The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

MONITORING OF BROADCASTING STATIONS
Part II

THOSE familiar with the TYPE 536-A Distortion-Factor Meter[1] and the TYPE 457-A Modulation Meter[2] will notice many points of similarity with the equipment described here. The older instruments were intended primarily for the experimental determination of the performance of transmitters, and experience over a period of four years has proved them to be entirely satisfactory on an electrical basis.

LAST month's *Experimenter* discussed new methods of monitoring broadcasting station output and described the uses and capabilities of the CLASS 730-A Transmission Measuring Assembly. The present article discusses in more detail the instruments themselves and explains their operation.

For continuous monitoring, however, equipment must be direct-reading, entirely self-contained, and must require a minimum of effort on the part of the operator. The CLASS 730-A Transmission Measuring Assembly has been designed to meet these requirements without sacrificing any of the accuracy obtainable with the older equipment.

TYPE 732-A DISTORTION AND NOISE METER

The Distortion and Noise Meter measures the harmonic distortion in the transmitter with 400-cycle modulation and the noise level in decibels below any given modulation level. Its operation is easily understood by referring to the diagram of Figure 1.

The carrier, modulated at 400 cycles, is applied to the input of the instrument. A capacitive attenuator is provided to adjust the carrier level to a convenient value. After a preliminary adjustment, this need not be changed. The carrier is rectified by a linear diode detector,[3] and the audio-frequency component of

[1] W. N. Tuttle, "Modulation Measurements on Broadcast Transmitters," General Radio *Experimenter*, Volume V, No. 10 (March, 1931).
[2] W. N. Tuttle, "Direct Measurements of Harmonic Distortion," General Radio *Experimenter*, Vol. VI, No. 6 (Nov., 1931).
[3] C. H. Sharp and E. D. Doyle, Crest Voltmeters, Trans. A.I.E.E., Volume 35, pp. 99-107, February, 1916.

