Reports

Forms of Sounds as Shown on an Oscilloscope by Roulette Figures

Abstract. *It has been found that with an oscilloscope driven through a simple network of two resistors and two capacitors it is possible to produce recognizable pictures from speech sounds. These pictures thus become a natural phonetic alphabet, with which both standard pronunciation and the nuances of dialect and accent can be represented. While a given speech sound has certain invariant characteristics, it has also an overlay of accent, which can be represented in the alphabetic character. It is suggested that the technique may be useful in teaching deaf children to speak.*

Some time ago, for amusement, we attempted to produce roulette figures by using a modern high-gain oscilloscope. The network needed turned out to be astonishingly simple (Fig. 1). In the course of the experiment we attached the output of a frequency modulation tuner to the network to see what music would look like. The startling observation came during the commercials when it seemed as if it might be possible to read the oscilloscope pictures (*1*).

The classical mathematicians knew and studied the roulette figure as a part of analytical geometry. Immediately after the invention of the cathode ray tube, there was a flurry of interest in roulette figures because they were simple to produce, but with the invention of linear sweep circuits the interest died (*2*). Our roulette figures are generalized circular cycloids in which the requirement of circularity of the two generating functions is relaxed.

The parametric equations of the circular cycloids are most easily set up as the motion of a point on the circumference of a rotating circle, the center of which is in turn rotating about a fixed point. If the two circles are rotating in the same sense, the figure is an epicycloid; if in opposite sense, the figure is a hypocycloid. Our pictures are produced by ellipses rather than circles and are hence distorted. The heart of the method is the network shown in Fig. 1. If stray capacitance and loading impedance can be ignored, then the *R-C* leg of the network produces a lagging phase shift exactly 90° from the leading phase shift of the *C-R* leg of the network. With appropriate adjustment of the relative gain on the two sides of the circuit a pure sine wave applied to the input will draw a perfect circle, and two sine waves of simply related frequencies will produce a simple epicycloid. (In order to produce hypocycloids it is necessary to use two of the networks of Fig. 1, with separate inputs, connected so as to produce rotation in opposite senses.) If the equations for the network are set up in differential form, the horizontal driving voltage e_h is given by $e_h = e \sin \omega t$, and the vertical driving voltage e_v is given by $e_v = RC(\mathrm{d}/\mathrm{d}t)(e_h)$ or $e_v = (eRC/\omega) \cos \omega t$. The input voltage e_i is given by $e_i = e_h + e_v$ or $e_i = e\,[\sin \omega t + (RC/\omega) \cos \omega t]$.

Sound pressure from a single voice or solo instrument has just the harmonic relationship between the fundamental and the overtones called for in the previous paragraph, and produces a stable pattern. Thus if we feed the output of a microphone into the circuit we can get a picture which can be essentially sound pressure versus the time derivative of sound pressure. The constraints which must be put on the values in the network include both that the input impedance of the oscilloscope be negligible and that the *RC* time constant of the circuit be placed well below the lowest fundamental frequency to be viewed. We suggest the values in Fig. 1 as a start.

It can easily be shown that there is no information lost in the network transformation except the integration constant representing the zero of time. Further, the time scale information is contained in

$$\frac{e_h}{e_v} = \left(\frac{1}{RC}\,e_h\right) \Big/ \frac{\mathrm{d}}{\mathrm{d}t}\,(e_h)$$

We chose the name *calligraphony* by analogy to *calligraphy,* beautiful writing. Calligraphony is then the beautiful writing of sounds.

Five subjects were used for the experiment. They were all members of the same family. The subjects were: No. 1, adult male, normal voice range, second tenor; No. 2, 11-year-old male, normal voice range, boy soprano, wearing braces for orthodontia; No. 3, 8-year-old male, boy soprano, missing four baby teeth; No. 4, adult female, normal voice range, mezzo-soprano; No. 5, 9-year-old female, normal voice range, soprano, braces on teeth.

The equipment used included an Eico model 425K oscilloscope, assembled from the kit, a Wollensak T-1515-4 tape recorder (used only as an audio amplifier), and the microphone supplied with the recorder, a Shure B-162-4. Pictures were taken with an Argus model AF camera at 1/25 sec and *f*/4.5; Kodak Tri-X Pan film was used. Each subject in turn spoke the sounds indicated in Fig. 2. He was asked to maintain the sound, and adjust volume and distance to the microphone to fill the screen of the oscilloscope, whereupon the picture was taken.

At the beginning of the experiment we had hoped that we could recognize

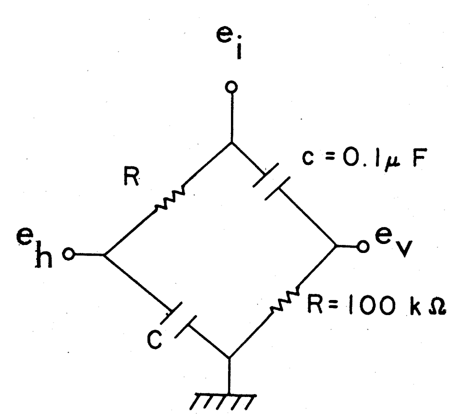

Fig. 1. Network used with oscilloscope: e_i, input voltage from audio amplifier; e_h, output voltage to horizontal amplifier of oscilloscope; e_v, output voltage to vertical amplifier of oscilloscope.

sounds by the shape. When we looked directly at the picture tube it was clear that some sounds were distinctive, but in order to prove this, photographs that could be studied were needed. Figure 2 shows that certain of the sounds are easy to recognize, but certainly not all. The consonants *th, v, z, m,* and *n* all show a difference from subject to subject. When we compared the photographs with a new attempt at production of the figures on the calligraphone, we found that there was a real difference among subjects in pronunciation of the sounds *m* and *n*, and the subject could control this by controlling the amount of nasal quality. In the case of *th, v,* and *z* the change could be explained away by the presence of braces or absence of teeth. These make a real difference in enunciation. At any rate the differences among our subjects are no greater than the differences in their handwriting. Note that the differences in pitch do not show up strongly when presented on the calligraphone.

