PROCESSING OF BROADBAND ACOUSTIC SIGNALS

by

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INTRODUCTION

The SACLANTCEN 5-channel digital recording system has been presented by Mr Barbagelata and we will now see some examples of what kind of processing we are applying to the recorded signals. The examples are taken from various studies conducted at SACLANTCEN and more information about these studies is, or will shortly be, published in separate reports.

The examples are all processing of acoustic signals derived from explosive sources with typical bandwidth of 8 kHz, sampled at a frequency of 24 kHz. The elliott 503 computer has been used for the processing.

FFT-TECHNIQUE

We started with signal processing on the computer at about the same time that the Fast Fourier Transformer became known. We were, therefore, fortunate in starting immediately with the new technique.

The use of FFT is now very well known and we shall not got into details but just mention that we are using the FFT as a routine for the following operations:

1. Spectrum calculations.
2. Correlations.
3. Convolutions
4. De-convolutions.
5. Interpolation.

In the following we will comment upon the use of FFT for de-convolution and interpolation being examples of not-so-well known applications of the FFT.

De-convolution

The de-convolution or inverse filtering has been applied for the removal of the effects of the bubble pulses of underwater explosions. The example to be shown is from the bottom reflectivity study, where explosive charges were used to obtain the impulse response of the layered bottom [Refs. 1 and 2]. As can be seen from Fig. 1, however, the responses caused by the bubble pulses render the interpretation of the responses difficult. The de-convolution consists in principle of taking the Fourier Transform of bottom responses and dividing it with the Fourier Transform of the direct signal from the explosion, and then Fourier Transform back to the time domain [Figs. 2 and 3]. Figure 4 shows the final result where the de-convolution has been applied to all responses shown in Fig. 1.

A limitation of the use of this technique is that it requires a record of the direct signal from the explosion. In order to overcome this we are at present studying the use of a model for the direct signal with some parameters which can be changed. Such an inverse filter may be of a recursive type with no restriction on the signal length.

(sin x/x) Interpolation

For technical and economical reasons one will normally try to keep the sampling frequency as low as possible, bearing in mind the permissible folding errors. In some applications, however, it is required to reproduce the continuous wave form more accurately than say, drawing straight lines between the sample values. This requires interpolation and the correct interpolation is the (sin x/x) interpolation which can be done very easily by the use of the FFT [Ref. 3]. Figure 5 shows an example of such interpolation applied on samples derived from a Gaussian pulse.

Another application of this technique is for delaying sampled signals by a fraction of the sampling interval. For instance, this is required for the beam steering of arrays.

RECURSIVE FILTERING

The FFT technique is extremely useful and has wide applications. We have, however, found that in certain applications other methods are preferable. This is the case for certain filtering operations where the use of recursive filters has proved to be of advantage.

For this reason we have recently implemented a set of low and band-pass filters with Butterworth and Bessel characteristics [Ref. 4].

The band-pass filter is at present used in the realization of filter banks and an example of 1/3 octave filter bank using 8-pole Butterworth filters is shown in Fig. 6.

Figure 7 shows an example where this bank of filters has been applied to a transient signal. The output of each filter has been squared and integrated over a certain time interval (in this case 15 ms). The result which is a time-frequency matrix, has been displayed by using the contour program described in Ref. 5.

FUTURE WORK

In the near future we expect to do most of the signal processing on the Hewlett-Packard computers at the Centre and also at sea during the trials.

Some of the programs we have now on the Elliott 503 will have to be converted to the HP computer. This work is not expected to be very extensive as all programs based on the FFT are already available. To convert the recursive filters will be more difficult because, for computation time reasons, they will have to be implemented in integer arithmetic and the word-length of the HP is rather short.

On a longer term basis we would like to do more multi-channel measurements and processing. As a first step in this direction we are now developing a wide band acoustic array which, due to a combination of hydrophone arrangements and processing, will result in a beam pattern independent of frequency of over more than 3 octaves.

The signal processing developed here is for scientific use only. However, we should keep in mind its possible application in future operational systems.

