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2. Illustrations should invariably be in black ink on white paper or tracing cloth. Blueprints are inacceptable.

3. Corrected galley proofs should be returned within 12 hours to the office of publication. Additions or major corrections cannot be made in an article at this time.

4. A brief summary of the paper, embodying the major conclusions, is desirable.

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PROCEEDINGS
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RADIO CLUB OF AMERICA

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# SENSITIVITY MEASUREMENTS AND PERFORMANCE TESTS ON RADIO RECEIVERS IN PRODUCTION†

## *A Discussion of the Test Methods Used in Building the Victor Radio Sets*

*By N. E. WUNDERLICH and W. R. DOHAN**

WHEN quantity production of radio receivers began, it was soon found that quantity production methods were equally necessary in receiver testing. Operational tests depending upon the operator's judgment were found to be incompatible with high speed production, and high quality of the product. It is a great economic waste to place defective parts in any assembly, and to avoid this, a comprehensive testing procedure for all parts is necessary. Although this field presents many facts of interest, the limitation of space confines the field of this paper to sensitivity and performance tests of the completed receivers.

The three principal performance characteristics of a receiver are: fidelity, selectivity and sensitivity. The fidelity and selectivity are chiefly functions of the design, and if the normal sensitivity is obtained, the selectivity will be close to type. The fidelity is further checked by gain runs on the audio amplifiers.

In the search for a suitable quantity production test, the natural development was along the lines of laboratory procedure. It seemed desirable, if possible, to use the standard procedure for receiver testing adopted by the Institute of Radio Engineers. Obviously, it is not necessary to actually measure the sensitivity in microvolts per meter of each receiver shipped by the manufacturer, but it is highly desirable to know that every receiver shipped has a sensitivity equal to or better than an arbitrary standard set by the manufacturer.

### *Testing Systems*

There are many systems which can be used for receiver testing, but they may be divided into two general classes—those employing local generation of the test frequencies, and those employing centralized generation and a transmission line of some description to each test position. Figs. 1 and 2 show outlines of the system elements for each class.

A third class might be mentioned in which the sensitivity of the receiver under test is compared to a standard receiver by switching the antenna. It is open to the objection that the signal input is not constant from minute to minute, and that the standard does not remain at the same sensitivity level. It may be regarded as a link between the plain operational test and the measurement system to be described.

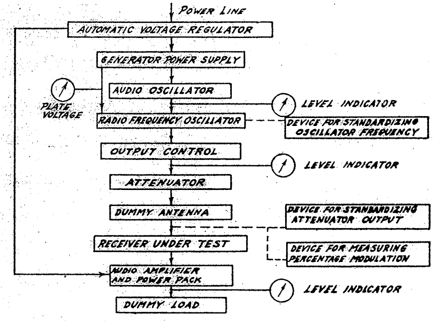

Fig. 1. Local generation system of receiver testing.

Centralized generation systems may attenuate to the desired signal level at the generator, or at each test position, depending on the performance desired, as indicated in Fig. 2. For accurate measurement of each set, attenuation must be local but a single passing mark may readily be set by a central attenuator.

Using local attenuation, the transmission line may be used to feed the grid of a coupling tube placed at each position. The power level in the line may then be kept quite low and the radiation will, therefore, be small. This system has the disadvantage of introducing an additional variable element, the amplification obtained from the coupling tube and thus rendering the calibration of the test position less permanent.

If it is desired to align the sets at the test position, the attenuation must, of course, be under the control of the testing operator. The problems connected with this system are much more difficult as the transmission lines must operate at a very high level in order to have sufficient voltage available for alignment purposes.

The problems of local generation and attenuation are principally those of keeping the frequency and output of all generators the same. The problem of frequency is especially important if the generator is used for alignment as well as testing. It may be solved by using a centralized source of high frequency for synchronizing purposes, or as a standard against which to match the generator frequency by the method of zero beat. The use of a portable reference standard is much more practical, however, and avoids entirely the transmission line problem. In this connection, the oscillator must have a reasonable frequency stability so that, once set, it will operate very close to the correct frequency for a considerable period.

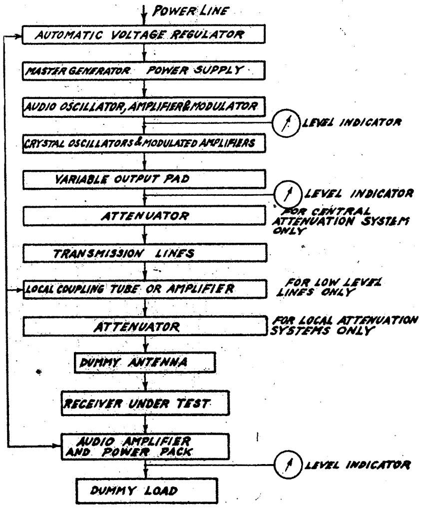

Fig. 2. Generalized central generation system of receiver testing.

