Time and Frequency Scaling in Magnetic Recording*

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Summary—An electrical signal recorded on magnetic tape can be relatively easily transposed in frequency by reproducing it at a tape speed different from the tape speed at which it was originally recorded. Transposition into the audio-frequency range is most frequently employed for convenience because of the ready availability of indicating and analyzing equipment in that frequency range. Examples where this technique has been helpful are cited.

Introduction

A HIGH DEGREE of perfection has been achieved in magnetic tape recording techniques in recent years. Since early use as a recording medium in the *audio*-frequency range, great strides have been made in perfecting this technique for recording signals in the kilo- and megacycle range on the one hand and in the fractional cycle range on the other. Although it is very frequently desirable to reproduce the recorded signal unchanged, it is often advantageous to transpose the signal into a different frequency range on reproduction by using different tape speeds for recording and reproducing the signal. Unless tolerances on permissible flutter are unusually severe, this is easily accomplished in many cases by interposing a simple arrangement of additional rollers and rubber idlers between the drive motor and the capstan driving the tape. By exercising a measure of ingenuity, the tape speed change can be accomplished by throwing a lever or pushing a button. Several designs are available commercially. Most commonly, the scaled signal ends up in the audio-frequency range; analyzing and indicating equipment is handy in the laboratory and easily calibrated. It must be remembered, however, that a frequency shift is traded for a change in time. A 100-kc signal of one-second duration becomes a 1-kc signal lasting one hundred seconds on scaling it down by a factor of 100 in frequency.

There is no claim on the part of the author to originality or even novelty of this approach. The main purpose of this note is to illustrate the technique of time and frequency scaling by citing examples of perhaps more than passing interest, and to draw attention to the fact that, by the use of this technique a nasty instrumentation problem may frequently be avoided.

Mechanical Vibrations

In the investigation of mechanical vibrations of equipment, signals containing contributions from fractional cycles to several hundred cycles per second are frequently encountered. The spectrum below 20 or 30 cps is most easily investigated by recording the signal on magnetic tape at slow speed and reproducing it at a higher tape speed. If a speed ratio of 30 is employed, contributions down to about one cycle per second are easily analyzed by conventional filters operating in the audio-frequency range. Fig. 1 shows an acceleration spectrum obtained in a railroad car for a fixed set of operating conditions.[1] The output signal generated by an accelerometer was recorded on magnetic tape, and the results were plotted in terms of acceleration level in decibels relative to 1 inch/sec^2 in third-octave bands. The open circles were obtained by using a tape speed ratio of 30:1 on reproduction; the solid circles were obtained with a 1:1 speed ratio. Note the generally good agreement in the overlap region between 40 and 150 cps after proper calibration of the systems.

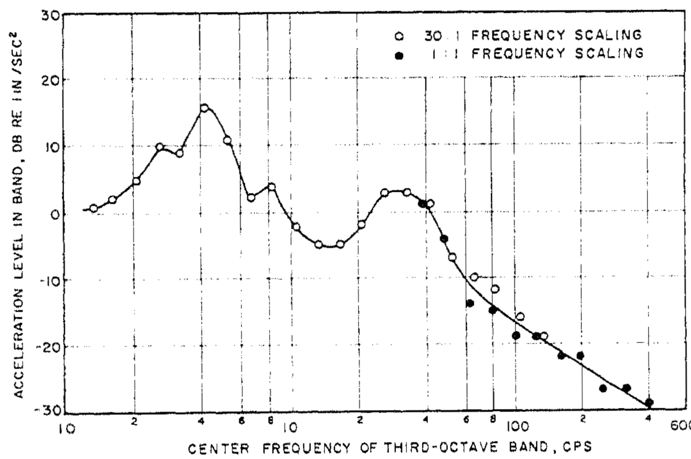

Fig. 1—Acceleration spectrum in a railroad car (after Dyer).

Low-Frequency Pressure Fluctuations in Wind Tunnels

Air supply systems for supersonic and transonic wind tunnels of present design frequently exhibit considerable pressure fluctuations in the frequency range below approximately 10 cps. These fluctuations are generally undesirable and before taking remedial measures it is necessary to determine their spectra. Fig. 2 shows a spectrum of the pressure fluctuations in the settling chamber of a blow-down wind tunnel operating in the supersonic range.[1] The output signal of a special microphone system, responsive to low-frequency pressure fluctuations was recorded on magnetic tape. A tape speed ratio of 30:1 was used on reproduction, and the spectrum was obtained by means of a conventional third-octave filter set.

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[1] I. Dyer, Bolt, Beranek, and Newman Inc., private communication.