REFERENCES

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3. J.M. Hovem, "(sin x/x) Interpolation of Sampled Signals", SACLANTCEN Technical Report No. 196, July 1971.

4. J.M. Hovem and M. Thompson, "A Description of Some Recursive Filters", SACLANTCEN Technical Memorandum No. 167, June 1971.

5. J.M. Hovem, "A Computer Program for Contour Mapping", SACLANTCEN Technical Memorandum No. 173, October 1971.

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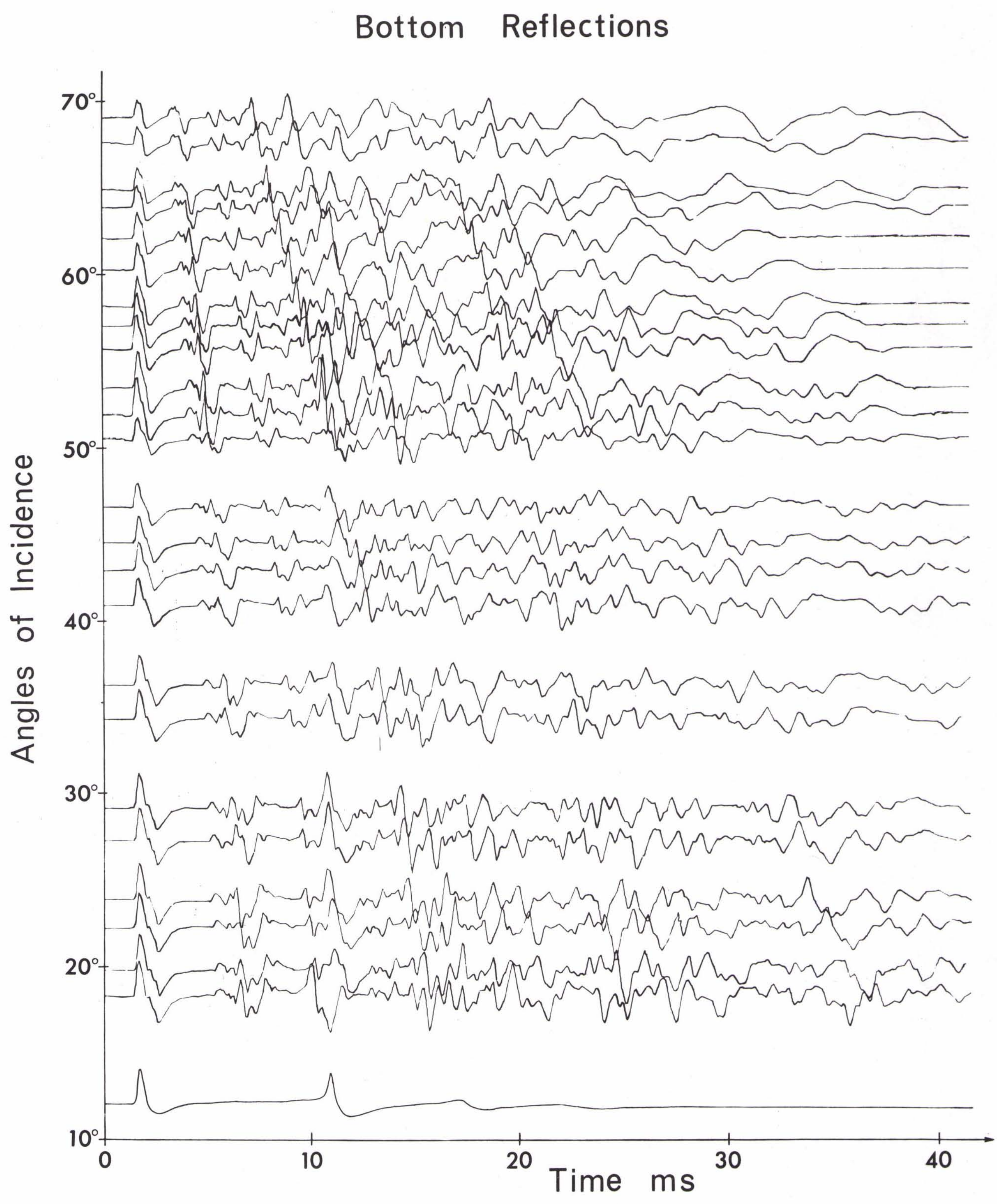