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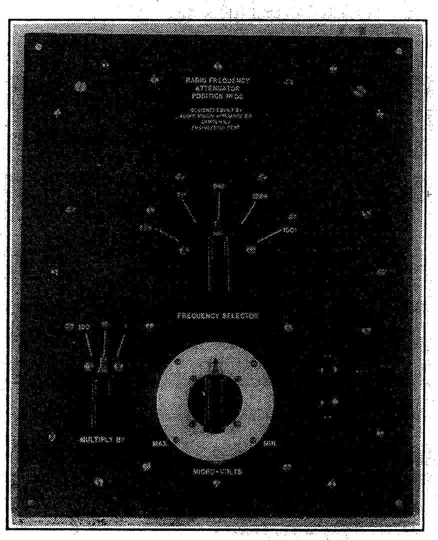
† *Delivered before the Club, November 13, 1929.*

* *Engineering Dept., Audio Vision Appliance Co., Camden, N. J.*

The use of individual generator frequency stability by means of crystal oscillators would be an ideal solution but the cost would be very high for the necessary crystals.

The question of standardization of the attenuator output is, of course, present in both systems, but the centralized system gives the advantage that all test positions vary alike, so that once a calibration of the test position is made, it remains accurate as long as the master generator gives the correct output voltage.

The most direct method of calibrating an attenuator is by comparison with a portable signal generator whose output and percentage of modulation may be accurately determined and then maintained constant. The radio receiver then operates as a voltmeter, and the calibration is independent of line voltage, tubes, receiver constants, tuning, etc. The main objection is the amount of time necessary to calibrate a position. This objection is entirely overcome if the calibration is semi-permanent as in a central generation-local attenuation system.



Panel view of one of the radio-frequency attenuators.

Alternative methods are those using a radio receiver carried from position to position. These methods may be divided into two classes, those using a standard production receiver and those using a special receiver of some kind. In the construction of these special receivers the number of tuned circuits is usually reduced, and an excessive amount of audio amplification is often used in an effort to reduce changes in the overall amplification due to regeneration in the radio-frequency amplifier. A particularly interesting example of this tendency is a set consisting of but one tuned circuit of very low resistance, and a bias vacuum tube voltmeter. The tuned circuit gives a gain of about one hundred times, so that a voltmeter which would indicate one volt could be used to measure 10,000 microvolts. The device can be used to check the attenuators on one of the higher multiplier taps. All of the special, or standard set methods are open to the objection that the amplification varies with line voltage, time, humidity, temperature, rough handling, and many other variables, but the calibration checks may be carried out much faster and with less interruption to production.

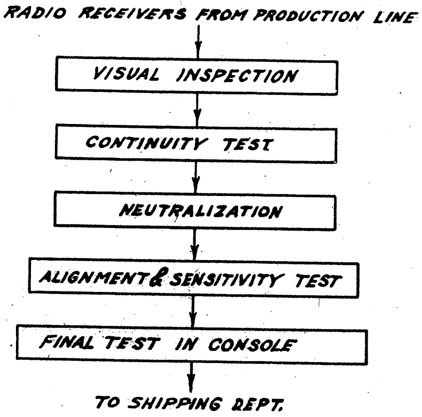


Fig. 3. Receiver inspection and test system.

### *A-F. Output Tests*

Measurement of the audio-frequency power output of the receiver is quite simple, but some methods have considerable advantage over others. The vacuum tube voltmeter at once suggests itself. It is especially desirable for systems combining alignment and test because a grid leak and condenser voltmeter may be built to saturate at a certain level and thus protect itself against overload. The disadvantage of changing calibration, as the tube ages, or the operating voltages change, and the relative complexity compared to other systems, have restricted its use.

The thermal meter is a practical solution where test only is contemplated, but a thermal instrument is not rugged enough when alignment is combined with the test operation.

Rectifier systems of some sort are usually very rugged and hold calibrations for quite some time. Contact rectifiers are superior to crystals as the calibration is more permanent. Full-wave rectifiers are to be preferred, and if the type ordinarily supplied for trickle charging is used, it can hardly be injured by the maximum output of the receiver. The d-c. meters used to read the rectified current withstand a tremendous overload, so that the combination is a very rugged one, suitable for aligning and testing, and with reasonable permanency of calibration.

Contact rectifiers for metering purposes have recently been made available commercially, and a complete meter containing a miniature rectifier has also been placed on the market. Both devices have proved satisfactory as output meters.

