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EXTRACTION OF INTERPRETIVE WAVELETS BY MODIFIED WIENER FILTER METHOD

—TEST AND EVALUATION WITH MARINE SESMIIC DATA

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修正 위너필터 方法에 依한 解釋波의 抽出

—海洋彈性波 探査資料에 依한 實驗 및 評價

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Abstract: Piazza's synthetic model, a modified Wiener filter method, was tested to establish the procedure of desirable interpretive wavelet extraction and its application to the marine seismic exploration using several approaches with a real offshore seismic data of the southeast Asia.

Noise spectrum acquisition is difficult and any assumptions for it do not produce interpretive wavelets as good as synthetic model result by Piazza (1979).

However the resolution could be improved with spiking deconvolution and following zero phase bandpass filter, and the testing procedure and evaluation of results can hopefully contribute in future study and practical evaluation of Piazza's method.

要約: 彈性波 石油探査資料의 分析을 위한 위너필터法이나 그 類似한 方法에 依한 彈性波痕(seismic trace)의 디콘볼루션(deconvolution or wavelet shaping)은 가장 基本的이며 어려운 處理過程으로 波形의 地層反射資料를 實際의 地層面과 地質構造에 가능한 한 가깝게 描寫하기 위한 反轉作用處理(inversion process)方法中의 하나이다. 위너필터法은 여러 學者들에 의해 解決方法이 修正 考案되었으며 그 연산자(operator)는 한 波形을 願하는 波形으로 바꾸는 가장 近似한(least-mean-square-error) 因子이다. 여기에는 騷音因子(noise factor)가 包含되며 그 性質과 程度에 따라 연산자의 모양이 달라지고 또 資料의 解釋能力도 달라진다. 이 연산자의 重要部分이 解釋波로서 어떤 波形反射를 하나의 스파이크(spike) 反射로 變化시킨뒤 그 스파이크를 鈍化시키는 役割을 하게 한다.

實際로 東南아시아 海底油田海域의 彈性波深査資料를 사용하여 騷音因子의 標本抽出(sampling)과 그 輕重因子(weighting factor)에 따라 解釋波의 抽出과 振幅스펙트럼(amplitude spectrum)을 導出評價하였다. 結果는 騷音因子의 最過抽出이 어렵고 또한 解釋波의 形態가 一般필터의 연산자와 類似한 관계로 一般的인 解釋波의 抽出에는 效果的이지 못한 것으로 推定된다. 따라서 스파이킹 디콘볼루션(spiklng deconvolution) 後에 通過帶域 필터를 同伴하는 것이 바람직하며 그 周波帶는 資料分析으로 騷音帶를 分離시킬 수 있어야 한다.

INTRODUCTION

Piazza (1979) has shown a filtering operation by means of modified Wiener filter to establish the best compromise between noise attenuation and resolution when shaping the field wavelet into an interpretive wavelet.

In the paper, interpretive wavelet is designed with incorporation of a weighting factor(=K) for the noise in the original Wiener filter and showed precise results of testing using synthetic models. The recommendable K value appeared 4~8 in general case by his conclusion.

To enhance high frequency contents and to improve resolution of our seismic data, a series of testing to derive mentioned interpretive wavelets and their amplitude spectra has been performed using several approaches with an offshore seismic data of the southeast Asia.

The primary and immediate purpose of this study is to establish the procedure of desirable interpretive wavelet extraction and its application.

Complexity of field data seems to cause difficulties in extraction of desirable interpretive wavelet. Thus, the results of this study is preliminary, incomplete, and somewhat unsuccessful but the testing procedure and evaluation of results can hopefully contribute in future study and practical evaluation of Piazza's method.

PROCEDURE

Interpretive wavelet(Wi) is given as following equation by Piazza.

Wi(f) = ((ABS(R(f)))**2*(ABS(W(f)))**2)/
((ABS(R(f)))**2*(ABS(W(f)))**2
+K*(ABS(N(f)))**2)

here R: reflectivity
W: input wavelet
N: noise
K: weighting factor of noise

(ABS(R(f))**2 means square of absolute value of FFT(R(t)) which is power spectrum of reflectivity time series)

For writing convenience, if S is signal, then

ABS(R(f))**2*ABS(W(f))**2=ABS(S(f))**2

thus giving,

Wi(f)=ABS(S(f))**2/(ABS(S(f))**2
+K*ABS(N(f))**2)

In the original Wiener filter, K=1 is assumed and resolved by Wiener-Hoof equation and Levinson algorithm.

