## Fluctuating Brightness of Quasi-Stellar Radio Sources

Banesh Hoffmann suggests [*Science* **144**, 319 (1964)] that a quasi-stellar radio source can alter its brightness in a time short compared with the light-time across its diameter, if the fluctuation originates at the center of the source and arrives nearly coherently at its surface.

However, since light from different parts of an extended object takes different amounts of time to reach an observer, a large coherent fluctuation, of duration small compared with the light-time across the object, will not be observed as an appreciable intensity fluctuation.

For example, imagine that we could magically turn off such an object completely for a year and then turn it on again. If the radius of the source exceeds 1 light-year, a distant observer will "see" the year of darkness as a dark zone that appears in the middle of the apparent source disk and spreads outward (that is, *away* from the observer) with time. If the radius of the source is 10 light-years, the maximum darkening observed will be only 19 percent; if the radius is 100 light-years, the drop in intensity will be only 2 percent.

As the observed brightness fluctuations of 3*C* 48 and 3*C* 273 are of the order of 50 percent in a few years, they evidently cannot have diameters larger than a few dozen light-years.

ANDREW T. YOUNG
*Harvard College Observatory, Cambridge 38, Massachusetts*

27 April 1964

## Action of Tetrodotoxin: A Reply

The comment by C. Y. Kao (*1*) on a report by Loewenstein, Terzuolo, and Washizu (*2*) on the separation by tetrodotoxin of transducer and impulse-generating processes in two receptor organs (the crayfish stretch receptor and the Pacinian corpuscle) needs an answer, since both the findings and the conclusions of the report were incorrectly stated by Kao. His comment starts from the premise that "in both the crayfish stretch receptor and the cat Pacinian corpuscles" the spikes were "clearly recorded in axonal extensions of the sensory receptors."

If by "axonal extension" Kao means the axon, the statement is in error, for it is explicitly stated in the report that the cell soma of the sensory neuron of the stretch receptor organ was impaled with a microelectrode. This was used both to record the electrical activities (see *2*, Fig. 1*A*) and to apply cathodal pulses of current. By this last procedure it was unequivocally demonstrated that if the soma is depolarized no impulse activity can be induced following treatment by tetrodotoxin. Therefore, Kao's contention that "more proximal [in respect to the axon] spike-producing mechanisms" were not shown to be blocked by the compound is contradicted by the published data.

This point is emphasized only to remove any ambiguity, although the dismissal of the premise would be sufficient to dispense us from considering any further Kao's comment, including his conclusion. We would like, however, to touch also upon this point since Kao writes: "Thus, *it cannot be concluded unequivocally* that different membrane patches in the sensory receptors are responsible for generator potential and spikes" (italics ours). The difference between this statement and the conclusions of the original paper is so evident that no additional comment is required. This conclusion was: "The above-described findings indicate that spike and generator potential in the two receptors examined are independent events being subserved by different mechanisms. If so, *these are likely to reside in separate regions of membrane*, although the spatial arrangement may vary in different receptors (coarsely discernible regions of the cell, separate membrane patches within a region, and submicroscopic mosaic)."

CARLO A. TERZUOLO
*Department of Physiology, University of Minnesota Medical School, Minneapolis*
WERNER R. LOEWENSTEIN
*Department of Physiology, Columbia University College of Physicians and Surgeons, New York City*

**References**

1. C. Y. Kao, *Science* **144,** 319 (1964).
2. W. R. Loewenstein, C. A. Terzuolo Y. Washizu, *ibid.* **142,** 1180 (1963).

30 April 1964

## Visual Display of Speech by Means of Oscillographic Roulette Figures

In a recent report (*1*), Barton and Barton describe the visual display of speech by means of oscillographic roulette figures, and suggest that this method of display might be useful in speech therapy with deaf children. With their method, a speech signal is applied across two identical circuits in parallel, each comprising a resistor and a capacitor in series. The output voltage to the vertical deflection plates is taken from across *R* in one leg of the network and that to the horizontal deflection plates from across *C* in the other leg. They indicate that the resulting patterns tend to be similar when a given speech element is pronounced by various speakers, and to differ between different speech elements.

It should be noted that the display of a signal versus its derivative is not novel to the literature. Servo engineers have long made use of plots of signal versus derivative (termed "phase-plane plots" or "phase portraits") in the study of systems by phase-plane analysis (*2*). The display of signal versus derivative was previously depicted (*3*) for speech elements and analyzed (*3, 4*) by Marcou and Daguet. Lerner (*5*) used all-pass networks and obtained distinctive patterns that for many utterances were talker invariant (*6*).

The Bartons state that their display shows "essentially sound pressure versus the time derivative of sound pressure." This is not in general true, for with their condition that "the *RC* time constant of the circuit be placed well below the lowest fundamental frequency to be viewed," the display is essentially a plot of input signal versus its integral. Thus, their statement would be appropriate only in the somewhat unusual case that microphone output is proportional to the derivative of sound pressure.

We have experimented with apparatus according to the Bartons' description, and we think that this display method has only limited value for the stated purpose, though it may perhaps be useful in other applications. We examined the display with the input signal plotted versus both its integral and its derivative.

