5	2.0	2.6	3.4	4.3	5.7	8.2
.80	.0	.2	.4	.6	.9	1.3	1.8	2.4	3.2	4.4	6.7
.85	.0	.0	.1	.2	.4	.6	1.0	1.4	2.1	3.2	5.3
.90	.0	-.1	-.1	-.1	-.1	.0	.2	.6	1.2	2.3	4.0
.95	.0	-.2	-.3	-.4	-.5	-.5	-.4	-.2	.3	1.2	3.0
1.00	.0	-.2	-.5	-.7	-.8	-.9	-.9	-.8	-.5	.1	1.4
1.05	.0	-.3	-.5	-.8	-.9	-1.1	-1.1	-1.1	-.9	-.5	.6
1.10	.0	-.3	-.5	-.8	-.9	-1.0	-1.0	-1.0	-.7	-.2	1.0
1.15	.0	-.3	-.5	-.7	-.8	-.8	-.7	-.5	-.1	.7	2.4
1.20	.0	-.2	-.4	-.5	-.6	-.5	-.3	.1	.9	2.1	4.6

Table 3. Smoothed Fourth Difference Filter, Deghosting Method I.

PERFORMANCE OF DEGHOSTING FILTER IN DECIBELS

10 LOG $_{10}$(VARIANCE AFTER DEGHOSTING/VARIANCE BEFORE DEGHOSTING)

← Echo-Time (sec) / Reflection Coefficient →	0	.09	.16	.27	.36	.45	.54	.63	.72	.81	.90
.05	-11.7	-11.7	-11.6	-11.4	-11.2	-10.9	-10.5	-10.0	-9.3	-8.5	-7.5
.10	-6.4	-6.4	-6.3	-6.2	-6.2	-6.0	-5.9	-5.8	-5.7	-5.6	-5.5
.15	-3.2	-3.2	-3.2	-3.3	-3.4	-3.5	-3.6	-3.8	-4.0	-4.2	-4.5
.20	-1.0	-1.0	-1.1	-1.3	-1.5	-1.8	-2.1	-2.4	-2.7	-3.1	-3.3
.25	.6	.5	.4	.2	.0	.3	-.6	-1.0	-1.3	-1.8	-2.2
.30	1.7	1.7	1.6	1.4	1.3	1.1	.9	.7	.7	.8	1.7
.35	2.5	2.5	2.4	2.4	2.3	2.2	2.2	2.3	2.6	3.1	4.3
.40	3.1	3.1	3.1	3.0	3.0	4.1	3.2	3.5	4.0	5.1	7.5
.45	3.5	3.5	3.5	3.5	3.5	3.6	3.8	4.0	4.5	5.3	6.7
.50	3.7	3.7	3.7	3.8	3.8	3.9	4.2	4.5	5.1	6.1	8.1
.55	3.8	3.8	3.8	3.9	4.0	4.2	4.4	4.9	5.5	6.6	8.7
.60	3.8	3.8	3.9	3.9	4.0	4.2	4.5	5.0	5.8	7.1	9.5
.65	3.8	3.8	3.8	3.8	4.0	4.2	4.5	5.0	5.8	7.2	9.8
.70	3.6	3.6	3.7	3.7	3.8	4.0	4.2	4.6	5.3	6.3	8.0
.75	3.5	3.5	3.5	3.5	3.5	4.7	4.0	4.3	4.9	5.9	8.1
.80	3.4	3.4	3.4	3.4	3.4	3.5	3.7	4.1	4.7	5.7	7.8
.85	3.2	3.2	3.2	3.2	3.3	4.4	3.6	3.9	4.6	5.6	7.6
.90	3.1	3.1	3.1	3.1	3.2	3.3	3.5	3.8	4.5	5.7	8.2
.95	3.0	3.0	3.0	3.0	3.1	4.1	3.3	3.7	4.3	5.3	7.5
1.00	3.0	2.9	2.9	2.9	3.0	3.0	3.2	3.5	4.0	5.0	6.8
1.05	2.9	2.9	2.9	2.9	2.9	3.0	3.1	3.3	3.8	4.6	6.3
1.10	2.8	2.8	2.8	2.8	2.9	2.9	3.1	3.4	3.8	4.7	6.4
1.15	2.8	2.8	2.8	2.8	2.9	3.0	3.1	3.5	4.0	5.1	7.5
1.20	2.8	2.8	2.8	2.8	2.8	3.0	3.2	3.5	4.2	5.3	7.7

Table 4. Smoothed Second Difference Filter, Deghosting Method II.