In the particular system to be described, as shown in Fig. 3 the receivers from the production line pass through visual and continuity tests and then to the neutralizing operators. The continuity panels present nothing of special interest, but several points in the neutralizing technique deserve mention. By laboratory test, it was determined that the receiver possessed the best sensitivity characteristic when the neutralizing condenser in the first three stages was set to a certain value, and that in the fourth stage to a slightly lower value. The method of neutralizing is the ordinary procedure of applying a voltage to the input of the receiver and adjusting the neutralizing condenser of one stage which contains a dummy tube until minimum output is obtained. The departure from the standard practice consists in the use of two dummy tubes adjusted to different values. A dummy of lower capacity, painted red for identification is used to neutralize the last stage and in this manner, the sets are rendered more stable than those neutralized with the higher capacity dummies in all stages. In addition, the sensitivity characteristic is improved as previously mentioned. From the neutralizing positions, the sets pass to the alignment and sensitivity measurement operations.

### *Alignment Operation*

Two methods are at present in use for the alignment operation and sensitivity test; one using local generation

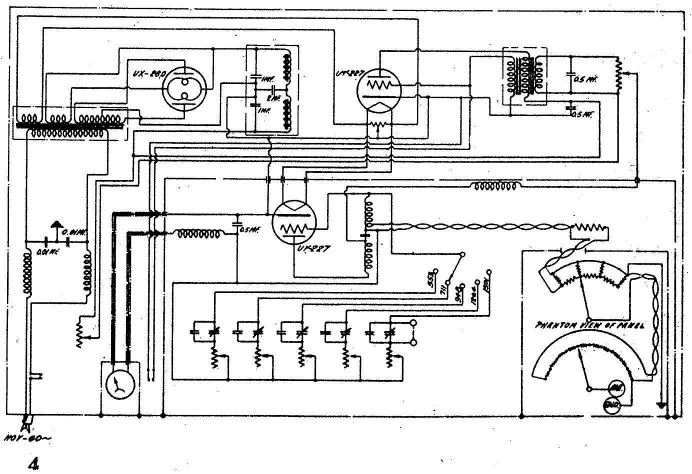
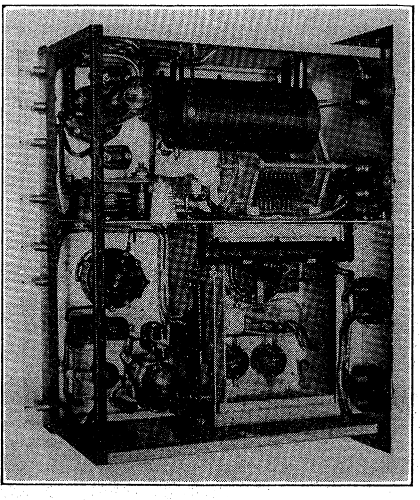


Fig. 4. Wiring diagram of radio-frequency test set.

which has been operating for some time, and a newer installation using central generation and local attenuation. The local generation system will be described first.

Alignment required outputs in the order of 10,000 to 100,000 microvolts from the attenuators for the preliminary stages of the process, as no steps were taken to pre-align the condensers. The passing mark was less than 100 microvolts, and therefore, satisfactory attenuation over a 1,000 to 1 range was required. It was desired to align and test at five frequencies—these were 553 kc., 711 kc., 948 kc., 1,264 kc., and 1501 kc. They are harmonics of 79 kc., so that a single 79 kc. crystal may be used for frequency standardization.



Top view of one section of the master generator.

Referring to Fig. 4, the signal generators used, consist of an r-f. oscillator, with the voltage for the attenuator tapped off a few turns from the low potential end of the grid coil. A tap switch connects any one of five semi-fixed condensers across the inductance for tuning purposes. In series or in parallel with the tuning condensers, are variable resistors used to adjust the oscillation amplitude, so that the attenuator output is held constant for each of the five frequencies. The general construction is quite similar to a laboratory generator.

The attenuator is a ladder type structure with multiplying ratios of 1, 10, 100 and 1,000, and a tapped slide wire which gives 100 microvolts in 10 microvolt steps. The resistor units are very small and wound on thin mica cards, reducing the inductance error to a minimum, and the entire attenuator is shielded from the oscillator to prevent direct pickup in the leads. A dummy antenna of standard constants is connected in series with the high terminal of the attenuator output.

A grid current meter is used to indicate the oscillation amplitude. The oscillator grid current is approximately proportional to the oscillation current at any frequency, so five different settings are required for the five frequencies. A standard set calibrated against a master generator is used to check the output of the attenuator. In this manner, the output of all generators may be kept the same.

A 400-cycle audio oscillator supplies the modulation voltage which is applied in series with the r-f. oscillator plate voltage. Since the oscillator plate current is changing from zero to twice the average value, the peak voltage required for 30% modulation will be approximately 30% of the d-c. plate voltage. This has been checked with a peak voltmeter and found to be close enough for practical work.

The attenuator is separately shielded, and the attenuator and radio-frequency oscillator are enclosed in another shield. The entire assembly is mounted in a wooden cabinet lined with copper which makes contact with the metal front panel, forming a complete shield around the whole unit. The 110 volt a-c. line contains a filter to keep the leakage from this source low.

