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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

SPEEDING UP THE STANDARD-SIGNAL GENERATOR

This article describes the mechanical features of a new precision standard-signal generator which materially speeds up routine standard measurements on broadcast receivers. The next article by the designer of the instrument discusses its electrical features

A YEAR or more ago, the General Radio Company began a study of measurement technique in the development and design laboratories of the radio industry. Attention naturally focused on the standard-signal generator and its accessories, since one of the set designer's most pressing problems is the evaluation of his models by means of the standard I.R.E.-R.M.A. broadcast-receiver tests. These tests even take precedence over many important details of design, because every engineer is a member of a commercial manufacturing organization whose management must be kept informed of the performance of its product in competition with that of other companies in the field.

Conferences with representative engineers in the industry shortly uncovered the fact that improvements in both the electrical and mechanical design of standard-signal generators would be welcome. Electrical improvements would include such points as the minimizing of frequency modulation, the so-called fly-wheel effect, and stray fields. Mechanical improvements would include a rearrangement of controls so that the standard tests could be made with greater speed. This would involve something of the same kind of transformation that radio sets went through in their progress from the "three dial" to the "single control" stage.

The result of the study was the new Type 600-A Standard-Signal Generator in which many radically new ideas in electrical and mechanical design were worked out.

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Any increase in the speed of manipulating a standard-signal generator must, of necessity, be dependent on the operation of two controls: the output voltage adjustment and the frequency adjustment. A third, the frequency control of modulation voltage for fidelity tests, must also be considered, even

