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THE USE OF A DIGITAL AUDIO PROCESSOR AND VCR FOR LOW FREQUENCY NOISE MEASUREMENTS

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INTRODUCTION

Magnetic tape recorders provide an excellent method of data storage and are particularly valuable during field trials where, often under trying conditions, personnel can concentrate on obtaining good accurate data on tape leaving complex analysis to the more amenable conditions of the laboratory.

Unless complex pre-triggering facilities are available tape recorders provide the only means of capturing fully, transient events such as pressure pulses from explosions and they are a necessity when the timing of such events is not accurately known.

There are however inherent disadvantages. Most tape recording systems have limited dynamic range requiring some knowledge of signal level if accurate noise free waveforms are to be recorded. If a wide frequency response is required, high tape speeds are necessary for conventional recording methods, limiting effective recording time.

Professional audio recorders using pulse code modulation (PCM) techniques overcome many of these problems but until recently size has limited their application to recording studios. Developments in digital processing circuitry have made possible the design of a compact PCM digital audio processor which uses a conventional video cassette as its recording medium. Although aimed at the domestic hi-fi market, the superior performance and specification has led to several laboratories adopting these systems for instrumentation use.

The basic specification covers only the audio frequency range and its use in solving problems associated with low frequency noise and vibration problems is limited. It is possible, however, by using a relatively simple modification to extend the performance to below .06Hz without loss elsewhere thus making a very versatile recorder.

DIGITAL AUDIO PROCESSING

Pulse code modulation is a relatively simple method of digitisation whereby the analogue signal is sampled at a fixed rate and the resultant levels are quantised into digital code for recording. Thus with the signals expressed in binary digits the information to be recorded is in a simple format which is resistant to noise and distortion.

Professional audio PCM's have standardised on 14 bit linear quantisation giving approximately 86dB dynamic range. However this portable unit uses 16 bit linear quantisation and provides a measured dynamic range in excess of 90dB. The theoretical range of ∿98dB is not achieved because of analogue circuit noise. Since the basic system was designed for audio use the standard processor covers the frequency range from 10-20,000Hz and uses a sampling frequency of 44,100Hz.

A significant problem with digital recording is caused by tape drop outs and signal instability (jitter) both of which can cause errors in the encoded signals and which result in audible clicks or waveform distortion on replay. All digital

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processors incorporate some form of circuitry to compensate for these errors by detection and correction methods which involve the inclusion of extra 'words' in the recorded data.

The coded information in this system in total comprises 42 bits made up from 14 bits for the right channel, 14 bits for the left and 14 bits for error correction and detection resulting in a binary code per second equivalent to a frequency of several megahertz.

Such a signal is not dissimilar in frequency content to the conventional demodulated colour television signals and although much too high in frequency for conventional recorders the conditions for faithful recording/reproduction can be readily met by video cassette recorders (VCR) once the digital signal has been suitably formatted.

The performance of the PCM processor with a Beta format portable VCR is compared in table 1 with other more conventional systems used for sound and vibration recording.

It can be clearly seen that the PCM system offers some considerable advantages over DR audio recorders and FM recorders operating in the audio frequency range. In addition to the superior dynamic range, low distortion and virtually negligible wow and flutter the system exhibits an advantage in tape usage as shown by the cycles/cm of tape data.

MODIFICATION TO LOW FREQUENCY RESPONSE

The obvious disadvantage highlighted in table 1 is the lack of low frequency response compared with FM recorders. Following consultations with the manufacturers it became obvious that only small modifications to the interstage coupling capacitors were needed to extend the frequency response downwards. Some concern was expressed at the possibility of circuit instability but none has been experienced.