Because signal and noise are not separately measurable to test above equation directly, this study used three different approaches to transform above equation in testable manner with available software.

All the calculations are performed by interactive software package SPEAKEZ and interfaces for data input, output and display are performed by inhouse batch and WGC programs.

TEST METHOD 1 AND EVALUATION OF THE RESULTS

This method is assuming that seismic data is signal plus noise and converting the equation as a function of data and noise power spectra.

If X(t)=S(t)+N(t) where X(t) is seismic data, then the power spectrum relation is as follow.

ABS(X(f))**2=ABS(S(f))**2+
ABS(N(f))**2

Wi(f)=(ABS(X(f))**2-ABS(N(f))**2)/
(ABS(X(f))**2+(K-1)*ABS
(N(f))**2)

Time domain is converted to frequency domain by fast Fourier transform (FFT) to produce power spectrum and inverse operation to produce wavelet time series is done by inverse fast Fourier transform(IFFT), both are available in SPEAKEZ contributor's functions. For these functions, number of input samples must be power of 2.

This test used 128 samples (256ms of trace) for data and noise portions. Longer length such as 256 and 512 samples are tested but gave equivalent results hence it is not shown here.

Data portion is sampled at time 1602~1856

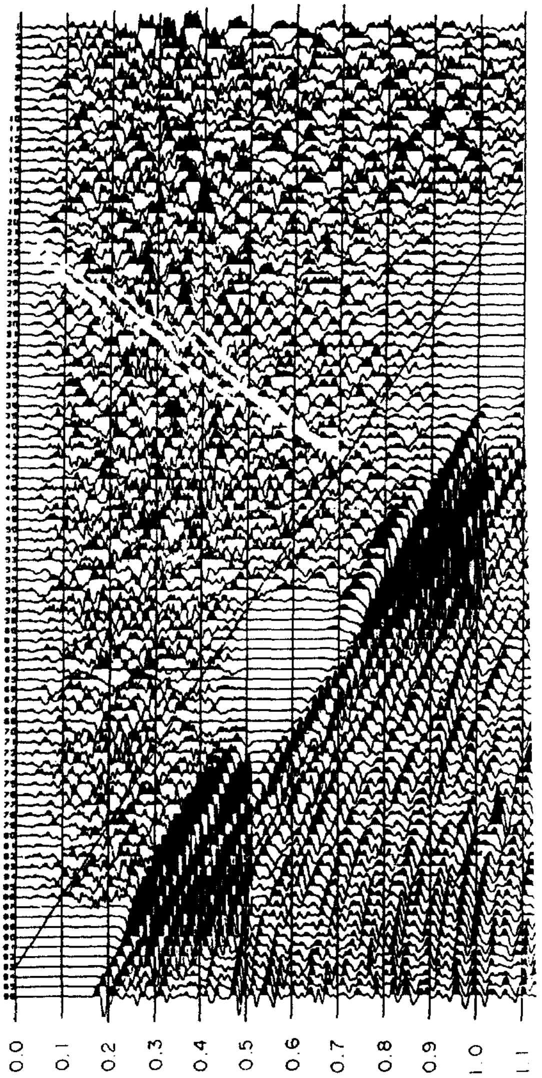


Fig. 1. A shot-gather record which is used for testing (96 data channels and 2ms sampling interval).

ms of trace 15 (Fig. 1). Noise portion is sampled at pre-first-break time 2~256ms and results are shown in Fig. 3~4. Other noise portion is sampled at 502~756ms and results are shown in Fig. 5~6.

Two noise portions have different power as shown in Fig. 1, and the amplitude ratio of data and noise (MEAN(ABS(X(f)))/MEAN(ABS(N(f)))) for 2~256ms noise portion is 454(26.6 db) and 502~756ms is 112(20.5 db).