Forty-five of these units have been operating successfully for seven months. The total time lost because of generator breakdown to date was only 300 man-hours, or 5% of total man-hours expended. This illustrates one of the great advantages of the system— a breakdown only involves one unit and the defective unit may be readily removed to the maintenance shop where repairing can be done wih maximum speed and efficiency.

The system also possesses great flexibility, as the entire test department may be moved overnight to a new location, or slightly rearranged at any time to suit conditions.

## *Central Generation and Local Attenuation*

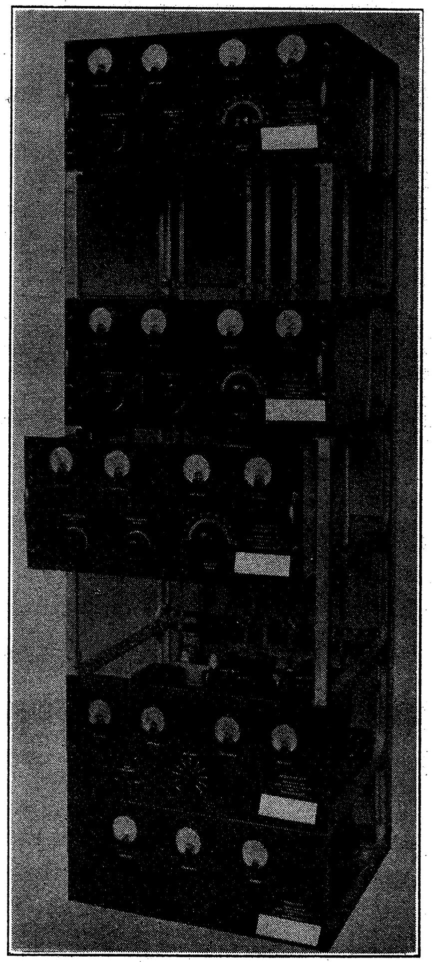
Central generation and local attenuation is the second system in use. Again the combination of test and alignment necessitated the choice of local attenuation. Referring again to Fig. 2, the attenuator at the generator is omitted and the lines are operated at a high level, eliminating the coupling tube. The five test frequencies were the same as those used in the local generator system. This system presents problems which are more interesting than the local generation system, especially the transmission lines used for conducting the five frequencies to the test positions.

The master generator logically comes first. In view of the future expansion in the number of test positions, a power output of about 10 watts was specified. UV-203A tubes were picked as being very rugged and reliable, but they necessitated the use of a high-voltage power supply. For standardization purposes, UV-203A tubes were used for both modulators and amplifiers.

The generator itself is built in six sections, five of which are detachable units built-in drawer form with plug-in connections at the rear. Referring to the circuit diagram, Fig. 5, each of the five units consists of a UX-210 crystal oscillator feeding a UV-203A amplifier. The amplifiers are fed with modulated plate voltage supplied from the sixth unit.

The crystal oscillator has two crystal holders in a constant temperature compartment, with a switch to connect either in the circuit, thus insuring continuous operation. A coupling coil of the required number of turns is located at the ground potential region of the plate coil, and the output is taken from this coil, using a balanced-to-ground circuit. The five frequency units are practically identical except for differences in circuit constants. The output may be controlled by slightly detuning either the crystal oscillator plate circuit, or the amplifier plate circuit. The current flowing in these circuits as well as the plate current of each tube is indicated by meters on each unit panel.

The bank of modulator tubes is located in the power supply section. Four UV-203A tubes function to modulate the five r-f. amplifiers, and by proper adjustments, the percentage



Master oscillator with two of the drawers removed.

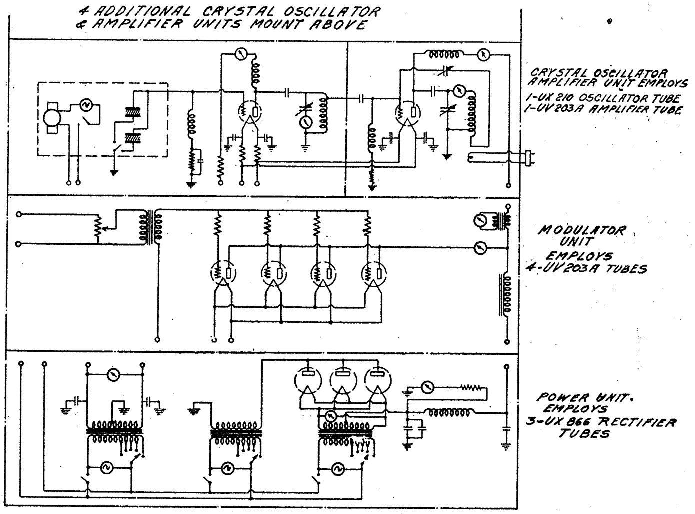


**Fig. 5. Wiring diagram of the five-frequency type signal generator. It is crystal controlled and a-c. operated.**

of modulation is maintained approximately equal for all the frequencies. The modulator grids are fed from a step-up transformer working from a 200-ohm primary. A 400-ohm potentiometer serves to control the input to the primary. Grid and plate meters for the modulators, as well as a current transformer and thermal meter for reading directly the a-c. component of the plate current supplied to the amplifiers, are mounted on the power supply panel. The thermal meter is used to set the modulation to the correct value as determined by measurement of the modulation percentage with a peak voltmeter.