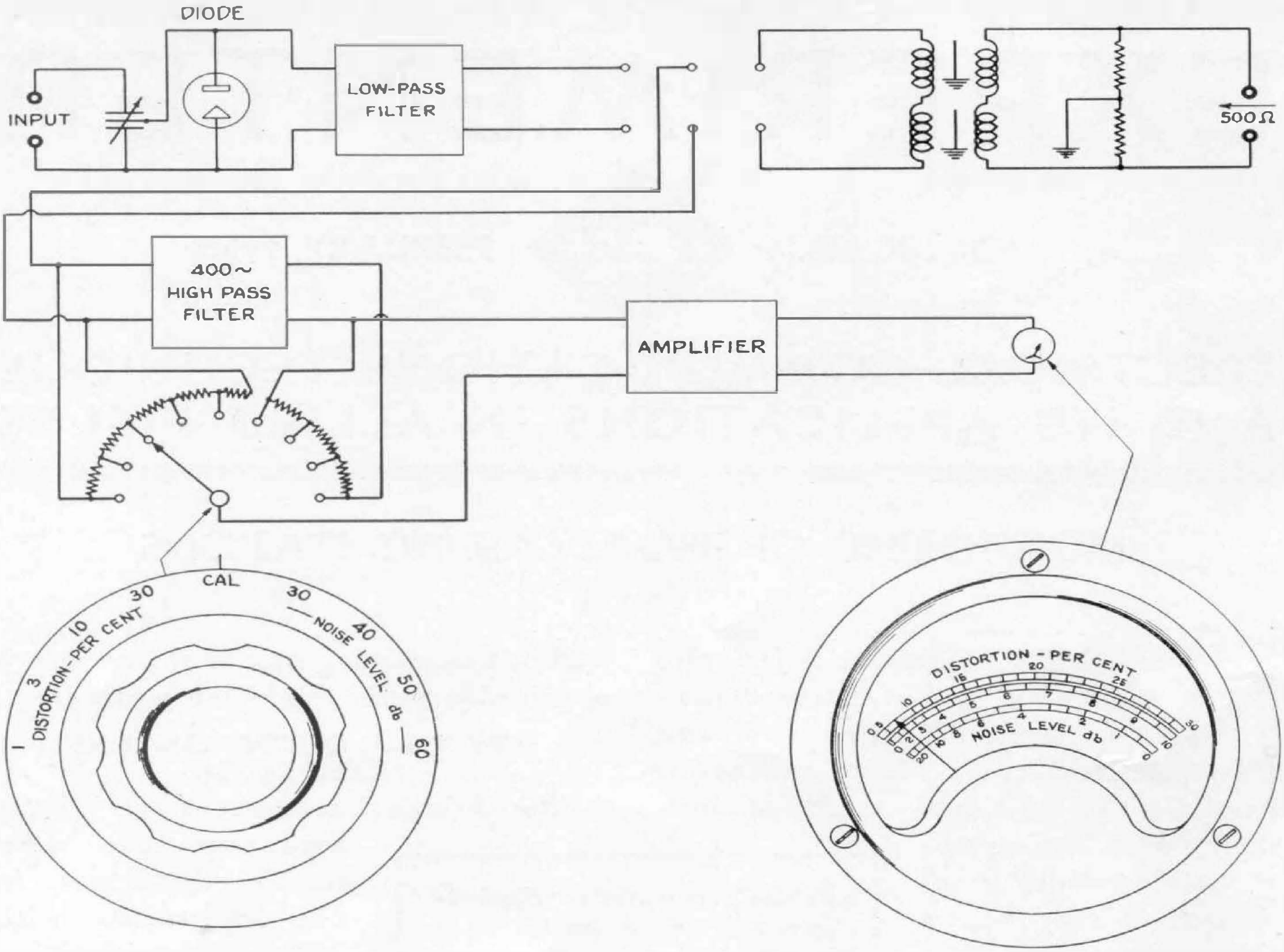


FIGURE 1. Functional schematic diagram of TYPE 732-A Distortion and Noise Meter

the envelope is applied to an attenuator and filter.

In order to standardize the direct-reading scales, a known fraction of the audio-frequency output is applied to the amplifier and the gain adjusted to give full scale deflection on the output meter. This is done at the CAL position of the attenuator.

To measure distortion, the 400-cycle component is then filtered from the signal, and a known fraction of the remaining harmonics is applied to the amplifier whose output meter is now direct reading in the distortion factor. Four scales are provided: 1%, 3%, 10%, and 30%. All are direct reading, as indicated in the drawing of the meter, which is a reduced reproduction of the actual scale.

In order to measure noise, the 400-cycle signal is applied to the transmitter and the amplifier gain adjusted as before. The modulation is then removed from the transmitter, and the residual audio components of the carrier envelope are applied to the amplifier. The ratio of noise to signal is given directly in decibels on a third meter scale. Full scale values of 30, 40, 50, and 60 db are provided, giving a total signal-to-noise ratio range of about 30-70 db.

As shown in the diagram, provision

is made for connecting the equipment directly to the carrier or to the audio system of the transmitter.

TYPE 733-A OSCILLATOR

A 400-cycle filtered oscillator (TYPE 733-A) specially adaptable to the distortion meter has also been designed. The distortion factor of this oscillator as filtered is less than 0.2% under load and less than 0.1% on open circuit.

TYPE 731-A MODULATION MONITOR

The modulation monitor consists of three essential elements: A linear diode rectifier which gives an instantaneous output voltage proportional to the carrier envelope, a peak voltmeter which measures the peak modulation, and a trigger circuit which flashes a light whenever the modulation momentarily exceeds a predetermined value. The output of the first diode is used as a measure of the carrier and is set at the start to 100, as shown in Figure 2. This meter will then indicate carrier shift as the station is modulated.

As shown in Figure 2, the audio frequency component of the carrier envelope in the desired phase for either positive or negative peak is applied to a peak voltmeter, which is specially de-

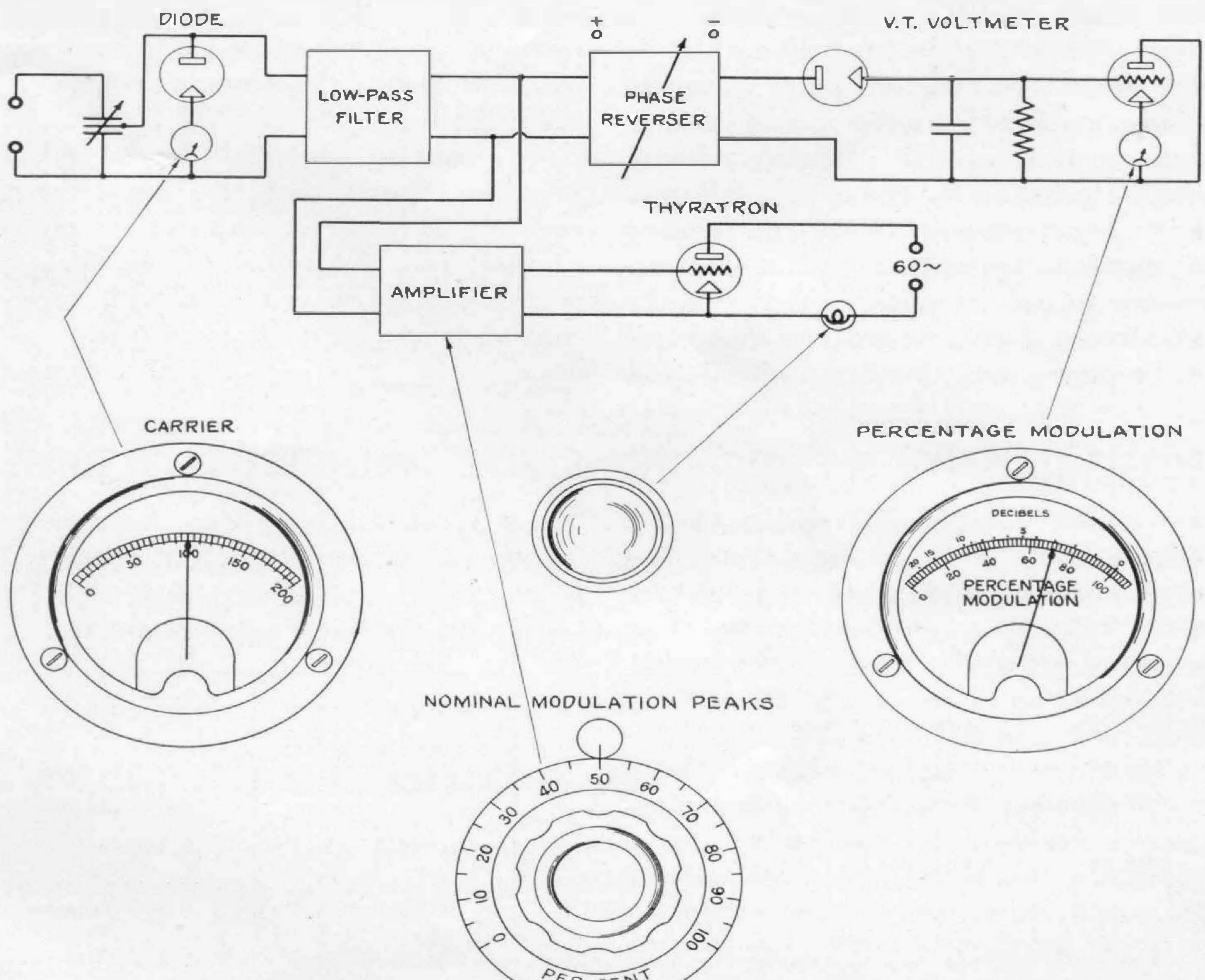


FIGURE 2. Functional schematic diagram of TYPE 731-A Modulation Monitor

signed to be highly independent of tube characteristics and to put an entirely negligible load on the first detector. This voltmeter circuit makes it possible to combine the accuracy of the older type of null method instrument[2] with a direct-reading, rapid-movement meter. The peak voltmeter reads directly in percentage modulation from 0 to 110% and has a superimposed decibel scale for monitoring purposes.