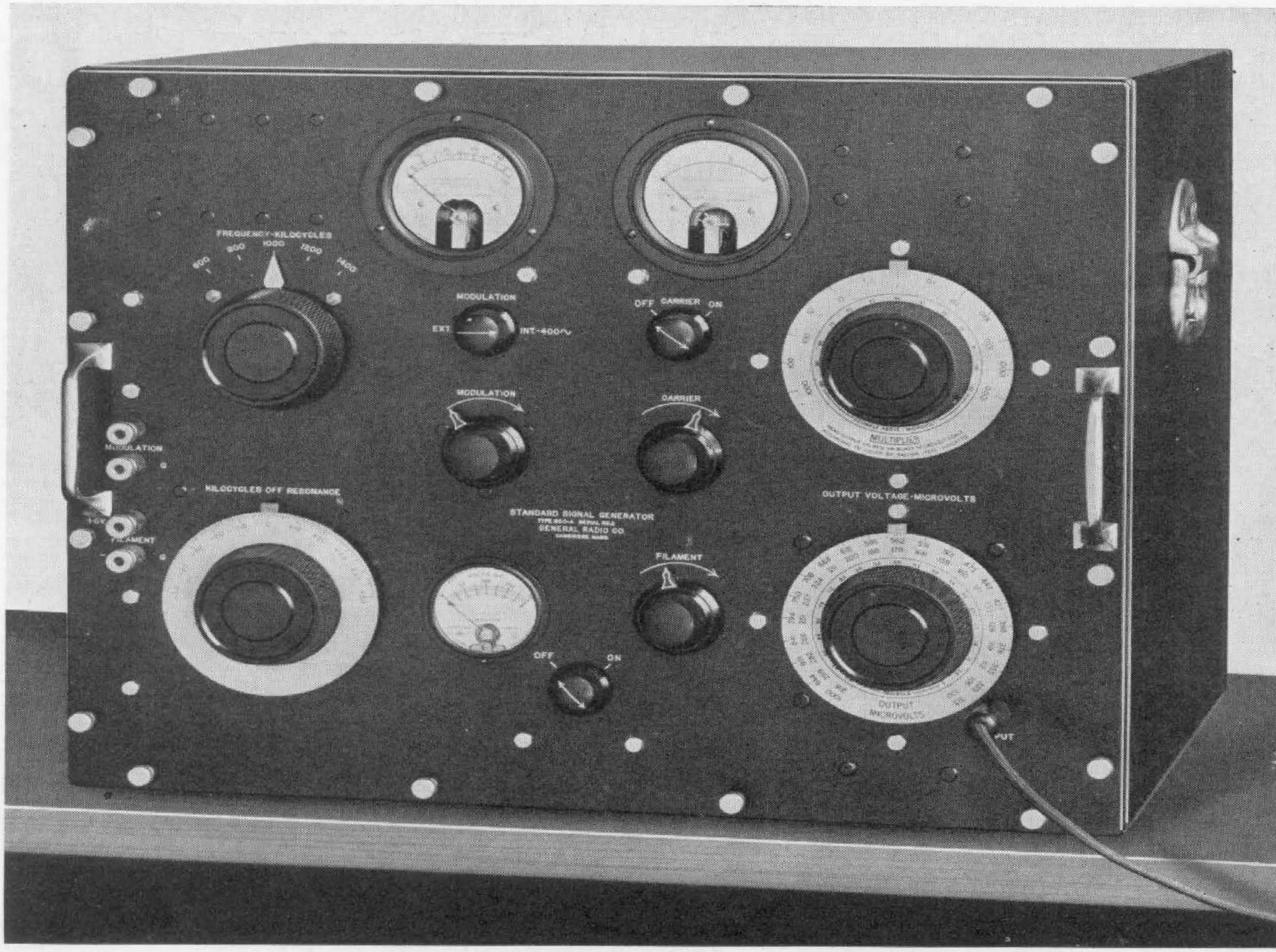

FIGURE 1. Panel view of the TYPE 600-A Standard-Signal Generator. At the upper left is the channel selection switch and immediately below it the selectivity or "kilocycles-off-resonance" control. At the right is the two-stage attenuator shown in detail in Figure 3 and to the left of it the voltmeter for indicating attenuator input

though this audio-frequency source is not usually a part of the standard-signal generator proper. This point can be disposed of at once by noting that the recently developed TYPE 513-B Beat-Frequency Oscillator meets all the usual modulation-source requirements as to power output, purity of waveform, and ease of manipulation.

A study of the different methods for adjusting the output voltage of a signal generator showed that a marked increase in speed could be obtained if an attenuator were built to cover the entire range in small enough discrete intervals to make reading a meter unnecessary. Previous practice had been to use the attenuator only as a multiplier for the ammeter or voltmeter indicating the attenuator input. This was excellent for certain types of work but a great handicap where speed is essential. This was due not only to the necessity for an added control but to the fact that interpolating on a meter is a time-wasting process.

When the actual design of the attenuator for the TYPE 600-A Standard-Signal Generator was considered, it was found that the decibel or logarithmic type had many mechanical advantages. The logarithmic attenuator is not only easier to build, but it makes possible incremental variations in accordance with Weber's law for the response of the human ear to an exciting stimulus. This fact was recognized when the standard I.R.E. plotting paper was laid out, since output voltages, which are the ordinates on the selectivity and sensitivity and band-width charts are arranged logarithmically. Another advantage appeared in the making of selectivity test, and this will be referred to later on.

A clue to the solution of the frequency-adjustment problem was furnished by the specifications for the I.R.E.-R.M.A. standard tests. These standards recommend the testing of broadcast receivers for sensitivity and fidelity at 600, 800, 1000, 1200, and 1400 kc., and the testing for selectivity and band-width at 600, 1000, and 1400 kc. Since only these frequencies are required, the obvious solution was to build an oscillator whose frequency was adjustable to the desired values by means of a switch. This eliminated all calibration charts and the loss of time occasioned by changing from one frequency to another. Later on it was also found that this permitted simplifications in the arrangements for taking band-width and selectivity runs.

By making selectivity tests at the three standard frequencies only, we could include an auxiliary dial controlling three straight-line-frequency condensers, one for each test frequency. Then, by building a switching arrangement into the main channel selector switch, the frequency adjustments for all tests were reduced to their simplest terms.