The input circuitry consists of an op-amp input stage and low-pass (anti-

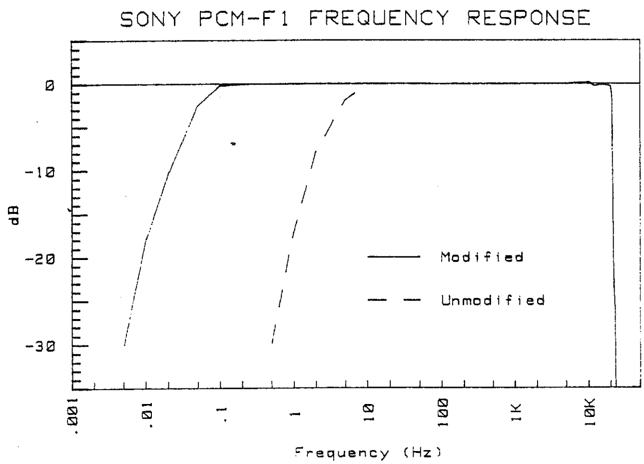

Figure 1

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TABLE 1

COMPARISON OF PERFORMANCE OF SOME TAPE RECORDERS USED FOR NOISE AND VIBRATION MEASUREMENTS

Recorder	Operating mode	Tape speed i.p.s	Frequency response Hz	Dynamic Range dB	Harmonic Distortion %	Wow & flutter (DIN 45507) %	Channel Separation dB	Cycles/ cm of tape
Nagra IVSJ	DR	15	30-35k	66	0.5	.05	60	919
B & K 7004	DR	15	25-50k	50	1	<.06	50	1312
Nagra IVSJ	FM	15	DC-4k	50	<3	-	N/A	105
B & K 7003	FM	15	DC-12.5k	44	1.5	.18	44	328
B & K 7005	FM	15	DC-12.5k	40 (>70 with compander)	<1.5	<0.6	>40	328
Racal Store 4	FM	60	DC-20k	48	<1	.35	-	131
Sony PCM-F1	PCM/VCR	0.737	10-20k	86(14 bit) >90(16 bit)	<.007 <.005	Below measurable limit	>80	10,667

Information taken from manufacturers data.

aliasing) filter AC coupled to the input of the ADC. Similarly for the output circuit, the DAC is directly coupled to the low pass filter and buffer amp. This is then AC coupled to the line output. The two sets of coupling capacitors for each channel are 10µf back to back giving a total capacitance of 5µf. This gives a -0.5dB frequency of 10Hz.

The modification consists of increasing the value of these coupling capacitors to reduce the frequency of the -0.5dB point. In this instance a total capacitance of 345µf is used at each point in the circuit, giving a -0.5dB frequency of 0.06Hz, thus retaining adequate AC coupling to protect the ADC.

The use of large value capacitors required that they be housed outside the digital audio processor case because of the tight internal packing of the existing circuitry. The external capacitors are connected to the circuit board by means of a miniature 'D' connector on the rear of the processor case. This allows their easy removal should the recorder be required to operate only over the audio bandwidth.

The frequency and phase response of the modified instrument are shown in figures 1 and 2 and the system noise floor in figure 3 where it is compared with that of a conventional FM recorder.