PERFORMANCE OF DEGHOSTING FILTER IN DECIBELS

$10 \log_{10}$(VARIANCE AFTER DEGHOSTING/VARIANCE BEFORE DEGHOSTING)

Reflection Coefficient →

Echo-Time (sec) ↓	0	.09	.18	.27	.36	.45	.54	.63	.72	.81	.90
.05	-10.8	-10.7	-10.7	-10.5	-10.3	-10.0	-9.5	-9.0	-8.4	-7.8	-7.3
.10	-5.3	-5.3	-5.2	-5.1	-5.0	-4.9	-4.8	-4.8	-4.8	-4.9	-5.2
.15	-2.0	-2.8	-2.1	-2.1	-2.3	-2.4	-2.6	-2.9	-3.2	-3.7	-4.1
.20	.2	.2	.0	-.1	-.4	-.8	-1.2	-1.6	-2.1	-2.6	-3.2
.25	1.8	1.8	1.6	1.4	1.0	.6	.1	-.4	-1.0	-1.6	-2.2
.30	3.0	3.0	2.8	2.6	2.3	1.9	1.5	1.0	.5	.0	-.5
.35	3.9	3.8	3.8	3.6	3.5	3.3	3.1	2.9	2.8	2.7	2.8
.40	4.5	4.5	4.5	4.5	4.5	4.5	4.6	4.8	5.3	6.2	8.3
.45	4.9	4.9	5.0	5.1	5.2	5.4	5.7	6.1	6.8	7.7	9.3
.50	5.1	5.1	5.2	5.4	5.6	6.0	6.4	7.1	8.0	9.4	11.8
.55	5.2	5.2	5.3	5.5	5.6	6.1	6.7	7.4	8.3	9.8	12.1
.60	5.0	5.1	5.2	5.4	5.6	6.0	6.5	7.2	8.2	9.8	12.4
.65	4.8	4.8	4.9	5.0	5.2	5.6	6.0	6.7	7.6	9.2	11.9
.70	4.4	4.4	4.5	4.6	4.7	4.9	5.2	5.7	6.4	7.5	9.2
.75	3.9	3.9	3.9	3.9	4.0	4.1	4.3	4.6	5.1	6.1	8.2
.80	3.3	3.3	3.2	3.2	3.2	3.2	3.3	3.5	4.0	4.8	6.7
.85	2.6	2.5	2.5	2.5	2.4	2.4	2.4	2.5	2.9	3.6	5.3
.90	1.8	1.8	1.8	1.7	1.6	1.5	1.5	1.6	1.9	2.6	4.0
.95	1.1	1.1	1.0	.9	.8	.7	.6	.7	.9	1.5	3.0
1.00	.6	.5	.5	.3	.2	.1	-.0	-.1	-.0	.4	1.4
1.05	.2	.2	.1	-.0	-.1	-.3	-.4	-.5	-.5	-.3	.6
1.10	.1	.1	.0	-.1	-.2	-.3	-.4	-.4	-.3	.0	1.0
1.15	.2	.2	.2	.1	.1	.1	.1	.2	.4	1.0	2.4
1.20	.6	.5	.5	.5	.5	.5	.6	.9	1.4	2.4	4.5

Table 5. Smoothed Fourth Difference Filter, Deghosting Method II.

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
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5. AUTHOR(S) (Last name, first name, initial)

Sax, R. L.

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13. ABSTRACT

Arrays of performance values showing the change in additive noise variance due to single channel deghosting indicate significant sensitivity to both the deghosting method and band pass filtering. Only part of the echo can be removed feasibly, for example, with less than one db increase in the noise, by the single channel deghosting filter. The maximum fraction of the echo which can be removed varies greatly with the echo time, especially if the noise was band pass filtered.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Performance						
Deghosting						
Pre-band pass filtering						
Synthetic noise						
Echo-suppression filters						

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