Amplitude spectrum of interpretive wavelet is just displaying array of Wi(f) which has 128 elements (same as input number of samples) and frequency ranges from 0 hz to 496.1 hz (SF-SF/NS; where SF is sampling frequency which is double of Nyquist frequency and NS is number of samples) and amplitude value is relatively scaled by RMS within a whole trace window.

As shown in Fig. 3 and 5, the amplitude spectrum is varying from flat white to edgeward spread losing more high frequency contents in the middle (Nyquist frequency is at middle point). This general trend is matching with Piazza's report but our test is showing rough variation and limitation of variation in higher K values.

K value which is showing flat spectrum is 1 in our test but 0.0000001 in the Piazza's result (Fig. 9). K value which is attenuating most of seismic data frequency contents (above 10hz) appears at K=1000 in Piazza's but much higher value in our results.

In general, our test results follow known trend very roughly and K values are also in quite different magnitude scheme.

Interpretive wavelets are product of inverse Fourier transform of Wi(f) and time scale ranges are 0~256ms (actually first sample is at 2ms and display starts at time 0, thus giving one sample to right). Amplitude scales are based on the relative RMS values within a whole trace window.

Maximum absolute amplitude values are varying from 1 to near zero by increasing K values. As shown in Fig. 4 and 6, the main lobes of the wavelets start from peak value at 1st sample (time is 2ms) and widening by increasing K values from spike when K values are small.

The widening of main lobes with increasing K values is general trend reported by Piazza

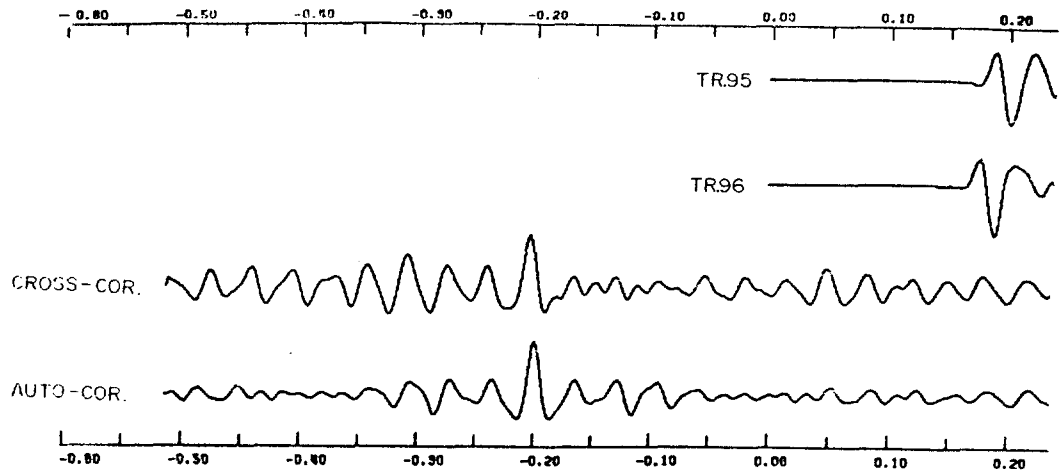
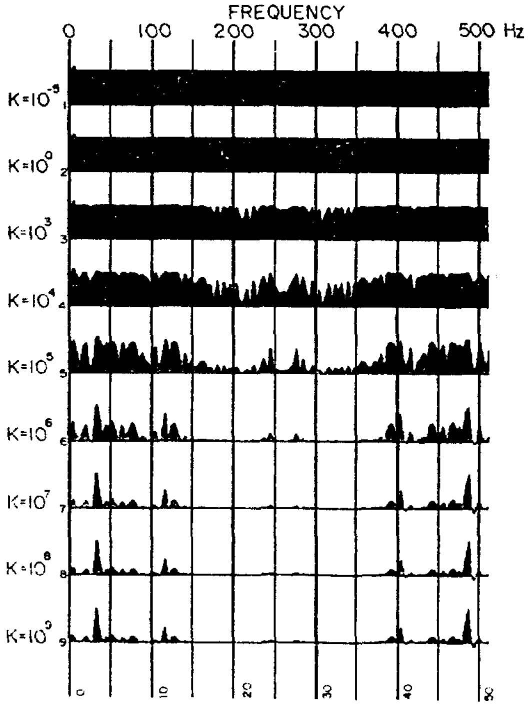


Fig. 2. Crosscorrelation and autocorrelation of 2 near traces.



