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EXPERIMENTER

ELECTRICAL MEASUREMENTS TECHNIQUE AND ITS INDUSTRIAL APPLICATIONS

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DISTORTION MEASUREMENTS IN THE BROADCASTING STATION

QUALITY OF TRANSMISSION is rapidly becoming an important factor in successful broadcasting. While program excellence and strength of signal go a long way toward determining to what station John Doe sets the dial of his 1937 receiver, he is definitely influenced by a third factor, *quality*.

Excessive audio-frequency distortion is annoying to the radio listener, and the difference between good-quality and poor-quality stations is easily distinguishable on modern receivers. Tests have indicated that a 10% total distortion is about the maximum which can be tolerated if the signal is to sound reasonably pleasant to the listener. Fortunately, it is not difficult to keep distortion well below this level in transmitting and receiving equipment.

In order to insure acceptable quality of transmission, the Federal Communications Commission has required that no broadcast transmitter shall have more than 10% combined audio-harmonic distortion when operating at a level of 85% modulation. This has been covered in paragraph (a) of the F.C.C., Rule 139, dated October 29, 1935.

During recent years, transmitter manufacturers have placed a good deal of emphasis on freedom from distortion and, as a result, transmitters are now available with distortion levels as low as 3%. Complete performance characteristics of all transmitters intended for general sale are submitted to the Commission as proof that the requirements are being met.

Holding distortion at a low figure has consequently become a problem of maintenance rather than of transmitter design. In the carefully balanced electrical circuits that make up the modern transmitter, changes in the operating biases and the characteristics of vacuum tubes, as well as the slow aging of other circuit elements, may result in excessive distortion. Proper care and maintenance are necessary to obtain best performance. Periodic tests are the obvious safeguard against excessive distortion and, when made as part of a definite maintenance routine, they add very little to the duties of the operating staff. Simple test methods and direct-reading instruments have reduced the testing time to a few seconds.

