An instrumentation for spectrum-matching experiments

Fujimura, O. and Lindqvist-Gauffin, J.
II. SPEECH PRODUCTION

A. AN INSTRUMENTATION FOR SPECTRUM-MATCHING EXPERIMENTS

In connection to the pole-zero analysis of the vocal tract response curves (1), an optical programming device (function generator) has been developed and has proved useful for the pertinent purposes. The system shall be described here in some detail, together with some supplementary remarks on other relevant techniques of the experiment.

The Brøel & Kjær oscillator-recorder (type 1014) is employed both for the data recording and for drawing the synthesized response curves. The built-in compressor circuit is utilized in order to add (in the logarithmic scale) a constant frequency characteristic to the response curve.

Fig. II-1a shows a schematic diagram for the data-recording procedure. In this case, the output voltage of the oscillator is fed into the compressor-input terminal through a simple RC-network, with the result that the signal level applied to the vibrator is a monotonically rising function of frequency (Fig. II-1b). This suppression of low frequencies is introduced in order to obtain a maximum signal power without distortion and at the same time a grossly flat average signal level at the microphone, over the frequency range of 100 c/s to 5000 c/s. A more exact correction for the constant characteristics, including the transmission characteristics through the body wall, is attempted in the synthesizing (matching) stage, rather than in the data recording, because these characteristics are liable to vary from subject to subject, and possibly from session to session, depending on the condition at the throat of the subject.

In the stage of synthesizing frequency-response curves for matching, it is therefore necessary to generate complex semi-variable frequency characteristics. For this purpose, an optical control system has been designed as an independent attachment to the regular B&K oscillator-recorder. It reads a frequency function which is given in the form of a painted plexiglass disc, and the read-in value for each frequency specifies and automatically adjusts the output level of the sinusoidal signal produced by the
Fig. II-1 a. Schematic diagram of the data recording procedure. For the compressor circuit in the oscillator, see Fig. II-2.
Fig. II-1 b. A standard frequency function for the output level of the sinusoidal signal, as generated by the RC-network in the feedback loop. The levels of the maximum and minimum plateaus can be selected by means of the built-in potentiometers for the "output voltage" and "compressor voltage", respectively.
B&K beat oscillator. A schematic diagram for this system is seen in Fig. II-2, and a detailed circuit diagram in Fig. II-3.

The light from a 20 mm-long filament of an incandescent lamp goes through the transparent portion of the program disc, then through a slit, and is finally received by a vacuum tube photocell. The control disc is mechanically linked to the dial shaft of the oscillator, through a toothed rubber band (see Fig. II-5). In the mechanical link, the rotation angle is amplified by a factor of three, so that 360° rotation of the disc covers a frequency range of 100 c/s to 4500 c/s. The range of the radius available for programming is from 75 mm to 100 mm on the disc. The frequency scale is logarithmic.

The shape of the slit opening is adjusted so that the width of the transparent portion on the disc more or less evenly corresponds to a dB-scale. The inner portion of the slit passes less amount of light flux than the outer portion, and if the inner edge of the unpainted portion is fixed at a radius of 75 mm, the radial distance to the outer edge which would represent the frequency curve is, in our present setting, incrementally 1.5 mm (at the outermost portion) to 0.5 mm (at the innermost portion) per 1 dB, covering a dynamic range of 16 dB (see Fig. II-4b). The maximum width of the slit is about 3 mm, corresponding to about 3% of the frequency value, and a lamp rated at 12 volts is operated on 8.5 volts. The width of the slit opening could of course be reduced readily by a considerable factor by increasing the lamp voltage slightly, if a faster change in the curve were required.

The light intensity received at the photo-sensitive cathode gives the reference voltage for the oscillator output level. A reasonably accurate and quite reproducible tracking is achieved by means of an electrical servo-system consisting of the built-in compressor circuit and an external transistorized comparator circuit. In the latter, the sinusoidal signal from the oscillator-output terminal is compared to and sliced by the reference voltage. This is done in a balanced form, mainly with the intention to eliminate the transient d.c. component (thump). Essentially, the central portion of the waveform is deleted and the remaining parts made abutted upon each other. The signal is amplified.
Fig. II-2. Schematic diagram of the programming device.
Fig. II-3. Circuit diagram of the comparator-slicer in the programming device.
A program disc (portion) for calibration. The windows are cut with approximately 1 mm. steps.

Frequency function (the output level of the oscillator) generated by the program pattern.

Fig. II-5. The oscillator equipped with the optical control system.
and fed into the compressor terminal, so that the output from the oscillator automatically follows, in the envelope, the specified value at each frequency. With a given control disc, the curve for the output level is satisfactorily precisely reproduced. A calibration can be given on the absolute output level for a reference point in the program, and a simple adjustment of the lamp voltage in reference to the absolute output level, in the beginning of a series of matchings, seems to guarantee a reproducibility with no observable variation in the relative frequency curve, both within a session and among sessions on different days. Particular care has been taken in the transistor circuit-design in order to achieve this stability. The temperature dependence of transistors are largely taken care of by the circuit itself, and a possible slow change in the characteristics of the A.C.-amplifiers after the comparison-slicing is not significant because the circuit is put in a servo loop.

The control disc is painted with a watersoluble black paint (a casein color). Fine adjustments of the edge of the painted portion, which determines the frequency function, can be made by scraping part of the dry paint or by repainting, but the best is to use a 1-mm wide adhesive black tape, which is used by draftsmen, in order to define the boundary. A special rule with a calibrated dB-scale has been made to facilitate drawing the frequency response curve on the disc. Fig. II-4 shows an example of the control disc, together with the function it generated in a standard condition. This pattern was made for a calibration of the scale. Fig. II-5 shows an overall view of the equipment.

O. Fujimura and J. Lindqvist

Reference: