The GENERAL RADIO
EXPERIMENTER

VOL. VI. No. 11 APRIL, 1932

ELECTRICAL COMMUNICATIONS TECHNIQUE
AND ITS APPLICATIONS IN ALLIED FIELDS

TESTING RADIO RECEIVERS ON THE ASSEMBLY LINE

THERE is no other single test that will give the figure of merit of a radio receiver more accurately than the measurement of its over-all sensitivity. Because it is one of the fundamental characteristics of any receiver, laboratory information on the sensitivity is usually well known. A quick comparison of the sensitivity of the sets as they progress along the final inspection line with the predetermined laboratory standards has proved to be a most satisfactory indication that their performance is acceptable.

It is almost always necessary to align the ganged variable condensers in a receiver during the final testing operation and a good radio-frequency oscillator is required for this. For superheterodynes, the alignment process must be made at frequencies both in the broadcast band and at the intermediate frequency. Since sensitivity tests must also be made, the standard-signal generator is often used as the aligning oscillator.

The General Radio TYPE 601-A Standard-Signal Generator has proved to be a most useful instrument for these tests. Figure 1 on the next page shows them in the final production line at the Kolster Radio Corporation's factory in Newark, New Jersey.

In order to take care of the peak production from this plant, ten test positions are necessary. Each one has its TYPE 601-A Standard-Signal Generator mounted upon a cabinet containing two loud-speakers (one is a stand-by in case of trouble) and an output meter. The completely assembled chassis are received in the test room from the slowly moving conveyer which has carried them down from the assembly departments. The power and loud-speaker leads are plugged in and the radio-frequency input from the standard-signal generator, working through a standard dummy antenna, is connected to the proper terminals.

Each standard-signal generator has two oscillator coils, one for the intermediate frequency and one for the broadcast band, either of which may be selected by a switch on the panel. While working at the low frequency,

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

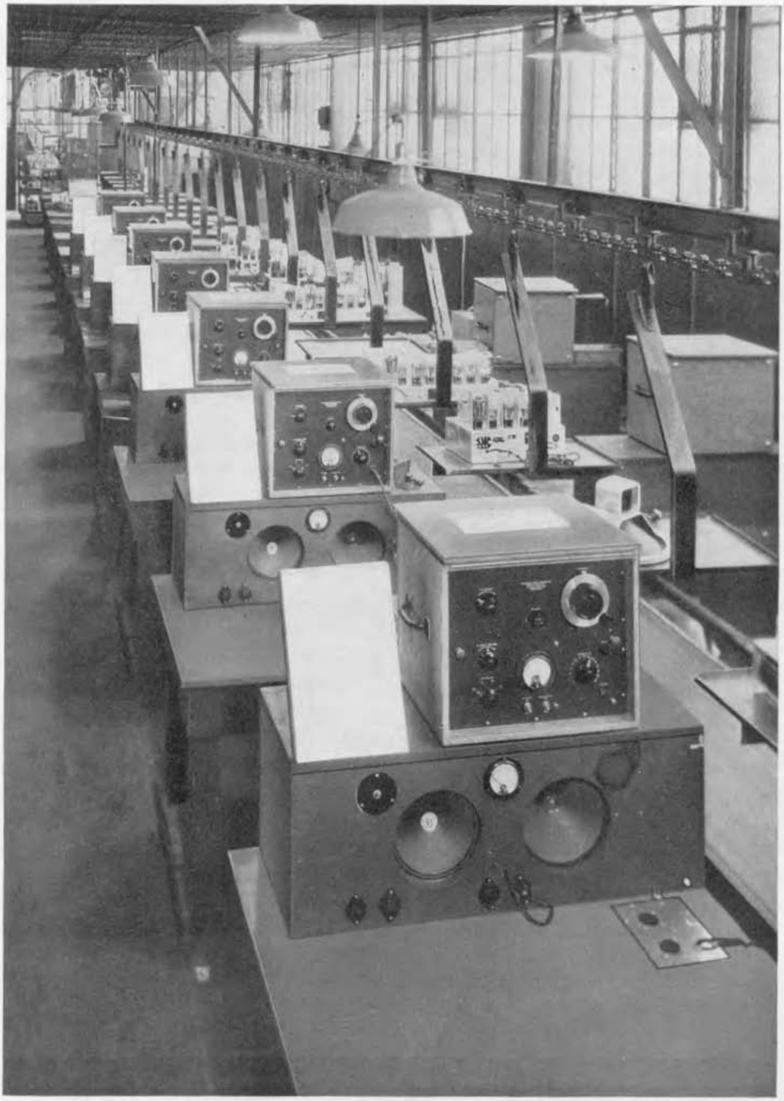

FIGURE 1. Kolster Radio Corporation's inspection room where every receiver is aligned, checked for sensitivity at several broadcast frequencies, and given a listening test. A dual-range TYPE 601-A Standard-Signal Generator is used at each of the ten test positions

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

the intermediate-frequency system of the receiver is lined up. After this adjustment the generator is switched to the high frequency and the general line-up of the receiver is made.