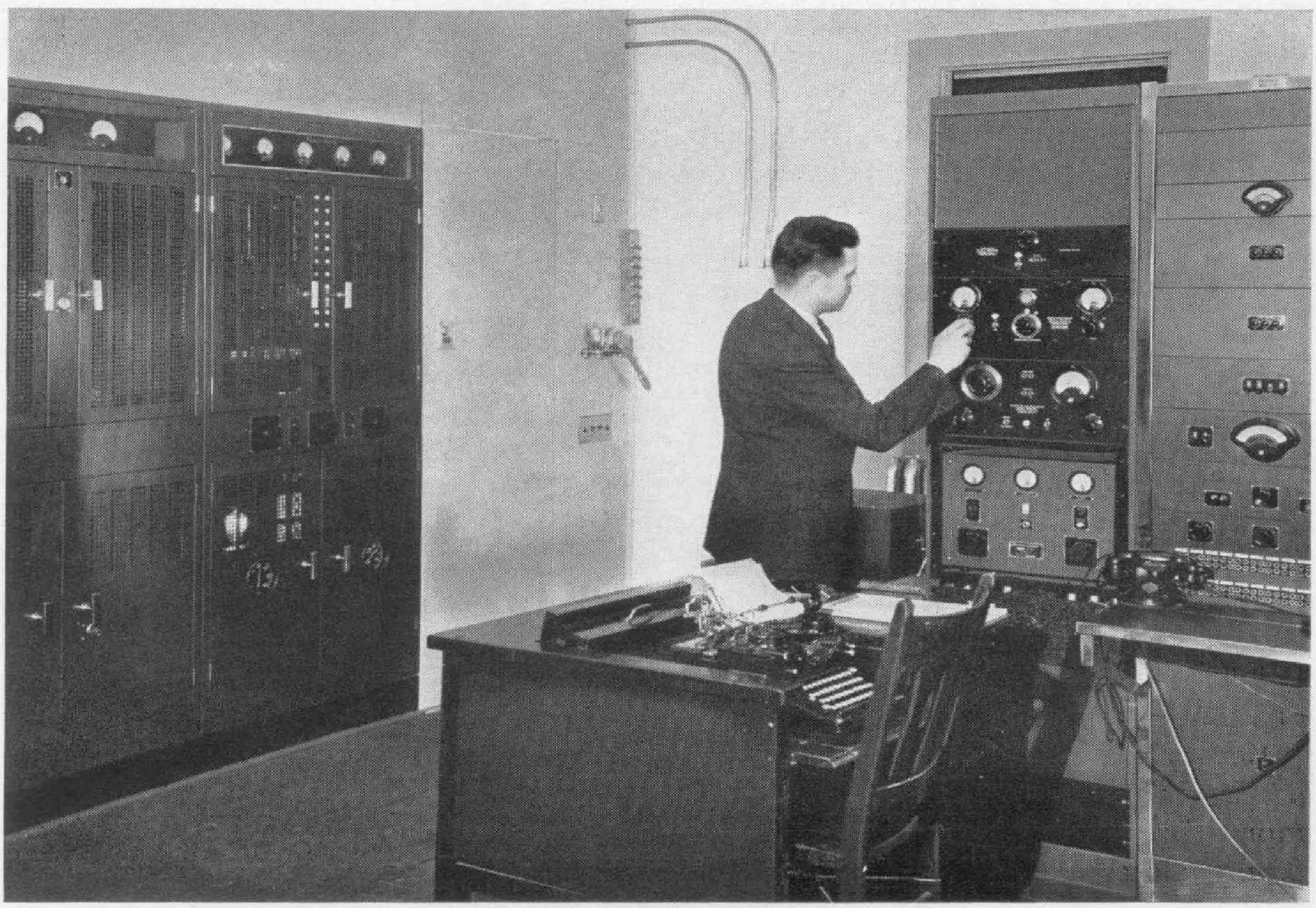
TEST METHOD

A transmitter which distorts at one audio frequency will usually do so at all frequencies, although the magnitude of harmonic components will vary with frequency in accordance with the over-all characteristics of the transmitter. A single-frequency test in the middle of the audio range, therefore, is generally accepted as an indicator of transmitter distortion. A standard test frequency of 400 cycles has been arbitrarily selected because it is commonly used in transmitter and receiver testing. Measurements made at this frequency are proof acceptable to the F.C.C. that the transmitter is operating properly as long as the combined audio-frequency distortion is less than 10% at 85% modulation.

The method of test is to apply a pure sine wave at the input of the pre-amplifier or speech amplifier and to measure the total harmonic distortion placed on this sine wave by the complete transmitting system up to the antenna.

TEST INSTRUMENT

The TYPE 732-A Distortion and Noise Meter has been designed to measure the combined harmonic distortion at 400 cycles. In practice it is loosely coupled to the output stages of the transmitter, preferably to the antenna loading coil or one of its as-



The Class 730-A Transmission Monitoring Assembly installed at WNAC. The operator is shown using the TYPE 731-A Modulation Monitor. The TYPE 732-A Distortion and Noise Meter is just below

Panel view of the Distortion and Noise Meter. Note the open, easily-read scales. Full-scale ranges of 1%, 3%, 10%, and 30% are provided

sociated circuits. The radio-frequency energy picked up from this circuit is passed to the distortion meter which reads directly in percentage the total r-m-s distortion which is present on the audio-frequency envelope of modulated carrier.*

Measurements are made with the distortion meter simply and quickly. All that is necessary is to make an adjustment to a reference level with the tone on, and then to turn one dial to read the distortion directly on a large meter. The whole operation does not take more than ten seconds, even with inexperienced personnel.

A wide range of distortion can be measured with this instrument, the maximum distortion that can be read being 30%. The sensitivity is sufficiently sensitive to permit measurements at low distortion levels. A distortion of 1% will give a full-scale deflection on one of the measuring ranges, and distortions as low as 0.2% are easily readable.

TONE SOURCE

To generate the test tone of 400 cycles, the Type 733-A Oscillator has been designed. This is a vacuum-tube oscillator generating a nearly pure 400-cycle tone with a level sufficient for all measuring purposes. The actual distortion of this oscillator is 0.2% or less, and this amount can be neglected in most measurements. Three output impedances, 50, 500, and 5000 ohms, are provided so that almost any studio circuit can be approximately matched.