FIG. 1 REFLECTED SIGNALS FOR DIFFERENT ANGLES OF INCIDENCE

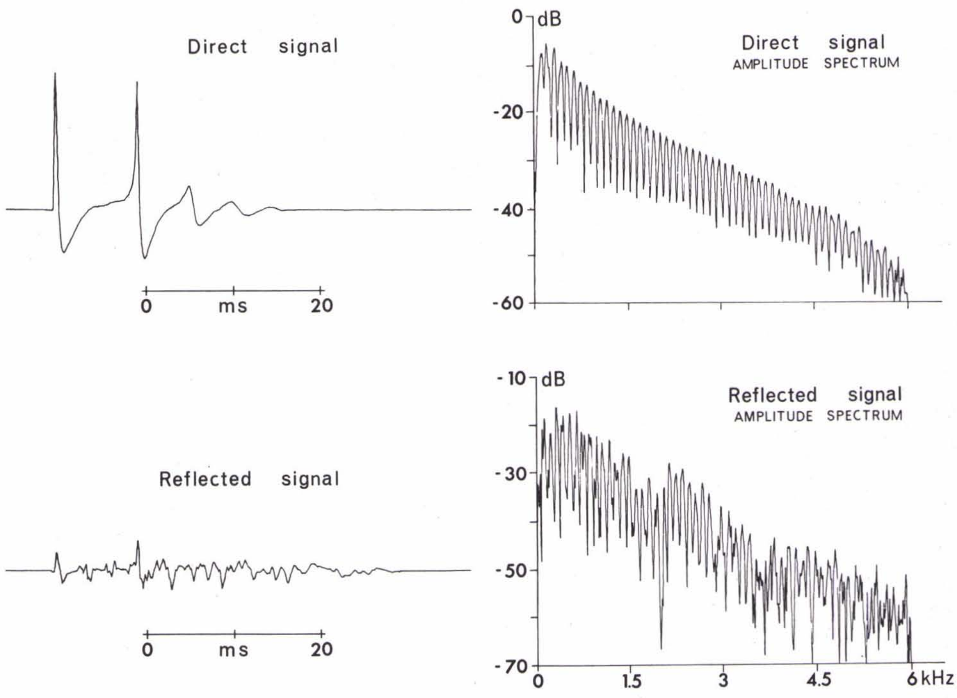

FIG. 2 DIRECT AND REFLECTED SIGNALS

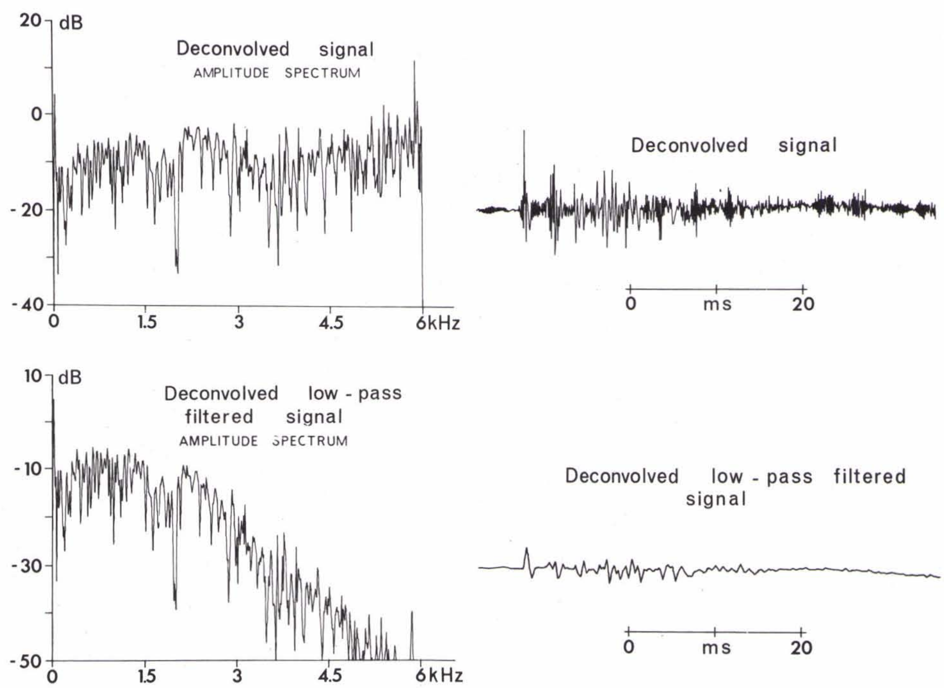