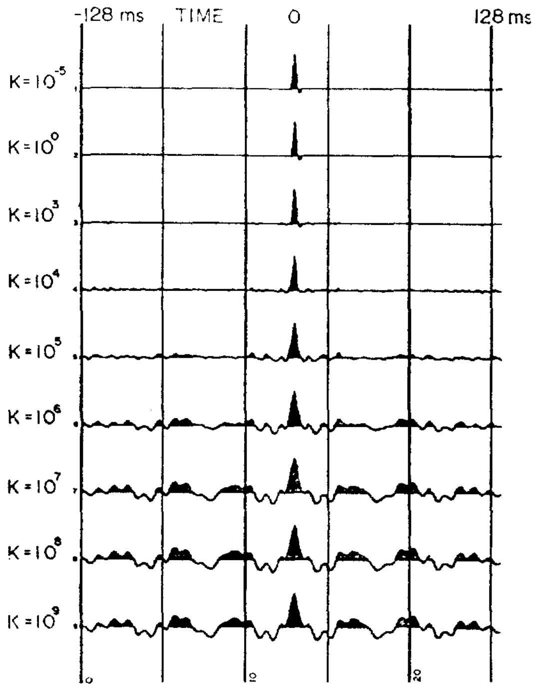


Fig. 3. Amplitude spectrum of interpretive wavelets by method 1 (noise sampled at 2-256ms of tr. 15).

Fig. 4. Interpretive wavelets by method 1 (noise sampled at 2-256ms of tr. 15).

(Fig. 10). But in this test result, main lobes are widening in very smaller extent than the Piazza's result and trailing oscillatory lobes are becoming bigger by increasing K values which is not appearing at all in Piazza's test.

Also in this test displays for the interpretive wavelets, negative time domain part starts at 130ms and ends at 256ms thus giving coefficients of -128ms to -2ms which is showing wrapping around phenomena. Interpretive wavelet is zero phase and symmetric at peak amplitude time at first sample which should be considered as

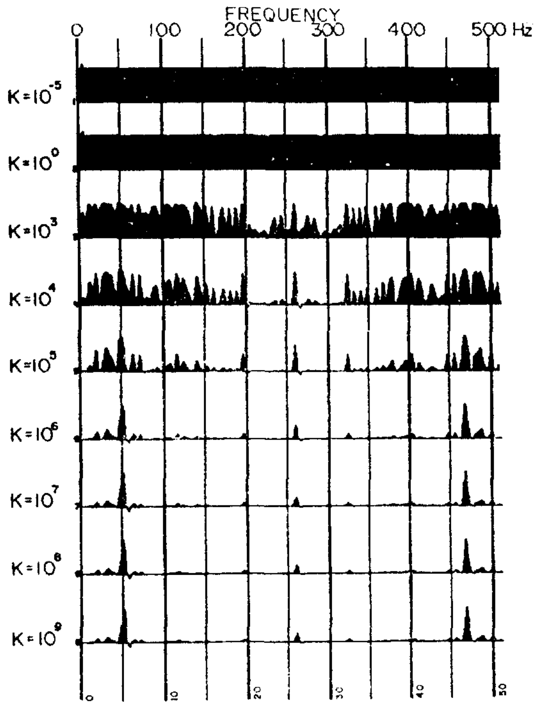


Fig. 5. Amplitude spectrum of interpretive wavelets by method 1 (noise sampled at 502-756ms of tr. 15).