ROUTINE

In many broadcasting stations where the Type 732-A Distortion and Noise Meter is already installed, it is customary to make a routine distortion measurement at the beginning of the day's operation and at the end, and to record these readings in the station log along with the other details of the daily operations.

NOISE MEASUREMENT

Another feature of the meter which is very useful in broadcast-station maintenance is the fact that it permits the measurement of the residual noise and hum level of the system. This measurement is made by comparing the residual noise in the transmitter to a reference tone level. For example,

*The principle of operation is described by L. B. Arguimbau in the General Radio *Experimenter* for February, 1935.

after the distortion measurement has been made with a modulation percentage of, say, 85%, the test tone is turned off, and the noise meter is switched by the single control dial to another position where the meter will register the residual noise in terms of decibels below the test-tone level. In this way excessive hum or a noisy transmitter tube can be discovered immediately.

Sources of noise, whether in lines or amplifiers, can be located quickly by patching out the various amplifiers and equipment in the system until the noise disappears. The fact that the noise level is measured in decibels is most useful in evaluating the amount of noise introduced by any element in the system. This method of test is very quick and serves in emergencies to isolate any noise promptly so that it can be cleared with a minimum of interruption to the program.

No standard of background noise level has been established as yet, but in good transmitters the noise level is sometimes kept as low as 60 decibels below 85% modulation. It is not difficult to keep the noise level at least 40 decibels below the distortion test-signal level, a figure which is good enough for most practical purposes.

DISTORTION IN THE AUDIO SYSTEM

In addition to its use in measuring the over-all quality of the transmitter, the Type 732-A Distortion and Noise Meter has an equally important application in measurements on the audio-frequency system alone. Two audio-frequency input circuits are provided for this purpose. One of these circuits has an input impedance of 500 ohms balanced to ground, and the other an impedance of 50,000 ohms unbalanced. Both circuits are available by means of jacks in the front panel. To make distortion measurements at the 500-ohm impedance, it is necessary to have a signal with a level of about plus 1 decibel, or about 2 volts as a reference level. The exact adjustment of this input voltage level is provided for by the panel meter. Approximately 20 volts are required across a 50,000-ohm circuit. The 500-ohm input circuit is carefully balanced to ground so that the measurement can be made on balanced as well as unbalanced circuits without disturbing the circuit under measurement.

Residual noise measurements in audio-frequency circuits can also be made by the same means.

SIMPLICITY

The Type 732-A Distortion and Noise Meter is relay-rack mounted and alternating-current operated. It replaces earlier distortion-measuring equipment consisting of Type 536-A Distortion Meter, Type 514-AM Amplifier, and Type 488 Copper-Oxide Rectifier Meter. All of the essential components are self-contained in the new instrument, and no external apparatus is required except the Type 733-A Oscillator. This is an obvious advantage for any laboratory application and is, of course, absolutely essential in broadcast-station practice.

— Arthur E. Thiessen

Type 732-A Distortion and Noise Meter and Type 733-A Oscillator are fully described on pages 111 and 112 of Catalog J.

This instrument is licensed under patents of the American Telephone and Telegraph Company solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.

A 1000-CYCLE BAND-PASS FILTER

● **TYPE 830-R WAVE FILTER** is a highly selective band-pass filter, passing only a narrow band of frequencies in the vicinity of 1000 cycles per second. In order to provide maximum flexibility in application, several input and output impedances are provided. One side of the filter has two impedances, 500 and 5000 ohms; the other side has four, 50, 500, 5000, and 50,000 ohms respectively.

FIGURE 1. Photograph of TYPE 830-R Wave Filter, showing the arrangement of terminals

This arrangement makes it possible to work from either a 500-ohm line or a vacuum tube into a circuit of almost any impedance with very little impedance mismatch.

The attenuation characteristics are the same for either connection on the two-impedance side, but differ somewhat for different connections on the four-impedance side. From the plot of Figure 2, it will be seen that greatest attenuation to harmonics is obtained on the 5000-ohm output tap (this is the curve shown in Catalog J). An attenuation peak at the second harmonic occurs when the 500- and 5000-ohm taps on the four-impedance side are used. This peak is not present with the other two taps.