FIG. 3 DECONVOLVED SIGNAL AND DECONVOLVED LOW-PASS FILTERED SIGNAL

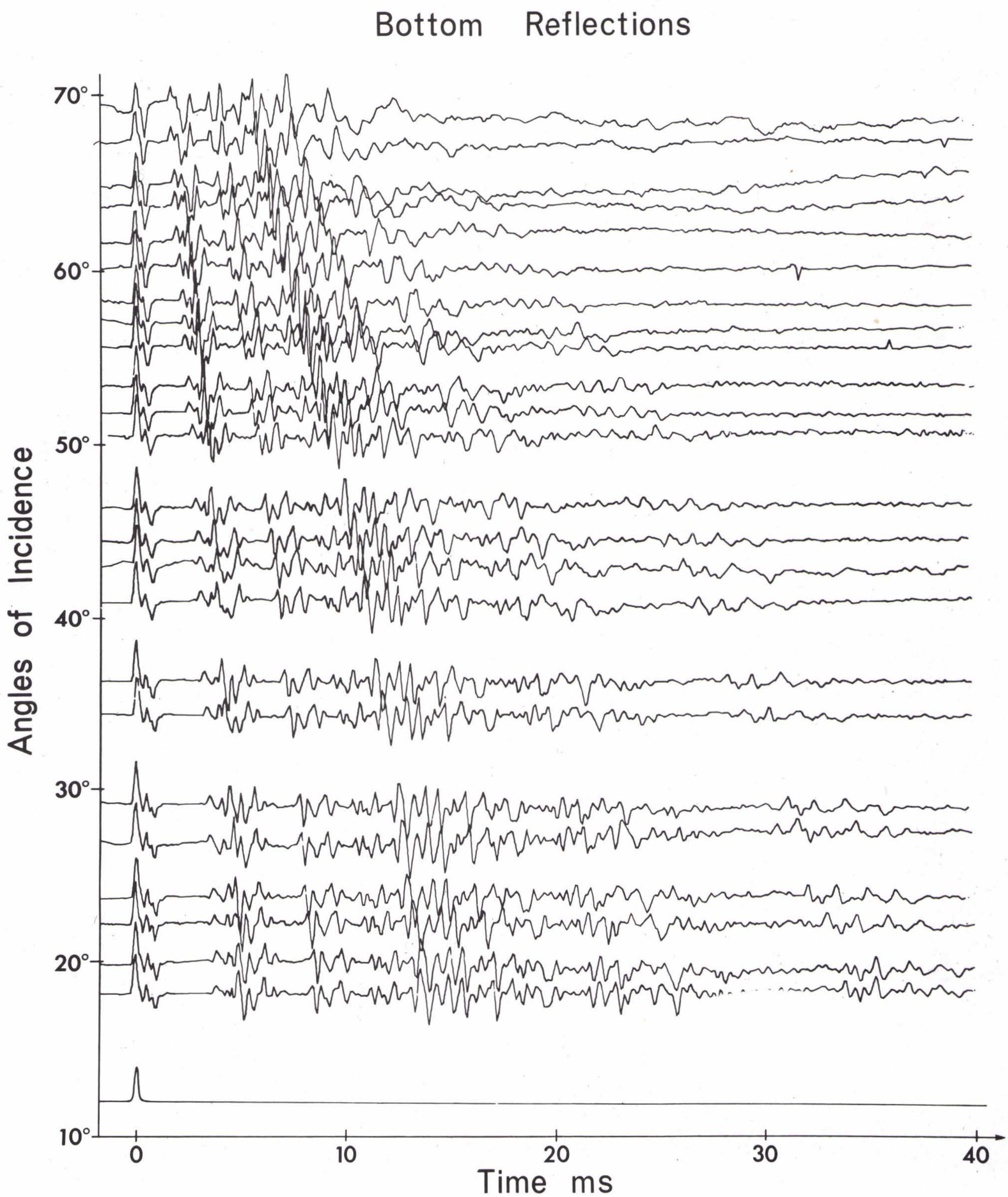

FIG. 4 REFLECTED AND PROCESSED SIGNALS FOR DIFFERENT ANGLES OF INCIDENCE

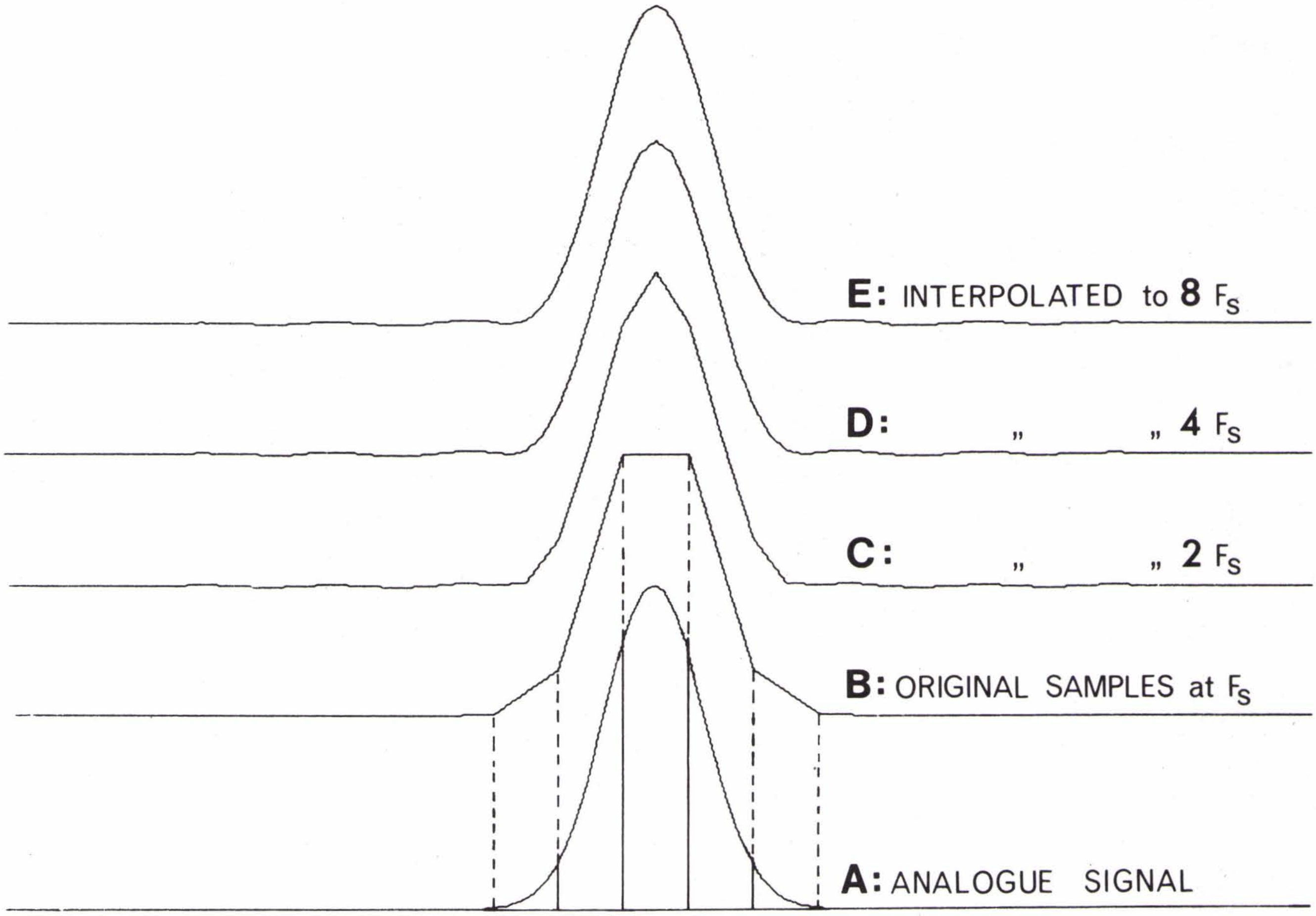

FIG. 5 INTERPOLATION OF A SAMPLED GAUSSIAN PULSE $\exp\left[-\frac{1}{2}(t/\tau)^2\right]$
Original sampling frequency $F_s = 0.8/\tau$
(4 times the 6 dB cut-off frequency)