The next step is to determine the over-all sensitivity at several points in the broadcast band. These test frequencies are indicated by lines on the main tuning dial. The generator is set step-by-step to each of these frequencies, the receiver tuned to them one at a time, and the sensitivity of the receiver measured in the usual way by observing the audio-frequency output for a given signal input.

Standard output is marked on the output meter in the lower cabinet and just above it is the meter and multiplier of the standard-signal generator showing microvolts input. In this way, the operator has the whole story before him. At times, he records his observations on the charts provided and these are most useful to the production supervisor.

As a final check, a loud-speaker is turned on for a listening test.

Although the tests were originally designed for broadcast-receiver measurements, sets intended for operation at the police or aircraft frequencies could also be quickly checked by changing the coils of the standard-signal generators.

Figure 2 is a view of the rear of the TYPE 601-A Standard-Signal Generator with the cabinet and batteries removed. The two toroidal coils mounted on the subpanel are for the radio-frequency oscillator. They are mounted on pin jacks for interchangeability with

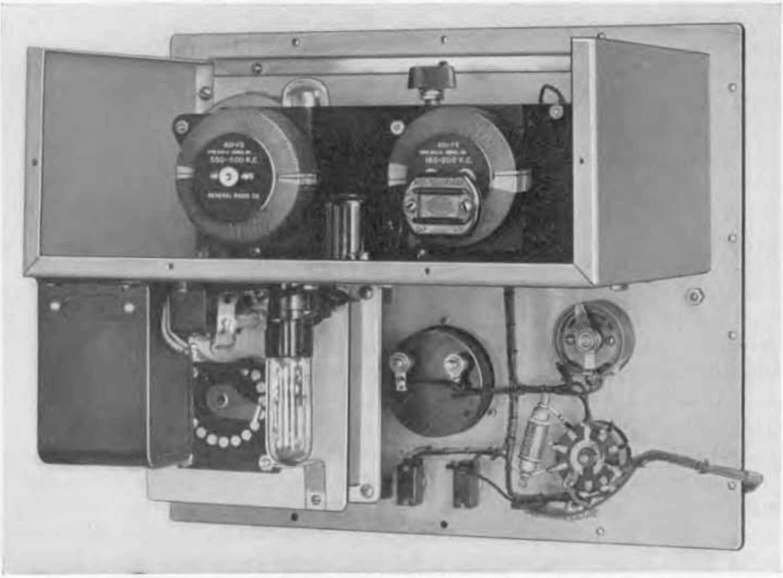

FIGURE 2. A view behind the panel of a TYPE 601-A Standard-Signal Generator. Either or both of the plug-in inductors may be replaced with others to cover special bands

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

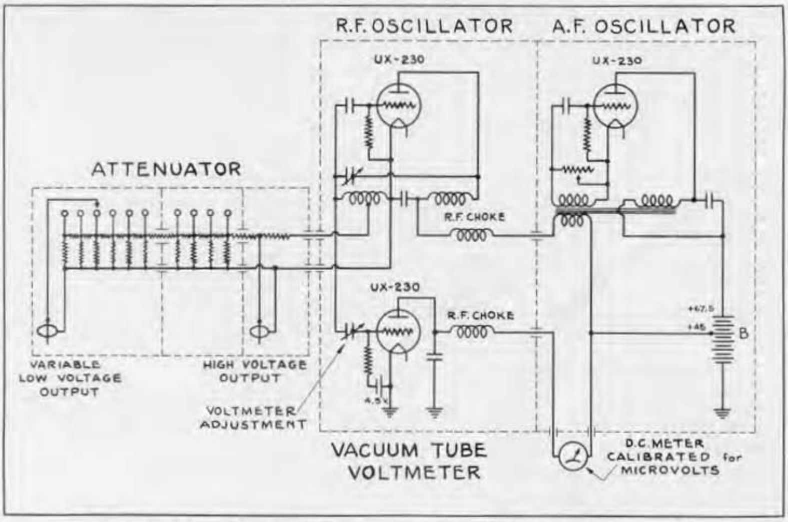

FIGURE 3. Schematic wiring diagram for a TYPE 601-A Standard-Signal Generator

other coils for different frequency ranges. Selection between them is accomplished by a four-point double-throw switch controlled from the front panel.

After some experimentation, toroidal coils were selected instead of solenoids because, although a little more difficult to build, they have so little external field that shielding is much simplified.