FIGURE 2. Transmission characteristics of the filter

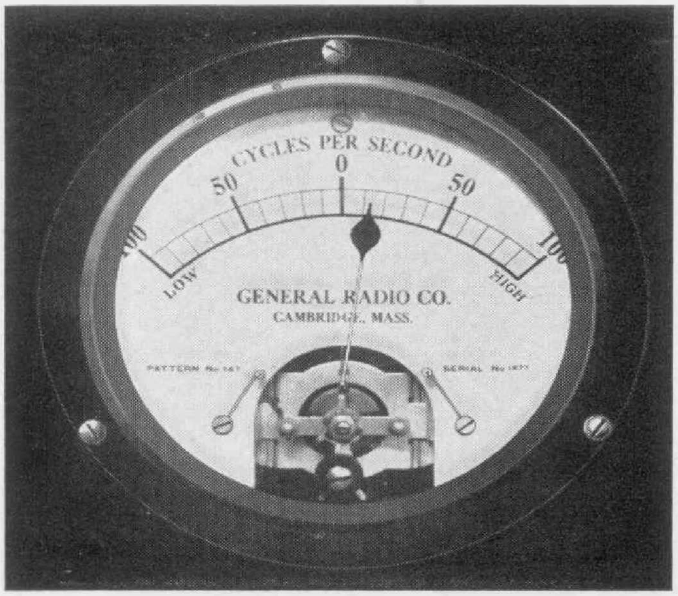
Since either side may be used as input or output, two different connections are possible when working between 500 and 5000 ohms. From the curves of Figure 2, it is evident that somewhat better characteristics will be obtained if the 500-ohm connection is made at the two-impedance side.

The attenuation for the desired frequency is about 5 decibels, so the discrimination against harmonics is 5 db less than the actual height of the curves.

— W. N. TUTTLE

VISUAL-TYPE FREQUENCY MONITORS

A-C OPERATION FOR BATTERY MODELS



● **WE ARE STILL PREPARED** to rebuild the early battery-operated broadcast frequency monitors, converting them to a-c operated instruments. These monitors have been in service from three to five years and a complete overhauling is desirable. Many stations have had their monitors rebuilt during the past two years, and the station engineers feel that the expense involved is justified by the results obtained.

The modification of the piezo-electric oscillator into a Type 575-E includes installing a new panel and modification of the terminal strip, replacing the temperature control relay with an a-c unit, installing fusible protective links in the temperature-control circuit, replacement of the heat indicator lamp by one of the "bull's-eye" type, and such other minor changes as may be necessary.

The quartz plate will be readjusted to exact frequency, and bakelite bases will be replaced by isolantite.

The deviation meter, after modification, will be called Type 581-B and will supply the power for the Type 575-E Oscillator. The instrument will be given a complete overhauling and put in first-class electrical and operating condition.

The total charge for the modification is $155.00. The rebuilt instruments will carry the same guarantee as new equipment. The quoted price will include minor repairs not strictly a part of the reconditioning operation, but necessary major repairs will be subject to additional charge at a fair rate. The time required to do the work will be between ten days and two weeks.

When, in addition to this work, a new Type 376-L, low-temperature-coefficient, quartz plate is installed, the total price is $215.00.

The Federal Communications Commission will grant a permit to operate a broadcasting station for a period of 30 days without a visual monitor, provided it is stated that the frequency monitoring equipment is being returned to the manufacturer for modification and calibration. It is, therefore, essential that the permit be granted before the equipment is returned to us.

Before returning instruments for this modification, write to the Service Department for shipping instructions.

— H. H. Dawes

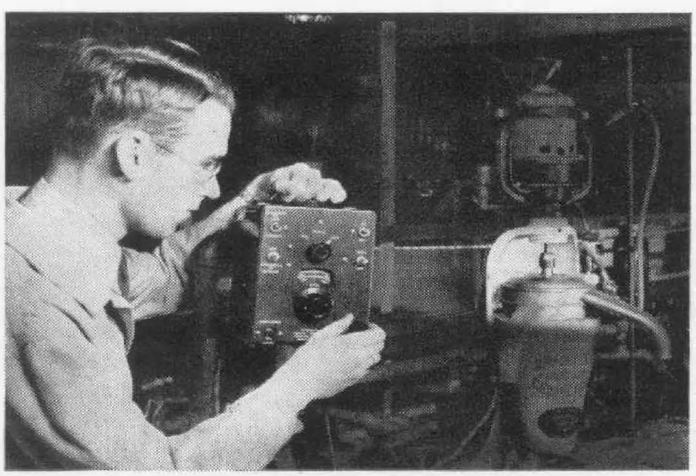
HIGH-SPEED MEASUREMENT WITH THE STROBOTAC

WE HAVE OFTEN BEEN ASKED how to measure speeds outside the fundamental range of from 600 rpm to 14,400 rpm covered by the Strobotac.