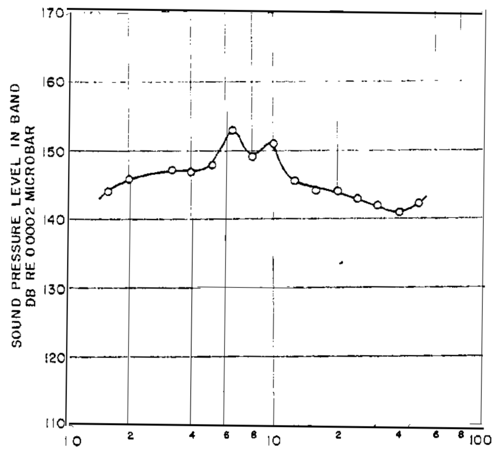

Fig. 2—Pressure fluctuation spectrum in the settling chamber of a blow-down wind tunnel (after Dyer).

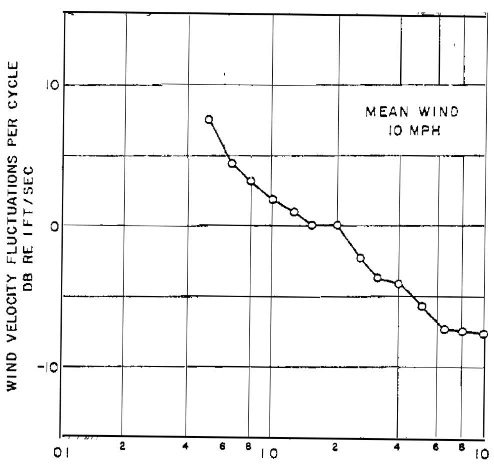

Fig. 3—Turbulent velocity spectrum in the atmosphere over open level terrain (after Keast).

Small-Scale Atmospheric Turbulence

The investigation of the velocity fluctuations in the open atmosphere near the ground, or in a laboratory wind tunnel for that matter, has recently received a good deal of attention. These fluctuations outdoors are of importance not only in their own right, but also in the study of the diffusion of atmospheric contaminants and the propagation of sound outdoors. Fig. 3 shows a spectrum of the velocity fluctuations obtained over open level terrain for a mean windspeed of about 10 mph. The output signal obtained from a small bead thermistor anemometer was recorded on magnetic tape. A tape speed ratio of 100:1 was used on reproduction, and the spectrum was obtained by means of a conventional third-octave filter set. The ordinate shows the velocity fluctuations in decibels relative to 1 foot/second reduced to bands one cycle wide.[2]

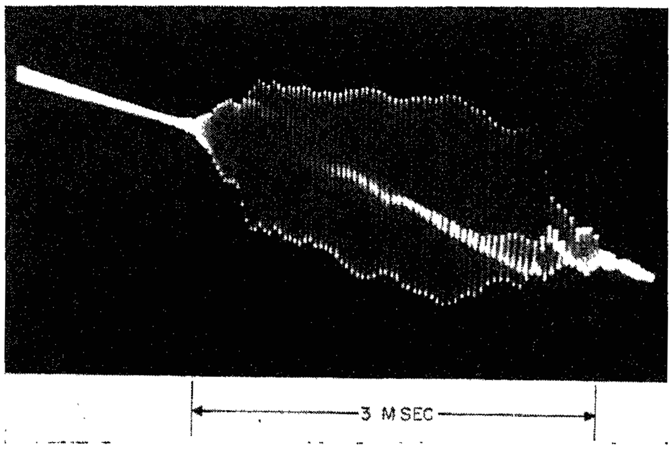

Fig. 4—Frequency modulated ultrasonic cry of a Panamanian bat (after Griffin).

The Ultrasonic Cries of Bats

It is well known that certain species of bats emit bursts of ultrasonic energy to avoid obstacles by echo location, and to locate and pursue their insect prey.[3] The frequency spectra of these pulses range from tens to hundreds of kilocycles. Very often the frequency of the ultrasonic oscillations changes markedly throughout the duration of the pulse. Fig. 4 is a photograph of the trace of a frequency modulated pulse on an oscilloscope screen.[4] For further study, the output signal obtained from a microphone responsive in the ultrasonic frequency region was recorded on magnetic tape. By employing a tape speed reduction of 1:10 or 1:20 the pulses emitted by a bat were made into a startling auditory display, and a frequency analysis was carried out conveniently. Moreover, the spacing between pulses, which changes markedly as the bat approaches an obstacle or his prey, could then be measured with a simple stop-watch rather than by the use of electronic timing circuits operating in the ultrasonic frequency range.

Conclusion

The technique of time and frequency scaling of signals by means of magnetic recording techniques, although not new, has several advantages. This process lends itself to scaling up or down in frequency, and it deserves the attention of workers in many diverse scientific fields.

[2] D. N. Keast, Bolt, Beranek, and Newman Inc., private communication.

[3] D. R. Griffin, "Listening in the Dark," Yale University Press, New Haven, Conn.; 1958.

[4] D. R. Griffin, Harvard University, private communication. The photograph was taken with a moving film camera—hence the tilt of the base line.