The complete generator has a double set of shielding, but due to ventilating requirements and physical limitations, the shields are not depended upon as electrical shielding. The entire generator is enclosed in a double wall copper screen booth about eight feet square. A transformer provided with an electrostatic shield between the windings, keeps the radio frequency from leaking out through the power line. The booth is provided with the usual "ice chest doors" used on measurement booths, and is practically leak-proof. A ventilating fan outside the booth draws the hot air out through a large pipe fitted with four screens, as the booth screening offers too much resistance to the passage of air.

At the rear of the master oscillator are located copper terminal boxes for the transmission lines. Each box contains an "H"-type attenuation pad with a ground at the center of the shunt arm. The arms of the side nearest the generator are made variable to control the output over small ranges. A short cable leads from each terminal box and connects with the proper frequency unit. There is no connection between the generator frame and the transmission line shielding or the booth walls, as this was found to increase the leakage.

At the junction of the transmission line proper, with the "H" pad are pin-jack terminals for measuring the line potential. A suitable thermocouple and balanced multiplier resistances are bridged across the line, and the d-c. voltage of the couple taken off through chokes to a microammeter on the control panel. The two arms of the pad are controlled simultaneously to preserve the balance to ground by means of an insulated shaft. This control is adjusted until the reading of the microammeter indicates that the required voltage exists across the line.

## *The Transmission Lines*

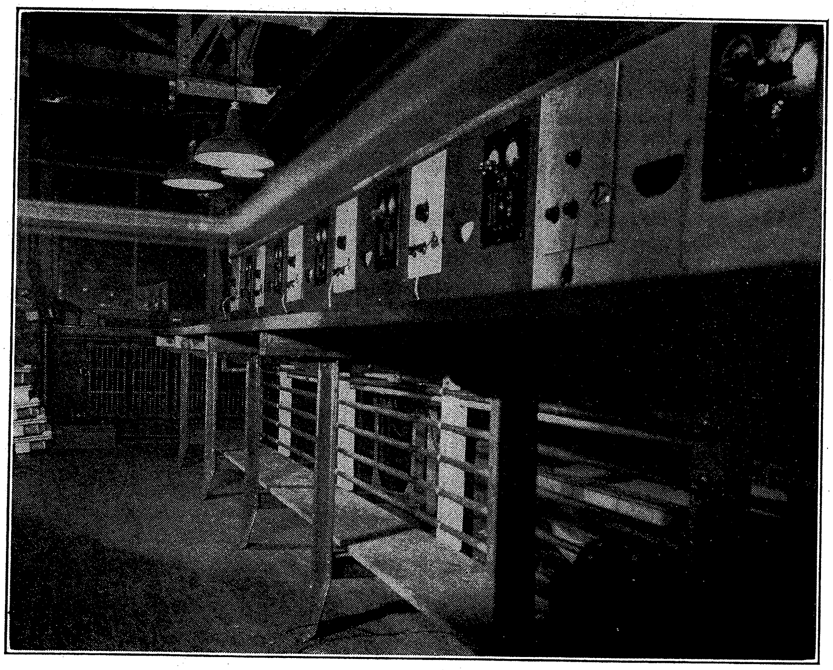
The transmission lines are perhaps the most unusual part of the system. A total of sixty attenuators, each of ninety ohms impedance, was indicated as the probable maximum load. Since a balanced-to-ground system was to be employed, this is equivalent to thirty loads of 180 ohms each, as one side of each attenuator is grounded and the other terminal connected to one side of the transmission lines. This is equivalent to a 6-ohm load on the main feeder line.

By referring to Fig. 6, the general location of the lines may be seen. The chief problems involved were the design of the main feeders to transmit, with small attenuation, a distance of about thiry feet at an impedance of 6 ohms, and the design of branch feeders in which the voltage change along the lines was small enough to be compensated for by the attenuator adjustments. The radiation and stray leakage from the transmission lines had to be below the level of normal interference in order not to interfere with the testing operations. In addition, the system had to be designed so that operation of one attenuator did not affect the operation of any other unit.

The radiation problem was to be disposed of, at least theoretically, by using the balanced-to-ground system, thus eliminating ground current, and shielding the line in a copper pipe which was used as the ground. The conductors were to be placed very close together, or twisted so that their combined field at points distant from the system would theoretically be zero.