Speeds of less than 600 rpm may be measured by the simple expedient of marking a single radius upon the end of the shaft to be viewed. The true speed is then the Strobotac setting to give a motionless multiple pattern divided by the number of radii seen in the pattern. Thus a cross seen on the end of a shaft at a Strobotac setting of 1000 rpm indicates a true shaft speed of 1000 divided by four, or 250 rpm. In this manner the range of the Strobotac may be extended to 600 divided by 6, or 100 rpm.

For speeds greater than 14,400 rpm, the formula is rpm $= \frac{ab}{a-b}$ where a and b are adjacent settings of the Strobotac for which a motionless image is obtained. Thus for stationary images at 8000 rpm and 12,000 rpm

$$\frac{ab}{a-b} = \frac{8000 \times 12{,}000}{4000} = 24{,}000 \text{ rpm.}$$



The TYPE 631-A Strobotac as used to measure the speed of a centrifuge

For higher speeds, the value of a-b becomes progressively smaller, giving increasing errors in speed determination for small errors in observation.

Take a and b at several patterns apart and multiply the answer by the number of patterns reached in going from a to b, in order to restore the accuracy of the measurement.

Thus, suppose a still image at a setting of 12,000 rpm and another, the tenth image away, at 7200 rpm. The true speed is then $10 \times \frac{12{,}000 \times 7200}{4800}$, or 180,000 rpm, as found in some types of ultra centrifuges. The Strobotac is the easiest and quickest way to measure these speeds.

Since the ratio of shaft speed to Strobotac flash rate must be a whole number, a slightly better result may still be obtained by correcting this ratio to the nearest whole number and multiplying the Strobotac dial reading by that whole number. — F. IRELAND

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MISCELLANY

● **GENERAL RADIO** employees have recently organized a camera and telescope club. The first meeting was enthusiastically attended by some forty people, including many, we suspect, who hadn't pushed a camera shutter for years, but were carried along by the current urge for hobby cultivation. The attendance was divided almost equally among the three divisions of still pictures, movies, and telescopes. Courses of instruction in fundamental photographic processes are planned, as well as the construction of a complete telescope.

● **THIS** is only one phase of an extensive program of out-of-hours activities promoted by General Radio's genial Dean of Education, Horatio W. Lamson. Classroom instruction in elementary electrical and radio theory has been available to our production men for several years. During the past few months a series of informal talks has been inaugurated, covering a wide range of popular and specialized subjects. Some of these, delivered by General Radio employees, serve to acquaint men with activities outside their own departments. Others have been presented by representatives from outside companies. Of these latter, two were outstanding: that by Messrs. Oleson and Lamb of the Weston Electrical Instrument Corporation on "Indicating Instruments," and that by B. W. St. Clair of the Mico Instrument Company on "Materials."

● **H. B. RICHMOND**, General Radio's treasurer, was the speaker at an Electrical Engineering Colloquium held at M. I. T. March 15 and 16. The subject: "The Operation of an Engineering and Manufacturing Organization of Moderate Size."

● **DR. W. N. TUTTLE** of our engineering staff has returned from his skiing vacation in the Alps. He reports the skiing conditions good in spite of continual blizzards. Combining business with pleasure, Dr. Tuttle visited our agents in Italy, Ing. S. Belotti and C., at Milan, as well as the National Electrotechnical Institute, Galileo Ferraris at Turin, where many General Radio instruments are installed.

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GENERAL RADIO COMPANY

30 STATE STREET - CAMBRIDGE A, MASSACHUSETTS

BRANCH ENGINEERING OFFICE — 90 WEST STREET, NEW YORK CITY