The meter movement is arranged to follow speech and music very rapidly. Over-all tests on the equipment show that a pulse lasting only 0.1 second will make the meter throw to within about 90% of the true value. This is the most rapid meter as yet commercially available, but it is not instantaneous and, even if it were, it would not be possible for the eye to follow it with any accuracy. In fact, in making dynamic tests on the meter, it was necessary to use screens to be sure of the maximum throw. In order to avoid this difficulty, a warning lamp circuit has been provided. After determining the permissible level of modulation by means of the distortion meter, a dial is set in the lamp circuit controlling the percentage modulation at which it will flash. An automatic biasing arrangement used in conjunction with a thyratron flashes a light whenever the percentage modulation exceeds the value at which the dial is set. This method is essentially an automatic null arrangement which requires no attention or adjustment.

A plug has been provided so that additional percentage meters and flashing lamps can be used externally. A connection is also made by this plug to provide an audio-frequency voltage proportional to the modulation for recording purposes.

To sum up, the modulation meter provides a pointer which gives a direct reading, dynamic measure of the modulation and, in addition, provides a warning signal when the desirable modulation is momentarily exceeded.

—L. B. Arguimbau

ERRATA

PERFORMANCE SPECIFICATIONS FOR CATHODE-RAY TUBES

In the November-December, 1934, issue of the *Experimenter*, the values of d-c voltage sensitivity given for Type 528-B Cathode-Ray Tube were incorrect. The entire table is reprinted below:

Type	*Screen Diam.*	*Fast or Slow*	*Accelerating Voltage*	*D-C Voltage Sensitivity**	*Maximum Spot Speed†*
635-P2	3 in.	Slow	1000 v	0.013 in/v	4,100 in/sec
635-P3	3 in.	Fast			11,000 in/sec
687-P1	5 in.	Slow	1500 v	0.012 in/v	6,400 in/sec
687-P2	5 in.	Fast			16,000 in/sec
528-B	7 in.	Fast	3000 v	0.0083 in/v	50,000 in/sec
			1000 v	0.025 in/v	. . . .
			500 v	0.050 in/v	300 in/sec

* Average for both pairs of plates.

† These values are maximum workable spot speeds S for Verichrome film, on the basis of a hypothetical aperture $f/1.0$ and with the screen at infinite distance from the lens. The maximum speed S' for any other aperature f/N and a ratio k between length of trace on screen and on the camera plate is: $S' = \dfrac{S}{N^2\left(\frac{1+k}{k}\right)^2}$.

SUPERSONIC SOUNDS IN NATURE*

By ELBERT P. LITTLE †

THE following article, curiously enough, shows the exact technique that would be employed to eliminate noise as the result of an industrial noise survey. The steps are, roughly, the location of the source, a frequency analysis of the disturbing sound, and a visual analysis of the mechanism parts having periods corresponding to the predominant frequencies in the disturbance spectrum.

The stroboscope used was a General Radio TYPE 528-A Edgerton Stroboscope, the clock a CLASS C-21-H Standard Frequency Assembly.

—THE EDITOR

BIOLOGISTS have often speculated as to whether or not animals produce supersonic noises, namely, sounds above the range of human audibility. We are able to hear noises due to vibrations in the air up to 18,000 per second, but anyone who has watched a humming bird singing must have observed that, as a note rises higher and higher, suddenly it can no longer be heard, but the bird's mouth will still be open and he will look as if he were still singing. The obvious conclusion is that he is singing above the range of human audibility.