Thus it has been shown that the patterns formed by the calligraphone form a natural phonetic alphabet with which one can capture nuances of pronunciation. In contrast to the more conventional sound spectrograph, which plots amplitude of the frequency components versus time, the calligraphone maintains phase information as well as amplitude information, though losing the time duration of the sounds.

The potential use which we find most exciting is the possibility that the calligraphone can be of help in the teaching of children with impaired hearing. It would enable the teacher to present to the deaf child a graphical illustration of the inadequacies of the child's enunciation. It has the particular virtue of low inherent cost, since all the unusual parts can be purchased for less than $60 (including the oscilloscope kit) and a clever teen-ager can assemble them in a couple of evenings.

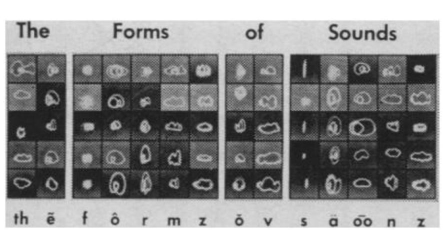

Fig. 2. Oscilloscope pictures of the sounds of the phrase printed at the top and repeated in phonetic symbols at the bottom (*3*). Top row, speech of adult male; second row, adult female; third row, 11-year-old male; fourth row, 9-year-old female; fifth row, 8-year-old male. (Picture of the *d* sound was omitted, because that sound is not maintained.)

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References and Notes

1. This experiment was submitted with a different text by one of us (S.H.B.) to the 1963 Alamo Science Fair.
2. J. F. Rider and S. D. Uslan, *Encyclopedia of Cathode Ray Oscilloscopes and Their Uses* (Rider, New York, 1959), in particular, chap. 4.
3. *Webster's New Collegiate Dictionary* (Merriam, Springfield, Mass., 1961), p. vii.

8 October 1963

Carbonate Rocks: Cleaning with Suspensions of Hydrogen-Ion Exchange Resin

Abstract. *The surface of carbonate rocks may be cleaned by etching or polishing or both, with hydrogen-ion exchange resin. This treatment reveals details in texture and fossil morphology so clearly that thin sections may be often dispensed with. Of four cleaning methods,* (i) *allowing resin to settle around the sample,* (ii) *stirring with a magnetic stirrer,* (iii) *agitating with an ultrasonic generator, and* (iv) *directing a jet stream at the sample, the first method was best for large specimens and the second method was best for well cuttings and chips.*

A method of cleaning calcareous fossils by means of ion-exchange resin has been described by Groth (*1*). He circulated a suspension of "colloidal" Dowex-50 cation exchange resin in the Na^+ form over the macrofossils to be cleaned. By a similar technique we have used commercial 200 to 400 mesh resin in the H^+ form to study carbonate rocks. The differential solution and polishing resulting from agitation of the suspension reveals the morphology of calcareous fossils and emphasizes the texture of the rock. These features are normally observed in the sample after thin sectioning, polishing, or acid etching.

The resin suspension can be used on chips, well cuttings, or on sawed or polished surfaces. Contact of the resin suspension is accomplished (i) by allowing the resin to settle around the sample in water, (ii) by stirring with a magnetic stirrer, (iii) by agitating with an ultrasonic generator, or (iv) by using a jet stream directed at the sample. The etching and polishing produced is controlled mainly by the time of treatment and the amount of agitation.

Samples having varying textures, fossil contents, and degrees of lithification were used in comparing these four techniques. Allowing the sample to rest undisturbed up to 24 hours in a bed of resin appears to be the best treatment for large specimens. The surface of the specimen is deeply etched with little polishing. A few pits may develop as a result of the resin beads remaining in one place. Stirring well cuttings or rock chips in the resin suspension for 10 minutes to several hours with a magnetic stirrer appears to be the best treatment for them. The surfaces are highly polished and greatly aid in the identification of microfossils. Agitating samples with an ultrasonic generator for 5 minutes to 2 hours results in some pitting and moderate polishing. Directing a jet of the resin suspension at a specimen is very unsatisfactory because the resin suspension acts slowly and many pits develop. Use of any one of the above methods depends upon the particular specimen being studied and upon the effect desired (etching or polishing).

The advantages of the method result from the chemical action which is limited to the rock surface, and the mechanical action of the beads on the rock surface when the suspension is agitated. The relief that is produced greatly aids in identifying fossils and seeing relationships between grains. Rough surfaces, such as those of cuttings, can be etched and the complete surface may be viewed. In many cases this eliminates the need for thin sections. Samples may be sawed in thin slices, etched, and the etched surfaces viewed. This minimizes the sampling problem and allows better selection of samples for thin sections, if desirable.

The main advantages over etching with acid alone are nonpenetration of H^+-ions into fractures and joints of the sample, smoother surfaces produced by H^+-resin, and convenience of control and handling of the resin. The used resin may be regenerated by treatment with acid, either in batches or in columns, and washing.

The main limitation is that the reso-