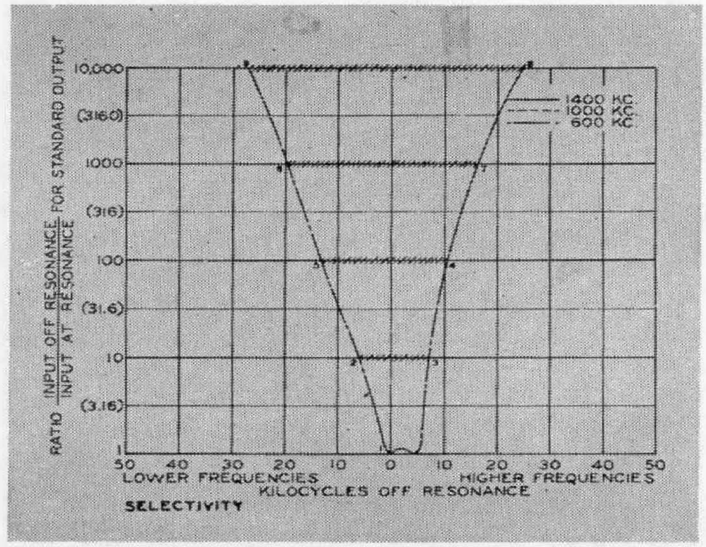

FIGURE 2. A selectivity curve, one of three made by the writer in three and one-half minutes with the TYPE 600-A Standard-Signal Generator. The horizontal bar lines represent band widths for their respective values of input to the receiver under test

The significance of these radical changes in the design of the output and frequency-adjustment controls can best be appreciated by noting the important fact that these adjustments give, respectively, the ordinates and abscissae on the plotting paper for all of the standard I.R.E. tests. These materially speed up the curve-plotting operation; in fact it is entirely feasible to take data directly on the plotting paper.

To show the possibilities of the new mechanical design, the writer, without previous experience, made a three-channel selectivity run on a commercial broadcast receiver in three and one-half minutes, using the TYPE 600-A Standard-Signal Generator. This involved the taking of nine points on each of three channels, a total of 27 separate measurements.

Figure 2 shows the curve for the 600-kc. channel as plotted on paper, which differed from the standard I.R.E. paper in two respects only: the "kilocycles-off-resonance" scale was ex-

