of a multipurpose measuring set.[2] This, however, would exceed the scope of this brief communication and will be described later.

Acknowledgements
I wish to acknowledge my thanks to Mr. F.D. Jacobsen, B & K, for his interest in this topic and for his efficient assistance connected with the manufacturing of the semitone switch board, and to Mr. T. Szabo, SAV Bratislava, for his careful technical assistance.

2) Among other functions, the switching circuit should also prevent from being analyzed the artifacts that may be caused during the tape (loop) starting time. This should be as short as possible.
(More elaborated tape systems have also been described in the literature, e.g. B & K Tech.Rev. 2/1970, pp. 21-25.)
Naturally, it would be much more attractive to have the signal stored in a digital memory instead of an analog tape loop memory. But even if we consider a frequency range of, say, 16 kHz, and a 46-dB signal-to-noise ratio, then the information flow represented by the signal amounts about 220000 bit/sec. With only 8.5-second samples (as are those used so far in the described equipment), this would require almost 2 Megabits of memory and the cost would exceed many times that of the basic equipment.

Brief Communications

The intention of this section in the B & K Technical Reviews is to cover more practical aspects of the use of Brüel & Kjær instruments. It is meant to be an "open forum" for communication between the readers of the Review and our development and application laboratories. We therefore invite you to contribute to this communication whenever you have solved a measurement problem that you think may be of general interest to users of B & K equipment. The only restriction to contributions is that they should be as short as possible and preferably no longer than 3 typewritten pages (A4).

Bekesy-Audiometry with Standard Equipment

by

B. Møhl)*

In laboratories investigating psycho-acoustic phenomena, the need often arises to measure the auditory sensitivity of human subjects. In many cases, the nature of the experiment does not justify the expenditure of specialised automated equipment and the audiogram is therefore taken manually, using available generators, sound sources etc. The purpose of this paper is to describe an automated method, which requires only general purpose equipment and yet gives a permanent record on calibrated paper.

The set-up used in our laboratory is shown in Fig.1. The output of a 1 volt RMS ac source (e.g. a filament transformer) is applied to the compressor input of an audiogenerator (Brüel & Kjær Type 2010) via a switch. The output of the generator drives a set of calibrated earphones (Beyer DT 480S) and is itself driven through a flexible shaft by a Level Recorder Type 2305 which is synchronized to it.

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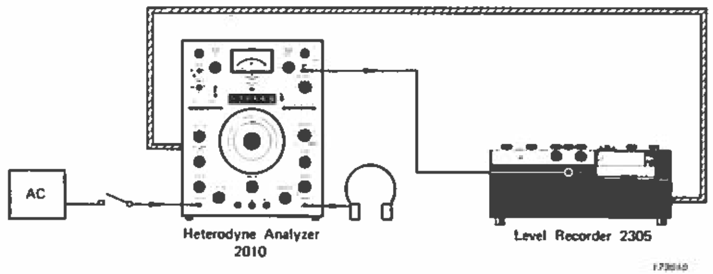

Fig. 1. Set-up for Bekesy audiometry

The principal feature of the set-up is the utilization of the compressor facility for adjusting the sound level (rather than employing a reversible, motor-driven attenuator). The compressor circuit is designed to adjust the output of the generator relative to a reference level, characteristically provided from a microphone in a closed servo-loop. In the set-up in Fig.1, the servo loop is opened, and the control voltage is supplied from the switch. Consequently, when the switch is open, the output will increase with a constant rate (selectable in steps from 3 to 1000 dB/sec) until the upper limit of the dynamic range of the compressor circuit is reached. With the switch closed, the output will decrease with a constant rate and eventually reach the noise level. The subject is required to press the switch, when a tone is heard and release it as soon as the tone disappears. Accordingly, the compressor circuit will adjust the input to the earphones to the threshold range (Fig.2).

An alternative way of describing the operation of the system is to consider that a new servo-loop is established, with the subject as an integral part. The reference level is then the threshold of the subject.