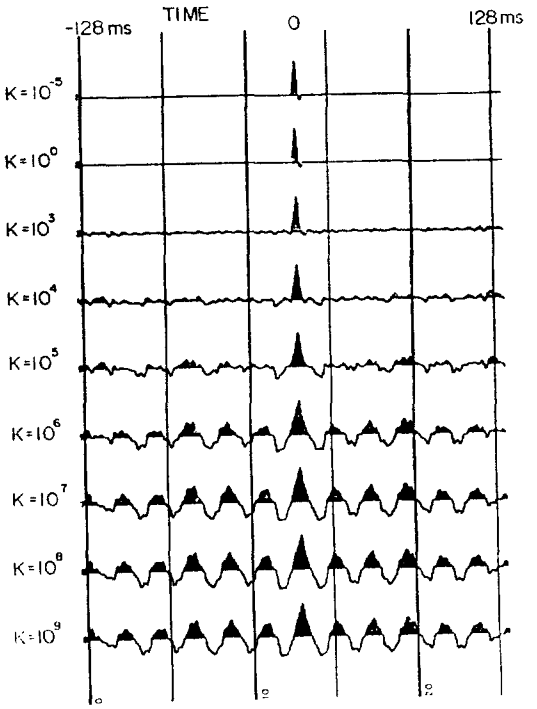


Fig. 6. Interpretive wavelets by method 1 (noise sampled at 502-756ms of tr. 15).

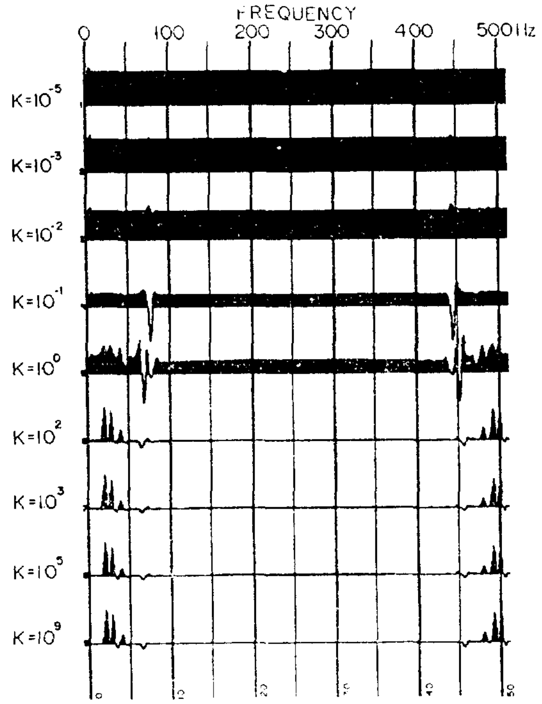


Fig. 7. Amplitude spectrum of interpretive wavelets by method 2 (crosscorrelation and autocorrelation method).

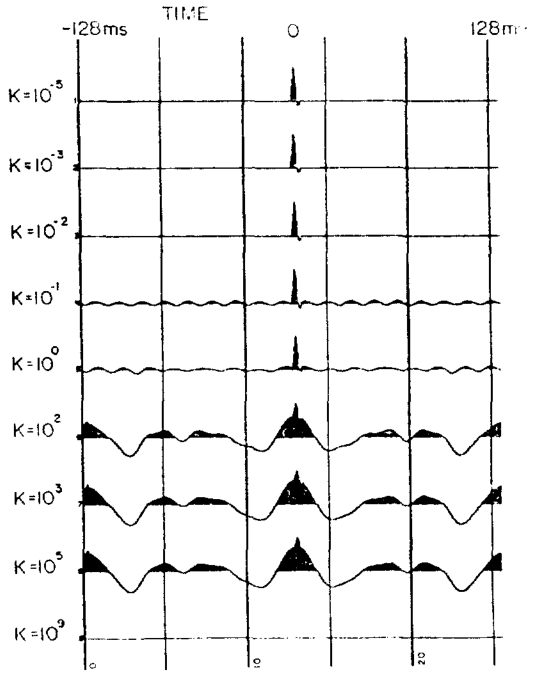


Fig. 8. Interpretive wavelets by method 2 (crosscorrelation and autocorrelation method).