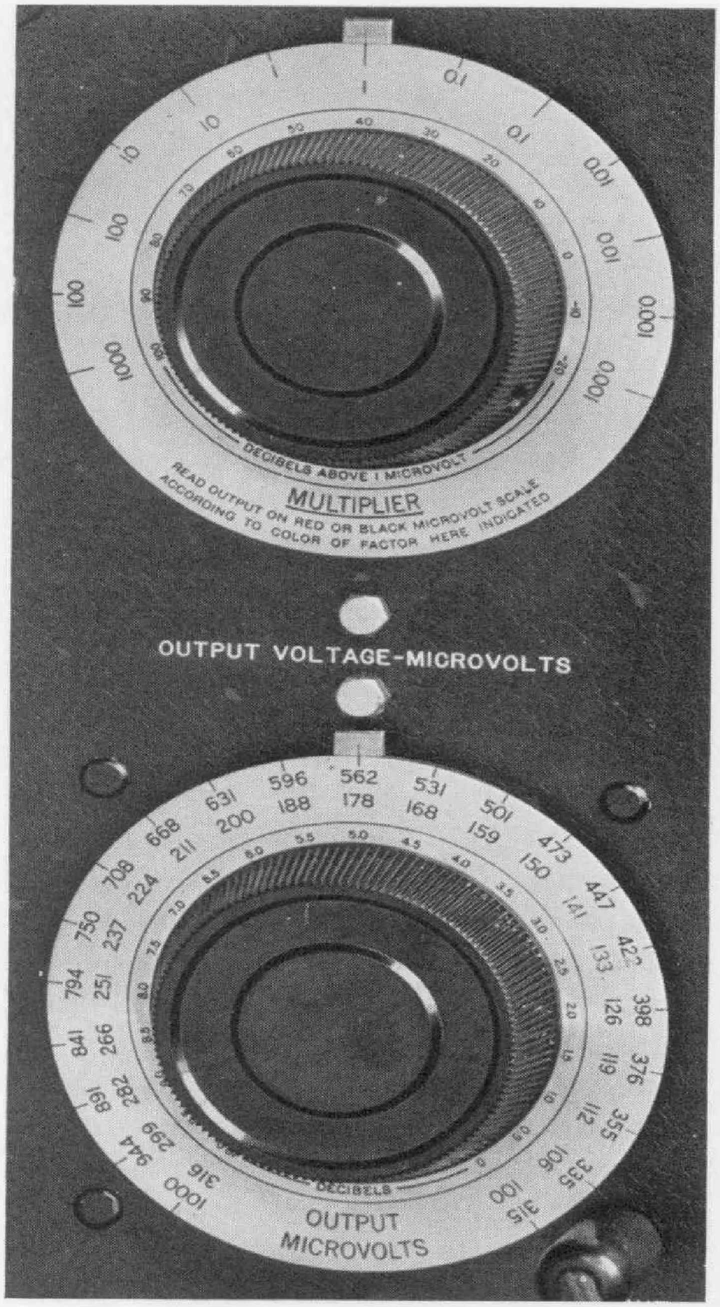

FIGURE 3. Output voltage controls for the TYPE 600-A Standard-Signal Generator. The dials are now set for 178 microvolts or 45.0 db above a reference level of 1 microvolt. If the upper dial were moved clockwise one division, the output would be 562 microvolts or 55.0 db

tended to 50 kc. instead of 30 kc., and an intermediate set of ordinates was inserted between the lines representing ratios of 1, 10, 100, 1000, and 10,000. The "kilocycles-off-resonance" scale was extended because the selectivity control on the TYPE 600-A Standard-Signal Generator spans that range. The intermediate scale of ordinates was inserted to enable us to make a curve having a greater number of points than are called for in the standard testing specifications. These were not used in the test we are discussing, the numbered points only being taken. The small hump located at the base of the curve was taken in another test as proof that 6% voltage increments could give all necessary detail.

The logarithmic or decibel control of output voltage on the standard-signal generator is arranged as shown in Figure 3, the steps of the upper scale being placed at intervals of 10 db, and the steps of the lower scale being placed at 0.5-db intervals. Therefore, turning the upper knob increases the output voltage 3.16 times for one step and 10 times for alternate steps; turning the lower knob increases the output voltage by about 6% for each step.

Since the output level for successive ordinates on the standard selectivity curve increases 10 times for every interval, it may be seen at once that the process of taking a selectivity run with the new standard-signal generator has been simplified considerably.

Refer to Figure 2, for example. Point No. 1 is obtained by setting the channel selector at 600 kc., and the "kilocycles-off-resonance" dial at zero, then adjusting the output voltage until standard output is obtained. The value of voltage thus obtained, is, incidentally, the sensitivity of the receiver at 600 kc.

Then the upper attenuator dial is advanced two steps which gives an "off resonance" to "at resonance" ratio of 10 to 1. Point No. 2 is obtained by turning the selectivity control until standard output is restored, after which the control is turned to the high frequency side to obtain Point No. 3. This process is repeated until all nine points have been obtained, when the curves for 1000 kc. and for 1400 kc. may be run.

On most receivers the overload point is sufficiently low to protect the output meter from damage as the dial is swung through resonance on its way from Point No. 2 to Point No. 3. On others a satisfactory arrangement is to shunt down the output meter for a moment.

Note that the data for band width at each input level are given directly by the sum of the selectivity control dial readings for the two (high- and low-frequency) positions.

As we said before, a complete run of three curves was made in three and one-half minutes, a time which would probably be reduced considerably by an experienced operator. Similar savings in time are obtained with the tests for sensitivity and fidelity.

Compared with the time taken by older methods, the new method seems unbelievably fast, more so in fact when it is realized that these tests are made with greater accuracy than has ever before been possible with a commercial standard-signal generator. The benefits of this to a busy engineer are obvious. —JOHN D. CRAWFORD

A LINEARLY MODULATED OSCILLATOR

THE use of high percentages of modulation by commercial broadcasting stations has materially altered the problem of receiver design. A square law detector when operated at low percentages of modulation gave entirely satisfactory fidelity, since over small regions a parabola is reasonably linear. With high fractional modulation, however, such a receiver causes marked distortion. This trouble has been decreased considerably by the use of so-called "power" detectors which are much more nearly linear. A standard-signal generator to test such a receiver should clearly be capable of linear modulation up to 100%.