Our observations may be summarized as follows, for the case that an input speech signal is plotted versus its integral. (i) Stable patterns suitable for visual examination or still photography are produced only for sustained speech elements. Transient elements, such as most consonants at normal speech rates, are represented by momentary flickers, too fast for the eye to evaluate. Thus, if a monosyllable such as "tap" is uttered at a normal rate, the spot present on the screen during quiet expands outward in a swift flicker during the initial consonant, assumes a quasi-stable form for the duration of the vowel, and collapses back into a spot after another flicker for the final consonant. The eye cannot extract useful information from the flickers representing consonants and can do little better for the vowels unless they are held for an abnormally long time, more characteristic of singing than of normal speech. (ii) Use of an oscilloscope with high-persistence screen or storage tube merely causes each monosyllable to "paint" an ill-defined blob. (iii) We obtained patterns similar to those illustrated in *1* for some speech elements (most notably for $\overline{oo}$), but for most elements the resemblance was not close. (iv) The form of the pattern obtained is quite sensitive to voice timbre, changing greatly with barely detectable variations in tone color. (v) Conversely, by deliberately trying to hold a monotone, one can make the patterns for all the vowels very similar and in some cases, for example, $\hat{e}$ and $\overline{oo}$, essentially identical. (vi) The patterns obtained when different voices utter a given speech element certainly tend to look alike (in our experiments, this was most evident with $\overline{oo}$).

Very similar comments can be made about the patterns observed with input signal plotted versus derivative instead of integral, although the patterns for transients tend to be more complex and hence even less readily interpretable. The patterns for sustained vowels are sometimes almost identical to those obtained with the integral.

Experimentation with sinusoidal inputs supplements the observations with speech signals. The Bartons observe that "two sine waves of simply related frequencies will produce a simple epicycloid." As a specific case of this, we found that the mixture of a fundamental with about 200 percent second harmonic will generate the limaçon pattern corresponding to the sustained vowel $\overline{oo}$ by an adult voice as illustrated in *1*. When played through a loudspeaker, this synthesized signal sounds surprisingly similar to the human $\overline{oo}$, and its wave form closely resembles that of $\overline{oo}$ when displayed versus time. This result suggests that the phase-plane type of display might be useful as a laboratory tool in research on speech synthesis.

The detailed structure of the pattern traced during each cycle of a periodic input wave is determined by the exact shape of the wave, which of course depends on both the amplitudes and the phases of the various harmonic components relative to the fundamental. The actual frequency of the fundamental does not affect the pattern, except for a shift in scale along one of the coordinate axes, which may be compensated for through the gain setting of that channel. This explains why male and female voices, though differing in pitch, can give similar patterns for a specified vowel.

Although the patterns are sensitive to the relative phases of components of a periodic signal, the ear is quite insensitive to phase changes. If two speech sounds give similar displays, their wave shapes must be similar and their power spectra must resemble one another in both amplitude and phase; they should therefore tend to sound like the same element of speech. The converse is not true, however, since two sounds differing only in the relative phases of the components will sound alike to the ear but give patterns that may not look at all alike, though there may be topological similarities.

The Bartons' technique is inherently best suited for displaying sustained signal elements and is unsuited for displaying transitory elements. This is particularly unfortunate, for the information content of speech (as of any signal) resides predominantly in the transient structure, and relatively little intelligence is conveyed by sustained elements. The inability of this technique to provide patterns adequately characterizing the prime information-bearing elements of speech is perhaps the fundamental reason for its limited value in speech therapy. The Bartons themselves note that their pattern photographs show greatest similarity for the vowels, which are relatively sustained speech elements, and least for the consonants, which are generally transitory elements in normal speech. In order to photograph the patterns, they requested their subjects to "maintain" the sounds. It proved impossible to produce a pattern illustrating the *d* sound, and this would be true in general for all the plosives. While the patterns they photographed for the fricatives *th* and *z* may adequately characterize the sustained sounds actually uttered in preparing the illustration, it does not follow that they have any particular significance relative to the corresponding transitory sounds as they occur in normal rapid speech.

It seems plausible that a musically uninitiated singer might perceive differences in the patterns more readily than the corresponding differences in tone color or timbre, and our simple experimentation suggested that this may be true. We observed that a singer can learn to alter his note so as to cause his pattern to resemble that of another voice. To the extent that he succeeds in this effort, he will necessarily match the wave shape of his mentor—that is, he will achieve similarity in timbre. Such a display might, therefore, be useful in musical instruction. It might, however, be preferable to use all-pass networks as did Lerner, rather than the simple frequency-dependent circuitry of the Bartons.

BERRY O. PYRON
FRANK R. WILLIAMSON, JR.
*Engineering Experiment Station, Georgia Institute of Technology, Atlanta*

**References and Notes**

1. G. W. Barton, Jr., and S. H. Barton, *Science* **142**, 1455 (1963).
2. J. G. Truxal, *Automatic Feedback Control System Synthesis* (McGraw-Hill, New York, 1955).
3. P. Marcou and J. Daguet, *Ann. Telecommun.* **11**, 118 (1956).
4. ———, in *Information Theory (Third London Symposium)* (Butterworth, London, 1956), pp. 231–244.
5. R. M. Lerner, thesis, Massachusetts Institute of Technology (1959).
6. Subsequent tests of these patterns at the Boston School for the Deaf are said to have revealed little or no utility in therapy.

12 May 1964