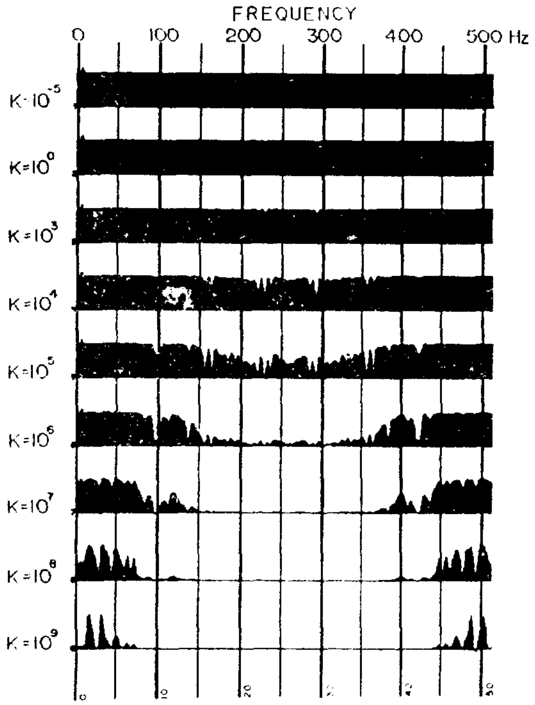


Fig. 9. Amplitude spectrum of interpretive wavelets by method 3 (assuming white noise of 20db amplitude of seismic data).

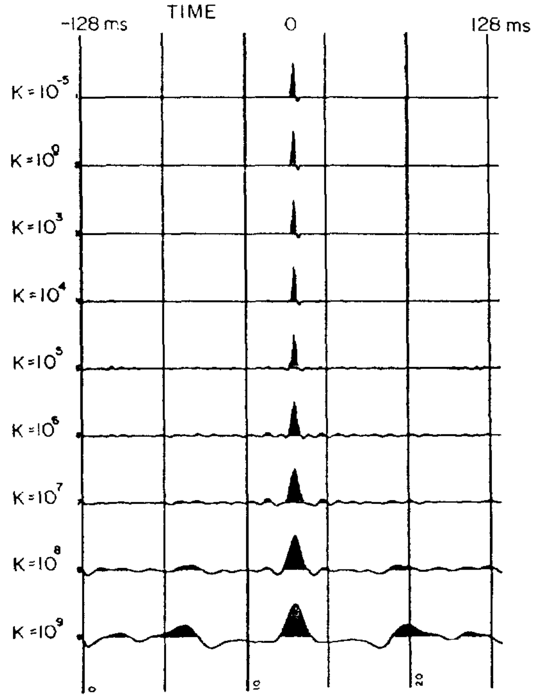


Fig. 10. Interpretive wavelets by method 3 (assuming white noise of 20 db amplitude of seismic data).

time zero.

Signal to noise ratios of the two tests (Fig. 4 and 6) are different and the lower ratio case (Fig. 6) seems to show a little more widening trend of main lobes by increasing K values, but overall result is very similar each other and gives poor comparison with Piazza's result.

In this test, another method of power spectrum derivation by cosine Fourier transform of autocorrelation has been tried, but it gave poorer result than above direct square amplitude spectrum method.

TEST METHOD 2 AND EVALUATION OF THE RESULTS

This method is assuming that crosscorrelation spectrum of adjacent 2 traces represents signal power and autocorrelation spectrum represents signal plus noise power.

If ABS(S(f))**2=REALPART(FFT(crosscorrelation))(...>RFX) and ABS(S(f))**2+ABS(N(f))**2= REALPART(FFT(autocorrelation))(...>RFA) then,

Wi(f)=RFX/(RFX+K*(RFA-RFX))

Crosscorrelation is obtained from 2 near traces (tr. 96 and 95) and autocorrelation is obtained from tr. 96(Fig. 1 and 2).

Coefficients are sampled from peaks and up to 128 samples for both correlations thus cancelling offset or moveout effect of crosscorrelation.

Amplitude spectrum on Fig. 7 shows rough general trend from white to attenuating edgeward by increasing K values. But K value schemes are quite different from method 1.

Interpretive wavelets on Fig. 8 show main lobe widening trend but change is rather abrupt than gradual which is shown in Piazza (Fig. 10). Also trend of change is rough with tailing noises and when K value is very high (9th wavelet in Fig. 8) magnitude of coefficients become zero in the 16 bytes format calculations thus producing no wavelet by IFFT.

TEST METHOD 3 AND EVALUATION OF THE RESULTS

This method is assuming that noise is perfactly white and its power is a certain ratio A of signal or data power.