At first, the use of twisted pair was tried, both plain and loaded with shunt capacity, but the loop inductance was found to be too high to even approach the 6-ohm impedance required, and the radio-frequency resistance was found to be excessive. Twisted pair has a characteristic impedance of about 130 ohms and loading with shunt condenser appears to be impractical. The loop inductance is about half a microhenry per foot, which would require a tremendous shunt capacity and loading at about two-foot intervals to obtain the required impedance.

It was recognized at once that some totally different type of construction



**Showing the location of the transmission lines underneath one of the production test benches.**

was necessary, not only to reduce the resistance, but to lower the characteristic impedance as well. Considering the approximate expression for the characteristic impedance of a line

$$Z_K = \sqrt{\frac{L}{C}}$$

it can be seen at once that the inductance must be reduced and the capacity increased to lower the line impedance. Obviously, the logical method of decreasing the loop inductance is to place the conductors in closer juxtaposition. This simultaneously increases the capacity and further decreases the impedance.

At this point, the use of two flat strip conductors giving a continuous loading suggested itself and a sample line was constructed, using six-thousandths paper as dielectric and half-inch by twenty thousandths strips as conductors. The whole assembly was securely taped together. A preliminary series of measurements at 1264 kc. showed promise; the impedance having been reduced to about 9 ohms.

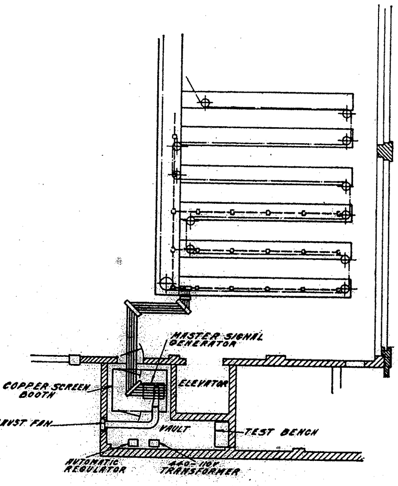


Fig. 6. General plan of the receiver testing department.

The inductance was, of course, too small to be measured with any of the usual laboratory equipment and the capacity was approximately 660 micro-microfarads per foot. The impedance was determined by working the line into various resistances, and noting the ratio of input to output voltages. For loads of less resistance than the line impedance, the output voltage is the lower; for loads of a higher value than the line impedance, the voltage is highest at the load, due to standing waves. The load resistance giving unity ratio is then approximately equal to the line impedance.

Paper obviously being an unsuitable material and the use of mica tape considered undesirable because of the necessity of "fishing" the finished line through the shielding pipes, varnished cambric was tried as an insulating medium. Measurements were made to determine the approximate magnitude of the dielectric loss to be excepted. A ten-foot section of line was included in a tuned circuit of known resistance, and the added resistance determined by the resistance variation method. The added resistance was 4.6 ohms; the series resistance of this line was negligible (calculation have placed it as about 0.01 ohm for the whole ten-foot length.) This is equivalent to a shunt resistance of approximately 4,750 ohms per foot, and at a one-volt line level with 400 feet of line in use, would give less than 0.1 watt power loss for the whole system.

## *Mathematical Treatment*

The placing of the two conductors with the current sheets parallel is known to give a very favorable ratio of high-frequency to direct-current resistance. The ratio calculated for this particular line at 1,500 kc. was 1.72 which gives a radio-frequency resistance of 0.00223 ohm per foot.

The loop inductance of two parallel strips is given by the formula

$$L = 0.004\,D\left[\frac{d^2}{b^2}\log d + 1/2\left(1 - \frac{d^2}{b^2}\right)\log\left(b^2 + d^2\right) + 2\,\frac{d}{b}\tan^{-1}\frac{b}{d} - \log b\right]$$

microhenrys

where $D$ = length of one strip in centimeters;

$b$ = width of one strip is centimeters;

$d$ = distance between strips in centimeters.

By tabulating the values of the various terms for the range of ratios of $\frac{d}{b}$ which are of interest, it can easily be seen that the first term becomes very small and negative in sign; and between $\frac{d}{b}$ ratios of 0.05 to 0.01, becomes only about 2% of the third term. The second term in this range differs from the last term (log b) by less than one per cent. Therefore, we may write approximately

$$L = 0.004\,D\left[2\,\frac{d}{b}\tan^{-1}\frac{b}{d}\right] \times 0.98 \text{ micro-henrys}$$

but the value of $\tan^{-1}\frac{b}{d}$ approaches the value 1.57 radians very slowly as the value of the tangent approaches infinity, so we may write for ratios of $\frac{d}{b}$ less than 0.05.

$$L = 0.0123\,D_{cm} \times \frac{d}{b} \text{ microhenrys}$$

The inductance, therefore, is approximately proportional to the distance between strips.