Until recently we have been unable to study supersonic phenomena because no adequate methods existed of detecting high sounds and determining their pitch. But in the Cruft Laboratory at Harvard apparatus has been developed making use of magnetostriction and piezo-electric controlled oscillators and detectors by means of which we are now equipped to listen to noises that have been heretofore inaudible. Certain crystals, when properly cut, have the ability to control the frequency of an oscillator to a remarkable degree. Quartz crystals cut in this manner have a very narrow response width — that is, they will receive or oscillate at frequencies only very close to some particular one. Rochelle salts, on the other hand, have a wide range of response.

In receiving sound, a Rochelle crystal is put into a parabolic horn that can be directed towards a noise. When a sound strikes it, it gives rise to a varying voltage across two metal plates holding it. This electric variation is amplified. The amplified vibration is then heterodyned or combined with a vibration of a different frequency. The result of superimposing these two vibrations, which are applied to a vacuum tube detector, is to produce an audible vibration in the loudspeaker. By analyzing this audible sound the nature of the inaudible sound is determined. The sound detector is so sensitive that it can pick up the song of a cricket 200 yards away. It is connected to the analyzer by a shielded wire and can be carried out into the field in the direction from which the song is loudest until the insect making the noise is found.

The noises that are made by crickets are now the main feature of this research on sounds in nature. Professor George W. Pierce (assisted by Dr. Noyes and Miss Prouty) has been

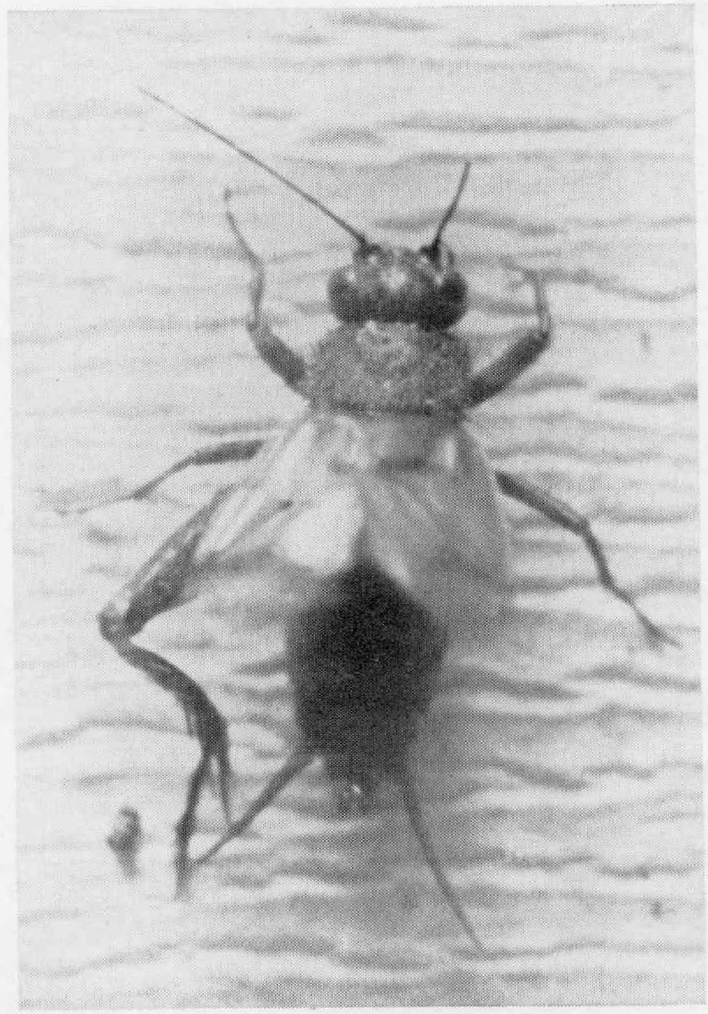
* Reprinted by permission from the *Harvard Alumni Bulletin* through the courtesy of Professor George W. Pierce and Miss Jane Prouty of the Cruft Laboratory where Harvard's work on Communication Engineering is done.