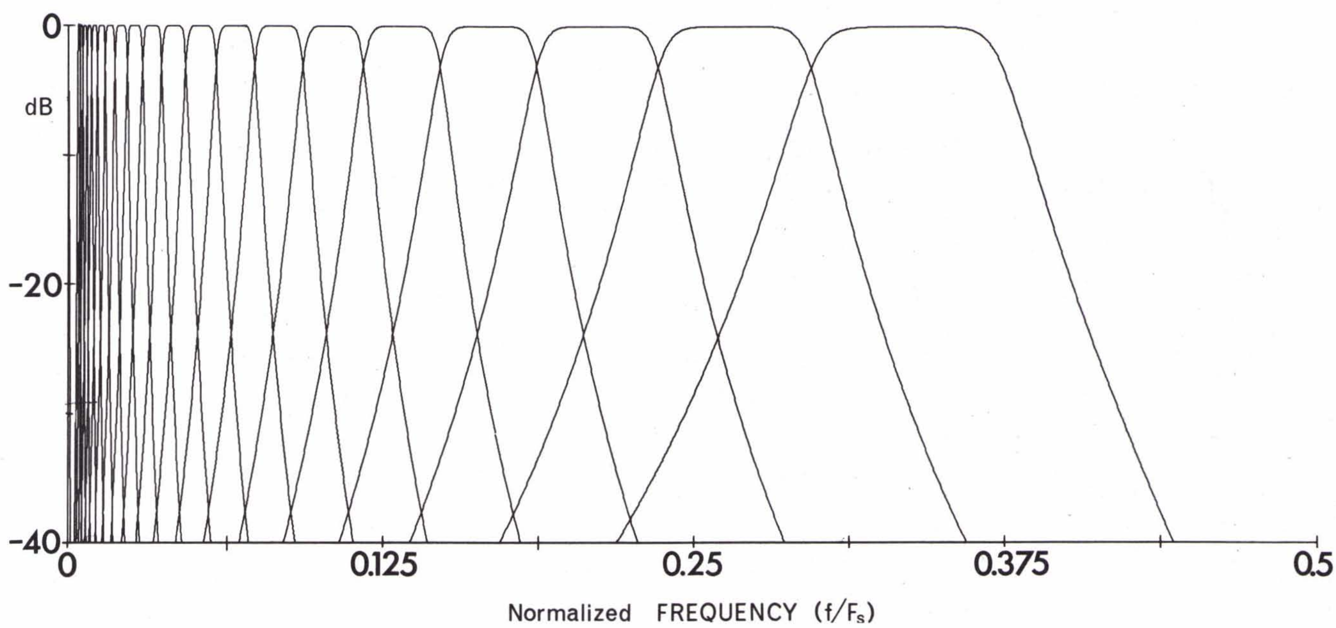

FIG. 6 1/3 OCTAVE FILTER BANK WITH 8-POLE