For the capacity between strips, we may write approximately, neglecting edge effect,

$$C = \frac{K \times S}{4\pi\,d} \times \frac{10^{-5}}{9} \text{ microfarads}$$

where $S$ = the area of one side of one strip in square centimeters;

$d$ = the distance between strips in centimeters;

$K$ = dielectric constant of insulating strip;

let $b$ = width of one strip in centimeters;

$D$ = length of one strip in centimeters.

Then

$$C = \frac{K \times b \times D}{36\pi\,d} \times 10^{-5} \text{ microfarads.}$$

Substituting these values of L and C in the approximate formula for the line impedance

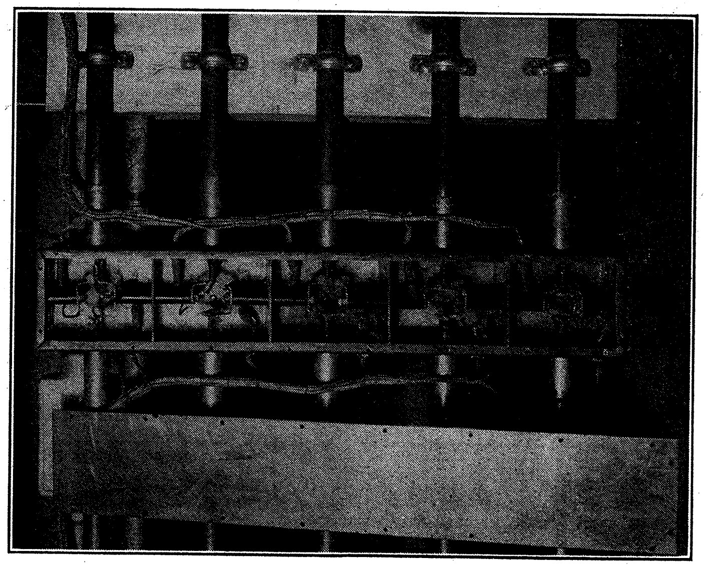
$$Z_K = \sqrt{\frac{L}{C}} = \sqrt{\frac{0.0123\,D \times d}{\frac{K \times b \times D \times b}{36\,\pi\,d} \times 10^{-5}}}$$

And

$$Z_K = \frac{d}{b}\sqrt{\frac{1.4 \times 10^{5}}{K}}$$

The impedance also is thus seen to be an approximately linear function of the spacing of the strips for ratios of $\frac{d}{b}$ less than 0.05.

Applying these formulas to an actual line where b was ½-inch and d was ten-thousandths varnished cambric with a dielectric constant of about 3.4 at high frequencies, the inductance



View of the coupling arrangement for the transmission lines.

was found to be 0.0075 microhenrys per foot, the capacity 0.000456 microfarads per foot, and the approximate impedance 4.1 ohms.

Using the more accurate formula, taking into account the series resistance and shunt conductance, we have

$$Z_K = \sqrt{\frac{R + j\,\omega\,L}{G + j\,\omega\,L}}$$

where $R = 0.00223$ ohm per foot;
$G = 0.00021$ ohm per foot.
gives an impedance of 5.32 ohms. The actual impedance of the line is even higher than this figure in practice because it is impossible to bind the two strips tightly enough together to approximate the thickness of the varnished cambric dielectric.

The propagation constant is

$$P = \sqrt{(R + j\,\omega\,L)\,(G + J\,\omega\,C)}$$
$$P = \sqrt{.000123 \underline{/178^\circ\,45'}}$$
$$P = .01109 \underline{/89^\circ\,22'}$$
$$P = A + j\,B = 0.0001208 + j\,0.01108$$

The attenuation constant is
$A = 0.0001288$ napiers per foot.
$= 0.001119$ db. per foot.
Or approximately 6 db. mile.

A line of this character thus fulfills the requirement of efficient transmission, and since the current sheets are so close together, the radiation is a minimum.

## *Voltage Distribution*

The second requirement of equality of voltage at the various points of attachment of the attenuators would require a line with different impedance for each section between loads to approximate the condition. For constructional reasons, this was ruled out, and all sections of the line were constructed with the same spacing after a preliminary test at 1264 kc. had shown that distributed loads, on an open circuited 6-ohm line 37 feet long (approximately the length of each branch feeder) gave a voltage rise of only about 30%, which could readily be compensated by the attenuator adjustments. By shunting about 10 ohms across the open end, a very uniform voltage distribution can be obtained.