If ABS(N(f))**2=A*MEAN(ABS(S(f))**2) and approximately MEAN(ABS(S(f))**2)=MEAN(ABS(X(f))**2) then,

Wi(f)=(ABS(X(f))**2-A*MEAN(ABS
(X(f))**2))/(ABS(X(f))**2-
A*MEAN(ABS(X(f))**2))+
(K*A*MEAN(X(f))**2)
=(ABS(X(f))**2-A*MEAN(ABS
(X(f))**2))/(ABS(X(f))**2+
MEAN(ABS(X(f))**2)*(K*A-A))

In the testing, we have assumed A to be 20db of noise amplitude of seismic data portion. This noise amount is equivalent to 1 percent of average amplitude spectrum of the seismic trace.

Fig. 9 shows amplitude spectrum of the interpretive wavelets which is varying from white top to edgeward concentration of amplitude strength.

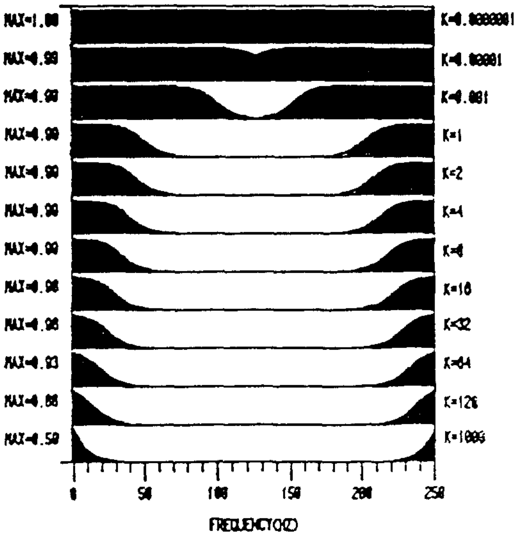


Fig. 11. Amplitude spectrum of interpretive wavelets by Piazza (1979).

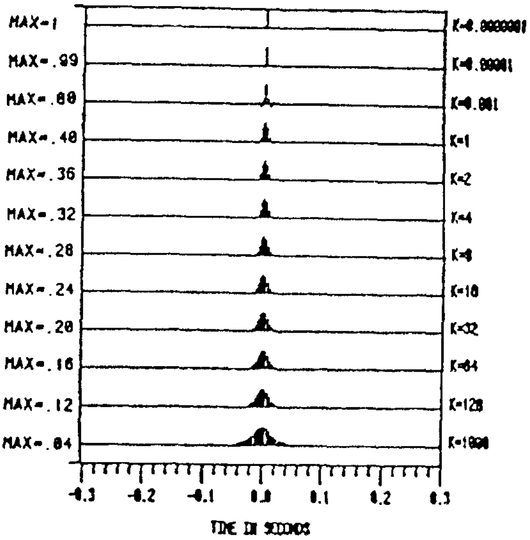


Fig. 12. Interpretive wavelets by Piazza (1979).

Fig. 10 shows interpretive wavelet time series according to K variations.

These results reveal most desirable clean variations of amplitude spectrum and wavelet time series depending on the noise factor K increments. General trend is following Piazza's synthetic model case.

But, in the real seismic world the noises are not white and not in constant power ratio to the signal.

SUMMARY

1. Noise spectrum acquisition is difficult and any assumptions for it do not produce interpretive wavelets as good as synthetic model result by Piazza.
2. When noise spectrum is obtained from a fraction of the seismic data under the assumption of white noise, the result shows relatively good similarity with synthetic model case.
3. Noise weight factor K values seem to be related to signal to noise ratio and their magnitudes are varying exponentially depending on data. Thus optimal K value for the best resolu-

tion can hardly be generalized.

4. If convolution of interpretive wavelet with optimal K value incorporated with spiking deconvolution (same function as modified Wiener filter by Piazza) improves resolution, then zero phase bandpass filter can follow spiking deconvolution for almost equivalent purpose.

5. Because it seems difficult to extract desirable interpretive wavelet from real field data and the wavelet is generally noisy depending on data even it is extracted, as an alternative tool, several ideal model wavelets can be applied and evaluated without extraction effort. User can control the spread of interpretive wavelet by frequency contents.

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