In order to establish the dynamic range of the recorder, the generator and the subjects, it is advisable first to open the switch, switch on the compressor circuit, set the generator output voltage at maximum output without clipping, turn the generator frequency to the lowest desired frequency (e.g. 100 Hz) and adjust the generator output step attenuator to the nearest step just above the threshold of the subject. This procedure ensures operation at the upper part of the compressor range. Next, the input potentiometer, and attenuator of the level recorder are adjusted so that the pen is approximately 10 dB above the scale used for the above mentioned setting of the generator. (For generators without an independent recorder output, it may be necessary to amplify the generator output before applying it to the recorder). The final step in the setting-up procedure requires a short track-

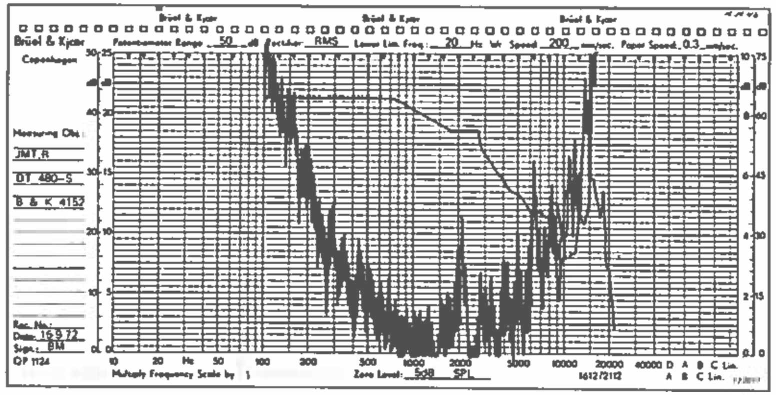

Fig.2. Audiogram of 25 year old male and calibration curve of the earphone, using a 6 cc coupler

ing of the threshold by the subject at his most sensitive frequency in order to ensure that the level is within the range of the recorder. If not, the experimenter has to decide which frequency range is of most importance and adjust the recorder accordingly. Alternatively, the attenuation of the recorder can be changed during the run, in which case, however, the set-up cannot be considered fully automatic.

Following the initial procedure, the generator is set at the lowest frequency of the audiogram, and the level recorder pen is positioned at the same frequency on the calibrated recording paper. The mechanical drive from the recorder is locked to the generator and the subject asked to track his threshold by pressing the switch on and off. When a stable response is obtained, the paper drive of the recorder is turned on, and the subject tracks his threshold as frequency increases (Fig.2).

To evaluate the obtained audiogram for absolute sensitivity, the frequency response of the earphone and the voltage applied must be known. The accuracy is improved if, after completion of the audiogram, the earphone is calibrated by an artificial ear on the same recording paper as was used for the audiogram. When justified by the nature of the problem, circuits can be inserted to normalize the response of the earphone as well as the combination "earphone-normal subject" as used in clinical audiometry. In other cases, where only changes in sensitivity are of importance, calibration procedures can be omitted altogether.

The limitations of the arrangement (apart from those set by the earphones) are the dynamic range of the compressor circuit (quoted by manufacturer to be 50 dB but measured to exceed 70 dB) and the dynamic range of the recorder. The adjustment procedure outlined ensures, that at low signal levels, noise will not mask the signal either for the listener or for the recorder. The decrease rate is dependent upon the magnitude of control voltage applied, as well as the compressor speed setting. The increase rate depends only on the latter. For symmetrical up-down regulation we have found 1 V RMS to be suitable.

Due to the versatility of general purpose instruments, the set-up is well suited to test the influence of settings for frequency increment rate, attenuation rate etc. For audiograms, it has been found that a compressor speed of 3 dB/sec, a writing speed of 200 mm/sec and scanning of the frequency range from 0.1 kHz to 10 kHz (log scale) in about 5 min. is suitable in most cases.