The radio-frequency amplitude is measured by means of a vacuum-tube voltmeter. This is a tube operating in the usual way by observing the incremental change in plate current due to changing amplitudes of radio-frequency voltage on its grid. The direct current is read by means of the micro-ammeter on the panel. All of the radio-frequency circuits except attenuator are located on the shelf and are covered by a shield.

Fastened to the under side of the shelf is the audio-frequency modulator circuit. It is a standard tuned-plate oscillator operating at 400 cycles per second with an amplitude sufficient to provide modulation at either 30 or 50 per cent. Normally, the TYPE 601-A Standard-Signal Generator is supplied with 30% modulation, but if desired General Radio can make the adjustments necessary for 50% modulation before the instrument is shipped.

The toroidal oscillator coil is tapped and a small part of the total voltage across it is led off through a shielded conductor to the attenuator. In Figure 2 the casting in back of the modulator circuit at the lower left corner of the panel houses the complete attenuator assembly. It is divided into three separate compartments between which the attenuation units are divided so that the total voltage reduction in each does not exceed 40 decibels. Due to stray admittances, it is virtually impossible to exceed this attenuation

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

within one shield without encountering serious errors.

The whole attenuator assembly is in contact with the front panel at only one point—where the low-voltage output jack is located. This helps to reduce circulating panel currents to a point where they do not affect the measurements at high frequencies to any extent. The output voltage lead to the receiver under test is shielded and enters the attenuator through a plug and jack construction that maintains the continuity of the shield directly to the attenuator circuit.

Two output jacks are provided, one connected to the variable voltage output and the other to a fixed point on the attenuator system at a higher voltage. The former provides outputs variable in discrete steps from 1 to 20,000 microvolts. The fixed tap is at 100,000 microvolts. All of these ranges can be multiplied by a factor of 1.5 by increasing the radio-frequency oscillator amplitude to the correct point as indicated by the vacuum-tube voltmeter.

Reference to the schematic wiring diagram shown in Figure 3 will indicate the arrangement of the circuit elements.

As will be noted, the modulation voltage is introduced in series with the plate-supply battery of the radio-frequency oscillator. With this method of modulation, it is necessary to provide a highly stable high-frequency oscillator, otherwise difficulty is encountered due to frequency modulation. That is, the plate voltage applied to the radio-frequency oscillator tube, varying at an audio rate, may shift the carrier frequency by a considerable amount unless the most stable high-frequency oscillator circuits are used.

The vacuum-tube voltmeter is connected across one half of the oscillator coil in series with a very small variable condenser, which is used to adjust the reading of the voltmeter. The attenuator voltage is taken across a part of the coil.

Only one of the two radio-frequency oscillator coils is shown in the diagram for the sake of simplification. The switching between these coils is arranged so that the one that is not operating is completely detuned by shunting a large condenser across it. Thus, no reaction can occur between it and the coil in use.

In order to provide a means for checking the voltages of the various batteries without a multiplicity of meters, the micro-ammeter is connected to a multi-point switch with suitable series resistors for making direct-current-voltage measurements on the A- and B-batteries.

The General Radio Company wishes to acknowledge its indebtedness to Mr. C. E. Brigham and Mr. G. Elcock of the Kolster Radio Corporation for their kindness in supplying the photographs of their plant used in this article.—Arthur E. Thiessen

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

LEANING MORE HEAVILY ON THE CRYSTAL

A New Piezo-Electric Oscillator Circuit

AN oscillator with frequency determined *solely* by a quartz crystal has been the ambition of every designer and user of frequency standards. Although it is still an ideal toward which to work, such an oscillator is brought one step nearer practicability by a new circuit which makes it unnecessary for the crystal to be calibrated in the oscillator with which it is to be used. The marked improvement in frequency stability of the new system is the principal reason for the exceptional performance of the General Radio frequency monitor which so many broadcasting stations have installed to meet the 50 cycle-per-second limit laid down by the Federal Radio Commission.

All who followed closely the development of crystal oscillators during the past few years[1] will not be shocked on learning that the frequency depends on other factors besides the mechanical properties (elasticity, mass distribution, etc.) of the crystal. True enough, the crystal influence predominates but the effect of the crystal holder, the tube, and the auxiliary tuned circuits can never be ignored where even a moderate degree of accuracy in frequency is expected. Quite often these latter influence the frequency more than a big change in the temperature of the crystal.

Any vacuum-tube oscillator operates at that frequency for which the net circuit reactance is zero. In a simple tuned-plate oscillator, for example, the resulting frequency is the resonant frequency of the tuned circuit modified by the reactance introduced by the tube and the feedback system.