† *Harvard Alumni Bulletin.*

working with Nemobius Fasciatus, a small, dark-brown cricket that is very common in the fields. It is about one-third as long as the common house cricket. It sings at a frequency of 8000-11,000, whereas the house cricket sings at 4600 vibrations per second. Instead of discrete chirps, as with the house cricket, this small cricket emits unbroken trills, some of them lasting for over five minutes without a pause.

The study was started, and will be continued, in the country where many different insects can be taken up, and it is possible that some will be found which sing entirely above audibility. At the present time a number of crickets (Nemobius Fasciatus) are being kept in the Cruft Laboratory, and a detailed study of their singing mechanism is being made.

Insect noises are not produced vocally, but are produced by friction of one part of the body against another, by vibrations of the wings, by vibrations of a muscularly-controlled diaphragm, or by tapping the body on some external object. The cricket has small wing covers, or tegmina, which, according to biologists, are not adapted for flight. It is these wings which rub on one another to produce the "song." It is the male alone who "sings" or stridulates, the female possessing no stridulatory organs. Sometimes he sings alone with no female at hand, and at other times he sings while quite obviously trying to interest her, but she is at all times silent, appearing rather indifferent to his long trills. After a prolonged song of sometimes half an hour, the male is seen to perform a sort of dance, chirping excitedly, and the female, standing a short distance from him, will then execute back-and-forth



Stroboscopic picture of cricket with wings raised in "singing." Taken with a Leica Camera, exposure 5 seconds, stroboscope flash speed 16⅓ per second

motions. The stridulatory apparatus consists of a series of file-like teeth (148 per millimeter) located on the under side of each wing, and a hardened, raised portion on the upper inner edge of the tegmina which is used as a scraper. During the song the cricket raises his wings to an angle of 45 degrees and draws the scraper on one wing rapidly across the file on the other. This mechanism of stridulation has long been recognized by biologists, and the present investigations are principally concerned with the character of the sound. No such analysis has heretofore been made of this type of cricket, although the common house cricket and the

European field cricket have been studied.

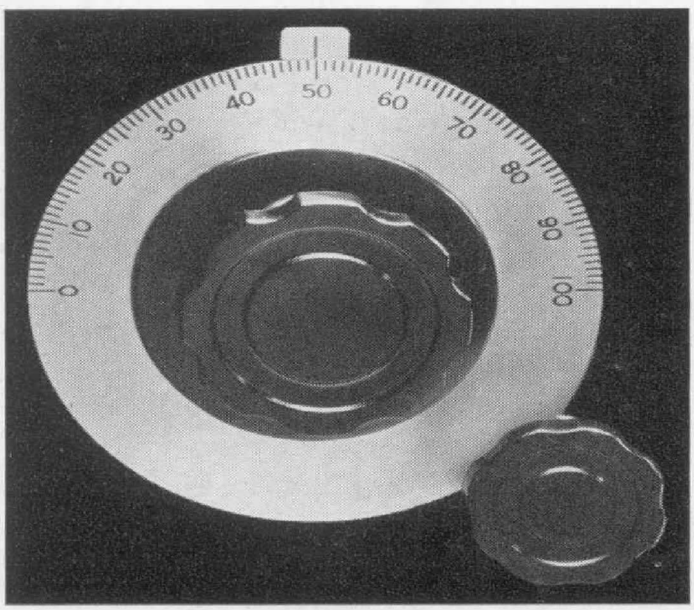
The main frequency of the note picked up by the detector was found to be about 8000 vibrations per second, or a note five octaves above middle C on the piano, but there are also strong vibrations at 16,000, 24,000, and 32,000 vibrations per second. If the signal in the amplifier is connected to a neon glow tube, the tube will flash every time sound is coming through the apparatus. The tube is attached to an arm and rotated once a second, and a photograph taken of the rotating light. A steady glow, indicating steady sound, will appear as a ring of light on the picture, whereas if the sound comes in pulsations separated by silence there will be spots of light separated by dark regions. The steady trill of Nemobius Fasciatus is seen to be made up of 16 pulsations of sound per second at room temperature, 70 degrees Fahrenheit; but if the cricket is heated up to the temperature of a hot summer evening, 94 degrees Fahrenheit, his song has 20 pulses a second. Each pulse is due to a single scraping of the wings, the pause between representing time required by the insect for changing the direction of the wing motion or going back to the start. In a previous investigation published by the American Museum of Natural History, Mr. Lutz and Mr. Hicks, working on the house cricket, concluded that this cricket did not have enough time in the .017 second pause between pulses to get his wings back to the center, so they assumed that he scraped in both directions.