A further requirement is imposed on signal generators by the greatly increased selectivity of modern receivers. In measuring the sensitivity of a receiver, it has been customary to vary the input to a coarse-step attenuator by means of a potentiometer, obtaining the output voltage as the reading of a thermocouple meter multiplied by a certain attenuation factor. This scheme, while satisfactory with the broadly tuning sets of a few years ago, causes trouble with very selective sets, since the potentiometer setting has an inherent reaction on the oscillator frequency. The increased sharpness also emphasizes the importance of freedom from frequency modulation.

To meet these newly arisen demands in the testing of modern broadcast receivers, the General Radio Company set about the design of a new standard-signal generator, the TYPE 600-A Standard-Signal Generator mentioned in the preceding article.

The problem of varying the output without reacting on the frequency was readily met by the use of two resistance networks. One (serving as a multiplier) varied the input to a T network arranged to give ½ db (6%) increments.

By means of these two networks (with proper precautions to avoid leakage effects), it has been possible to provide a voltage output range of 3 million to 1 (0.1-316,000 microvolts).[1] At the high levels (100,000-316,000 microvolts), the attenuator reacts somewhat on the frequency. This reaction is not very serious in practice, since data at such high levels are not needed with nearly as high precision as at the lower levels.

The main difficulty in design was experienced in attempting to get an oscillator which would modulate linearly up to 100%. The usual plate modulation system having a grid leak and condenser in the oscillator circuit gives fairly good characteristics with modulations up to about 50%, but at higher values it becomes seriously non-linear. Even at low modulations the calibration of the modulation meter depends appreciably on plate voltage and simple corrections are not always accurate. Furthermore, attempts to modulate it at high frequencies lead to dynamical effects (sometimes called "fly-wheel" or "inertia" effects), due to the finite time taken for the oscillations to change in amplitude when the plate voltage is changed. These considerations led to the discarding of conventional types of oscillators and made it necessary to develop an entirely new circuit.[2]

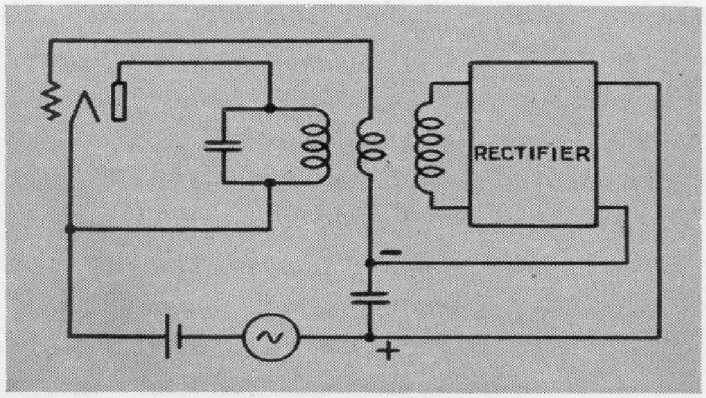

FIGURE 1. Functional schematic of the new oscillator. Fractional modulation is given by the ratio $\frac{Em}{Eo}$, where *Em* is the peak voltage of the modulating source (represented by the generator symbol) and *Eo* is the rectifier voltage output which is proportional to its high-frequency input. In practice, the grid battery is the control for carrier amplitude and is adjusted to keep *Eo* constant

As is well known,[3] in order to establish equilibrium in an oscillator, the vacuum tube must operate at a certain effective plate resistance, the value of this resistance being determined by the constants of the resonant circuit and by the amplification factor of the tube. This resistance is usually obtained in practice either by overloading of the tube due to its non-linear characteristics or by adjusting the external circuit to match the tube conditions by means of a variable feed-back control. In the newly developed circuit this matching of plate resistance to the circuit is brought about by means of an auxiliary rectifier which shifts the oscillator grid bias by an amount proportional to the amplitude of oscillations. Since for oscillatory equilibrium the plate resistance, and hence the effective grid bias, must stay constant if the oscillator bias is arbitrarily

[1]Space does not permit a discussion of this part of the work. Special heterodyne circuits in conjunction with a harmonic analyzer made it possible to check all of these levels with an accuracy of better than 2%.