A complete analysis of the mechanism by which the frequency shifts to a value which makes the net reactance zero is complicated. In brief, however, it amounts to this: Anything that causes a change in the reactance of any element associated with the oscillator will result in a change in operating frequency.

The same discussion applies directly to a piezo-electric oscillator with the important difference that the principal frequency-determining element is not an electrical circuit but an electro-mechanical system. The crystal has its own resonance characteristic and it is always possible, in theory at least, to construct for any given crystal oscillator an equivalent electrical circuit to represent it. This equivalent circuit will have many of the reactance characteristics of an ordinary tuned circuit and the circuit will operate at a frequency for which the total reactance of the crystal and its associated equipment is zero. And so, no matter how closely a crystal may be ground to desired frequency, the frequency that results when it is operated in a circuit will be modified by the reactance characteristics of that circuit. So, also, will the operating frequency shift if changing voltages, temperature, etc., cause the reactance of tubes, coils, condensers and crystal mountings to change.

[1] See GENERAL RADIO EXPERIMENTER for February, 1930; October and November, 1930; and December, 1931.

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

The obvious conclusion is, therefore, that for high-precision frequency standards, the crystal, and the oscillator associated with it must be treated as a single unit when calibrations are made, and the General Radio Company has insisted that this be done wherever an accuracy better than 0.1% is required. A slightly more liberal figure could possibly be set by building the oscillators to even closer manufacturing limits, but it has not been possible to go very far in this direction without running into prohibitive expense. Transmitter manufacturers get around this by building crystal oscillators as a unit and, when replacements are required, shipping the customer a complete new assembly.

If some means could be found for operating the crystal at its own resonant frequency, the crystal could be treated as a single unit. There are very few circuits which make such operations possible because of the difficulty in securing enough feedback for the tube to drive the crystal, and, besides, there is now no practical way of determining when the resonant frequency of an oscillating crystal has been reached.

The best alternative to operating at the resonant frequency of the crystal is a circuit which will permit of an indication to show when the crystal is operating at a given condition, such as the new General Radio circuit which was described in the December, 1931, issue of the *Experimenter*.

The new circuit allows the crystal to operate much closer to its true resonant frequency than the circuits heretofore available. But what is more important, it is possible to always duplicate the original calibrating condition so long as the constants of the oscillator circuit are of approximately the same order of magnitude as those of the calibrating circuit. By adjusting the tuning condenser of the circuit until the plate current is a minimum, the original calibrating condition can be restored. This means that the constants of the oscillator circuit can be allowed to vary over fairly wide limits (due, perhaps, to temperature and aging of the elements), but it can always be restored to normal by a readjustment of the tuning condenser. Greater reliance is placed on the crystal and less on the circuit by the new system, which is as it should be, for the crystal is inherently more stable than coils and condensers.

The General Radio Frequency Monitor shown mounted on a desk-type relay rack. Its exceptional performance is due to the use of the new crystal circuit

The fact that the new system operates at a frequency near the crystal's resonant frequency brings about an improvement in the tempera-

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

ture coefficient of the crystal. This is because the crystal's reactance-frequency characteristic is steeper near resonance, and for a given change in reactance caused by a change in temperature, the frequency shift required to restore the "zero reactance" condition is smaller than would ordinarily be required.

The new oscillator circuit, as was pointed out in the December *Experimenter*, has an overall frequency stability of something like ±5 parts in a million. Frequency stability (sometimes called deviation capability) is the best available index of the reliability of a frequency standard. It is the amount that the frequency will vary due to changes in temperature, tubes, etc., assuming that the changes all tend to shift the frequency in the same direction.

Frequency stability of this high order can, of course, be obtained only if the crystal is operated at a power level so low that internal heating causes no appreciable rise in its temperature. This condition is readily brought about in frequency-monitor equipment where the oscillator is inherently one of low power. Where crystals are used to stabilize high power transmitters, it is a very great temptation to operate the crystal at high power levels thus reducing the number of tubes required. The wisdom of such design is debatable and is, perhaps, not to be recommended where a high order of frequency stability is demanded. Most of the economies resulting from high power crystal operation disappear, for instance, when it becomes necessary to install very elaborate temperature-control equipment to secure anything approaching satisfactory frequency stability.

— John D. Crawford

WE'LL SEE YOU IN CHICAGO MAY 23-26

GENERAL RADIO will exhibit samples of all instruments developed during the past year in Chicago, May 23–26. The occasion is the sixth annual Trade Show of the Radio Manufacturers' Association held at the Stevens Hotel.

Our display will include a number of new pieces of equipment which have not yet been announced. Among them will be a precision standard-signal generator, a direct-current-operated beat-frequency oscillator, and a new vacuum-tube bridge.

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

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

PRINTED IN U.S.A.

IET LABS, INC in the GenRad tradition
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988