The present investigators, in order to study the wing motion of Nemobius Fasciatus, set up a stroboscope beside the vivarium containing a cricket. The stroboscope is an instrument where a light can be made to flash on and off at any desired rate. If the cricket is singing, his wings are moving too fast to study. He is therefore put in the dark and the instrument is adjusted until the wings appear to stand still. Once during every cycle of the wing motion the light is flashing on for 1-100,000 second, the rest of the cycle occurring in the dark. The wings are therefore lighted every time they reach the same position. The stroboscope has a scale where the number of flashes per second can be read. The investigators found that they must adjust the speed to 16 1-3 flashes per second in order to make the wings appear stationary; hence there are 16 1-3 complete, back-and-forth wing flaps. As was stated above, at room temperature there are 16 pulses per second in the song. If stridulation was produced while the wings moved in both directions there would have to be 32 pulses per second; so in these crickets noise is produced while the wings move in one direction only.

This is, of course, only a preliminary study. Professor Pierce has listened to other noises, the song of newly-hatched robins, which is loudest at 15,000 vibrations per second, and the black pole warblers which sing at about 15,000. The ultimate object of this series is to study and classify the sounds in nature and if possible to determine whether they serve some purpose for communication. In addition to noises made by animals, Professor Pierce has found a large number of persistent supersonic noises, such as the vibrations emitted by leaves under the action of the wind, noises produced by air jets some of which are inaudible to the ear, the rubbing of clothing or of hands, noises made by the burning of a match when freshly ignited. The ticking of a watch may be heard at a distance of 30 feet or more by means of sounds of a frequency as high as 30,000 vibrations per second. The devices which are here employed in scientific study have also highly important practical applications in the production and detection of sounds under water, as a means of signaling between vessels or of finding the depth of the sea by timing echoes, or in detecting vessels by means of supersonic noises produced by the vibration of their hulls or propellers.

The vibrations produced by magnetostriction oscillators and piezo-electric crystal oscillators have a high constancy of frequency and are used in controlling the frequency of radio sending-stations and to provide time-keeping mechanisms for clocks of high precision. One such clock operated at the research laboratory, based on principles discovered by Professor Pierce and manufactured by the General Radio Co., keeps time so accurately that it changed in rate by less than 1-10 of a second per day in four months.

NEW DIALS



As companions to the 2¾- and 4-inch dials used on much of our equipment and in the assembly of laboratory and experimental apparatus of others, two new General Radio dials having diameters of 3¼ inches are now available. The new dials are similar to the Types 702 and 710 Dials, except for the larger dial plates. The dials are nickel-silver finished, with photo-etched engraving, and are insulated from the shaft. The fluted knob is polished black bakelite with rounded edges. These dials are available for both ¼- and ⅜-inch shafts, with and without friction drive.

Type	Dial Diam.	Dial Arc	Scale Div.	Diam. Shaft	Diam. Knob	Reduc. Ratio*	Code Word	Price
712-A	3¼ in.	180°	100	¼ in.	1⅝ in.	....	DIAPE	$1.25
712-F	3¼ in.	180°	100	⅜ in.	1⅝ in.	....	DIFAR	1.25
705-A	3¼ in.	180°	100	¼ in.	1⅝ in.	1 : 4	DIARK	1.75
705-F	3¼ in.	180°	100	⅜ in.	1⅝ in.	1 : 4	DIFAL	1.75

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