[2]This circuit has been described by the writer in a paper presented before the International Scientific Radio Union (U. R. S. I.) at Washington, D. C., in May, 1931. It was entitled "A Vacuum-Tube Oscillator Having a Linear Operating Characteristic." It is being presented to the Institute of Radio Engineers for publication.

[3]See, for example, L. B. Arguimbau, "A Low-Frequency Oscillator," General Radio Experimenter, October, 1929.

shifted by external means, the detector output must shift to compensate for it. But this means that the amplitude of oscillations must change by an amount proportional to the change in bias. This fact provides the key to the whole situation.

The interdependence of oscillatory amplitude and rectifier bias together with the external bias provides an oscillator whose amplitude varies linearly with a modulating voltage. All that has just been outlined holds equally well if the bias is varied slowly by an audio source. This means that the oscillator provides a modulated wave whose envelope varies linearly with the instantaneous voice amplitude.

A little consideration will show that under these conditions the fractional modulation is given directly by the ratio of the peak modulating signal (applied in series with the rectifier) to the average rectified output. In practice it has been found convenient to use the rectifier bias as a measure of the input to the signal generator attenuator, keeping the reading constant by means of a variable grid-battery bias. This means that whenever the oscillator-output meter on the generator is "set to the red line" the rectifier output voltage has a definite value. This fact enables us to calibrate a voltmeter connected across the modulating source directly in percentage modulation without making any corrections for circuit conditions.