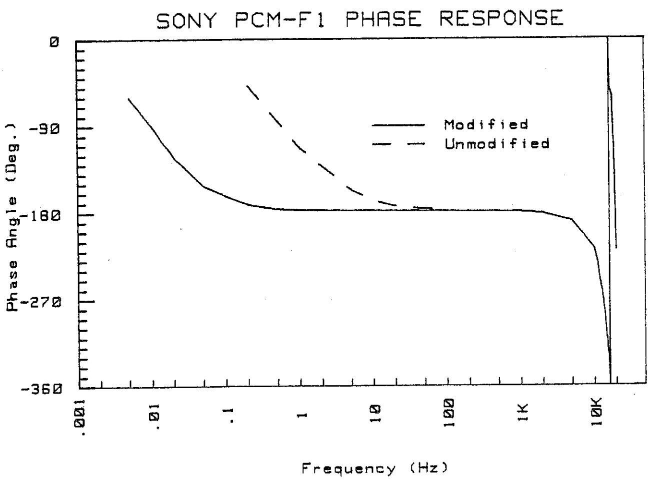

Figure 2

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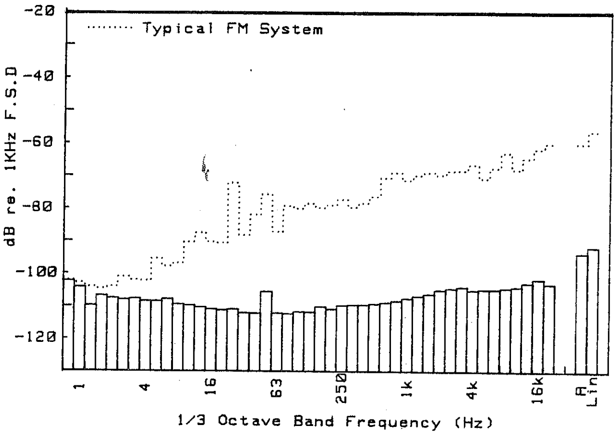

Figure 3

Sony PCM-F1 (modified) Noise Floor

USE IN BLAST NOISE INVESTIGATIONS

The need for a recording system with extended low frequency response and large dynamic range became obvious during a study of blast noise propagation.

This particular study involved the use of a variety of explosive sources ranging from large scale quarry blasts using up to 10,000kg of ANFO explosive down to small scale evaluation experiments using 100 grams of plastic explosive. Earlier work by others [1] had indicated that a frequency range extending from below 0.1Hz to at least 15,000Hz was required in order to capture such a range of waveforms faithfully.

During the initial studies a variety of portable tape recorders were used including many of the types detailed in table 1. It quickly became obvious that on many occasions all these recorders restricted the reproduction of accurate waveforms. Some of the problems encountered were:

a) Frequency response - Only the FM recorders with extended low frequency response gave accurate waveforms. The FM track fitted on the Nagra IVSJ originally for pilot synchronisation signals proved particularly valuable and internal modification allowed us to couple the DR and FM tracks in parallel to give a very effective wideband response. However synchronisation of the two tracks of information after analysis is difficult and time consuming. The wideband PCM system has obvious advantages.

b) Dynamic range - It is in this area where most of the problems lay. A 40dB linear dynamic range was perfectly adequate to faithfully record most blast waveforms and to allow frequency analysis of significant information. However this assumes that the signal is recorded at optimum level. With one off events this is difficult to achieve particularly with blast noise monitored at some distance from the source. Figure 4 shows the variation in peak level measured at 3.5 kilometres from a series of 1kg explosions during the lifting of a temperature inversion. A change of 20dB is difficult to predict and recorder gain setting is purely guess work. Although the problem can be overcome to

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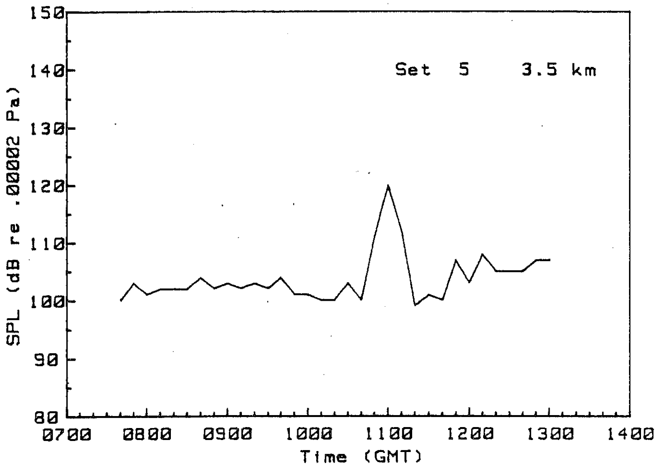

Figure 4

Measured SPL v Time

some extent by using stepped gain settings on multi-track recorders the large dynamic range on the PCM system eradicates it. This is demonstrated in figure 5.

c) Tape duration - The operation of DR and particularly FM recorders at high frequencies requires high tape speeds with a consequent reduction in recording time. With small portable recorders this can be as little as 5 minutes which can be very restrictive when recording quarry blasts, the firing of which is often delayed for safety reasons. Tapes of 3 or 4 hour duration are common place with VCR's and this is adequate for most applications and indeed coupled with the large dynamic range of the PCM the instrument can be used unattended quite successfully.