BUTTERWORTH FILTERS

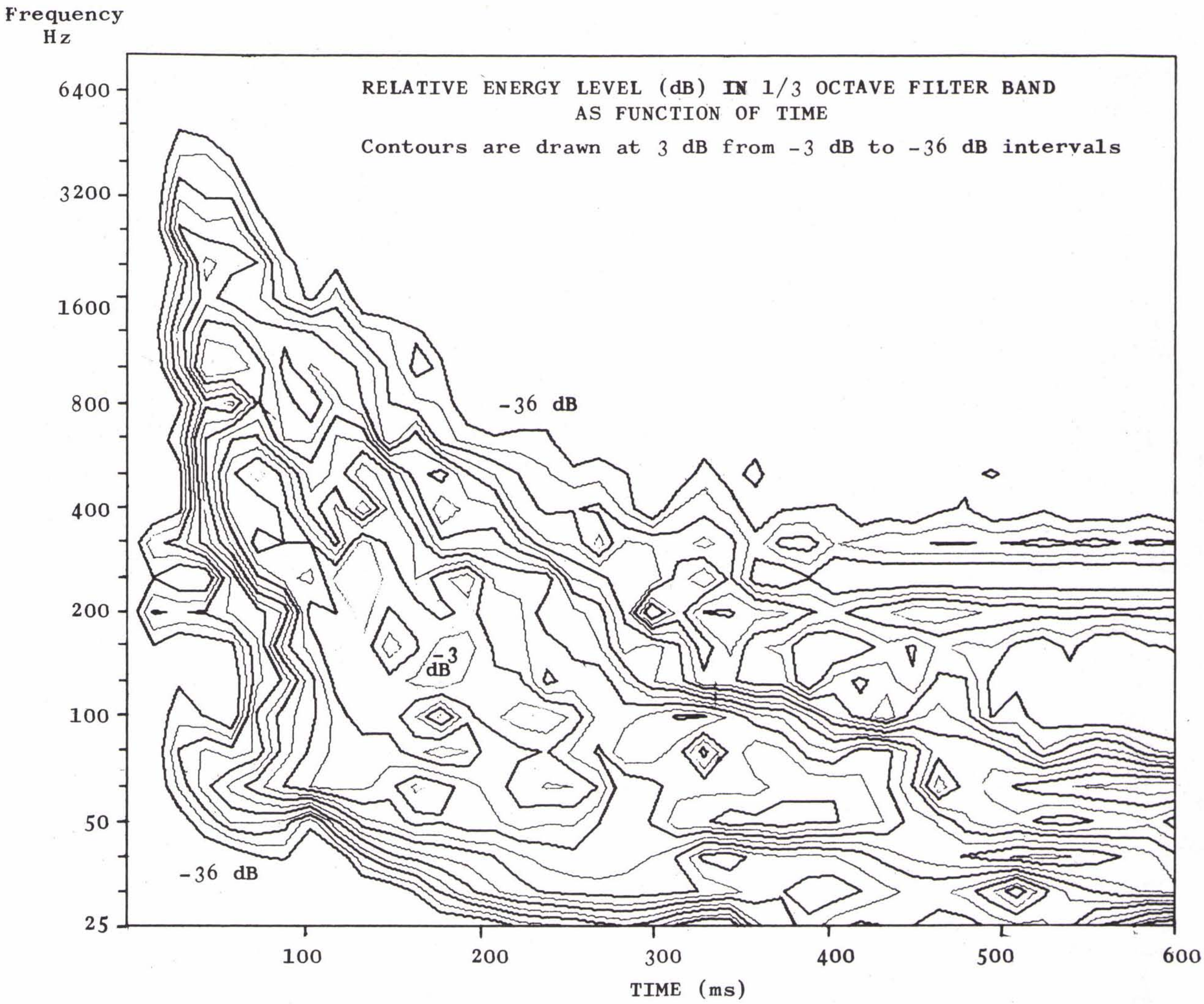

FIG. 7 EXAMPLE OF A CONTOUR MAP