The use of this circuit makes it possible to approximate quite closely to

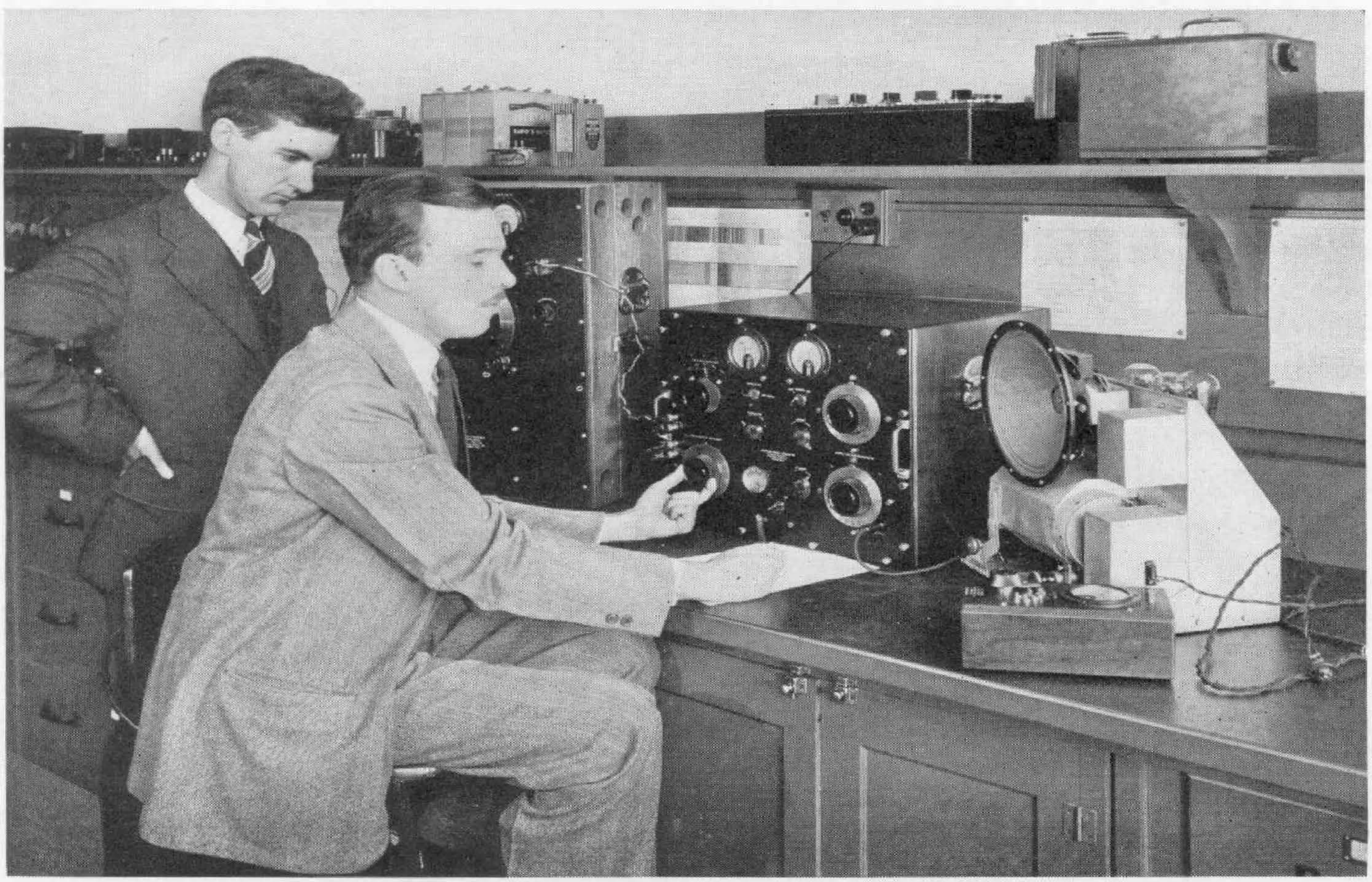

FIGURE 2. L. B. Arguimbau (left), designer of the TYPE 600-A Standard-Signal Generator, showing John D. Crawford, another General Radio engineer, how to operate the instrument

the ideal broadcasting station even replacing the usual single-frequency modulation source by the output of an actual speech amplifier if desired, varying the output until the modulation meter jumps most frequently somewhere near the required percentage modulation. —L. B. ARGUIMBAU

CATALOG SIZE ▲ ▲ ▲ Last spring when we mailed out address revision cards to our mailing list, we asked some 5000 readers to tell us which of two possible sizes they would prefer for the General Radio catalog. The two sizes were 6 by 9 inches (like the present *Experimenter*, the *Proceedings of the I.R.E.*, and a number of other technical publications) and 8½ by 11 inches (like standard letter paper and other material that is intended for storage in a standard drawer-type filing cabinet).

The results were overwhelmingly in favor of the smaller 6 by 9-inch book. The reasons for preferring one to the other were almost as numerous as the number of readers reporting, but all seem to depend on the reader's favorite method for storing catalogs when not in use. Some used the drawer file; others a bookcase or desk drawer.

The actual results were as follows:

For the 6 by 9-inch size 54.5%
For the 8½ by 11-inch size . 35.2%
Not voting or "either size" 10.3%

What clinched the argument was the majority preference for 6 by 9 inches and a reason best expressed in the comment received from a well-known consulting engineer. After invoking divine wrath on the larger size, he adds, "General Radio catalogs are as likely to live with the reference books as with the catalogs—or to perch in the top desk drawer. The large size is a damned nuisance in those places—*the small size goes anywhere*—including files."

We (the editorial we) feel that the larger page makes the mechanics of layout a little more simple; "*the small size goes anywhere*" is, however, an almost indisputable argument.

Too many suggestions were received to permit our acknowledging each one individually. We, therefore, take this opportunity of thanking those who wrote in, and of assuring them that we appreciate their assistance.

TYPE 600-A ▲ ▲ ▲ Formal commercial information about the new TYPE 600-A Standard-Signal Generator is contained in Catalog Supplement F-306, announcements concerning which have appeared in previous issues of the *Experimenter.* Extra copies are available and will be sent without charge to interested persons.

The price of the instrument is $885 complete with tubes and dummy antenna.

THE GENERAL RADIO COMPANY mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the

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