CONCLUSIONS

The PCM and portable VCR provide a very cost effective form of data handling and storage. With the aid of a simple modification the performance can exceed that of generally available instrumentation recorders used in noise and vibration analysis.

REFERENCES

[1] M J Crocker and L C Sutherland, "Instrumentation requirements for measurement of sonic book and blast waves - A Theoretical Study". J. Sound Vibr. 7, 3, 351-370, (1968).

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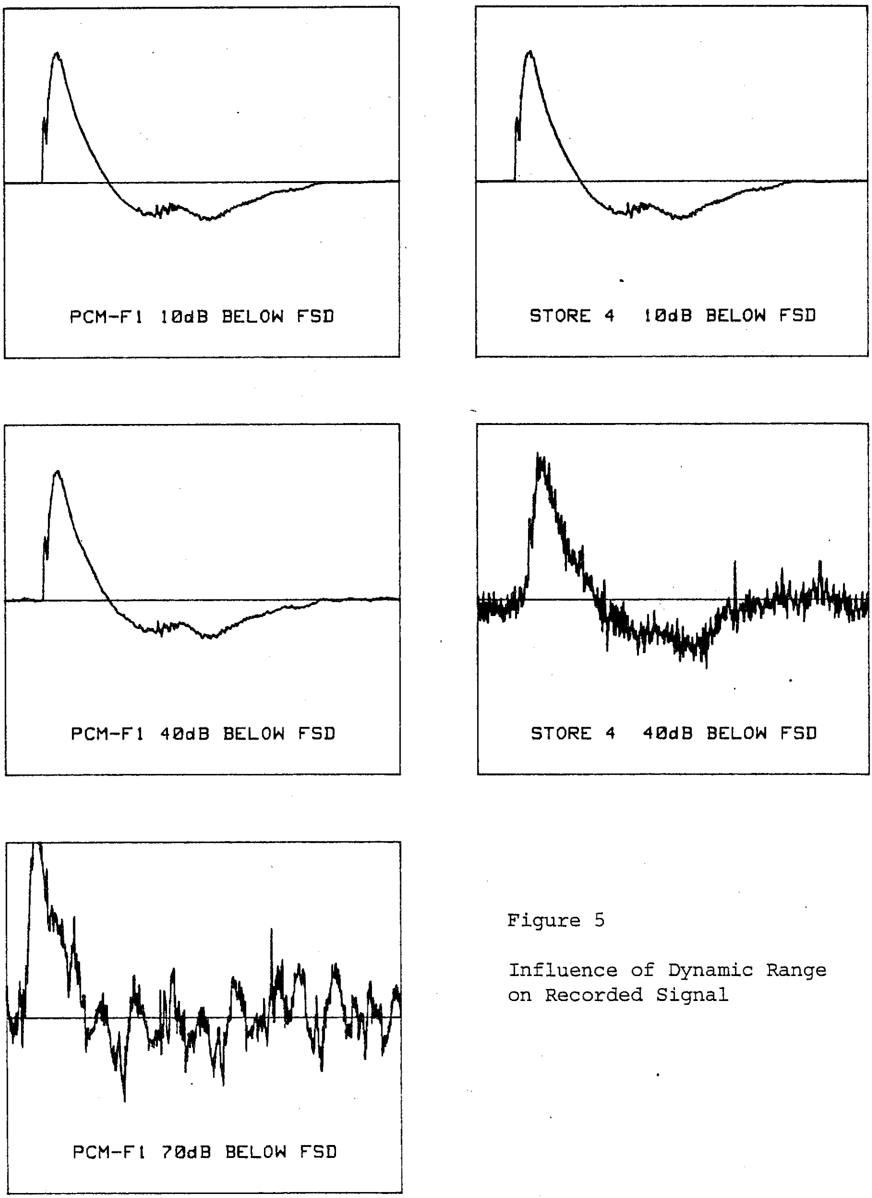

Figure 5

Influence of Dynamic Range on Recorded Signal