The actual voltage distribution on one of the branch feeders with the attenuators connected, is tabulated below in terms of percentage of the initial voltage.

| | *Length from Origin* | | | | |
|---|---|---|---|---|---|
| | 0 | 73″ | 146″ | 219″ | 292″ |
| *Frequency* | *Percent of Initial Voltage* | | | | |
| 553 kc.. | 100 | 100.4 | 101.8 | 102.6 | 102.9 |
| 711 kc.. | 100 | 100.8 | 103.3 | 104.2 | 104.5 |
| 948 kc.. | 100 | 105.3 | 110.5 | 113.0 | 114.0 |
| 1264 kc.. | 100 | 113.8 | 122.4 | 128.6 | 129.3 |
| 1501 kc.. | 100 | 115.8 | 129.0 | 136.8 | 138.4 |

It will be noticed that at the higher frequencies, a voltage rise is occuring. This is due to the fact that the branch line is not properly terminated, and a standing wave exists.

The lines are thus seen to fulfill the requirements, and at the same time, keep within the practical limits of construction.

The one-half inch lines with varnished cambric tape insulation were placed inside of ¾″ round copper pipes. The line then took a position approximately on a diameter of the pipe so that the capacity to ground was small. The pipes were connected by suitable junction boxes as it was difficult and undesirable to "fish" the strips around corners. The entire piping system was securely bonded together by making the junction boxes common to the five frequencies, and using internal partitions to divide the boxes into five compartments. All pipes were "sweated" into the boxes and the covers securely screwed in place so that a completely shielded system was obtained.

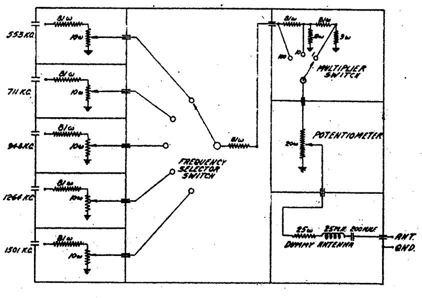


Fig. 7. Radio-frequency attenuator and dummy antenna.

The attenuators are connected in pairs across the line with the junction grounded. Five shielded leads are brought from each junction box to a connection box at the rear of each attenuator, which contain terminals for the attachment of the attenuator leads. This construction permits rapid replacement of the attenuator unit should it become defective. The connecting leads have a characteristic impedance of about 100 ohms so that the attenuator impedance of 90 ohms is a good match.

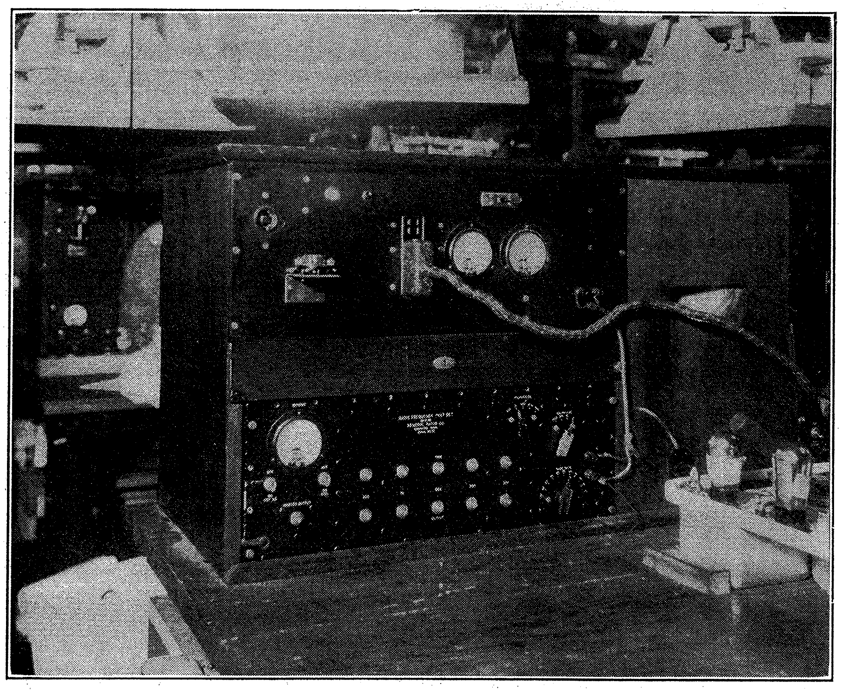
## *The Attenuator Unit*

The attenuator unit consists of an aluminum casting divided internally into nine compartments. Five of these compartments contain the input sections of the attenuator for the five test frequencies. Referring to the circuit diagram of Fig. 7, these sections consist of 81-ohm resistors in series with 10-ohm potentiometers. The sliding arms of the potentiometers connect to the taps of a frequency-selector switch in a sixth compartment. The potentiometers are adjusted with a screw driver through holes at the rear of the attenuator to give the desired input to the selector switch contacts. The holes are covered by sliding tabs to keep the shielding as complete as possible.

The contact arm of the frequency-selector switch is joined through an 81-ohm resistor to the final attenuation network. The sections just described serve as "buffer" sections to reduce the effect on the line voltage of placing the multiplier switch on the 100 times tap.

The multiplier is located in the seventh compartment, and consists of a network of an 81-ohm and a 10-ohm resistor to give the 10 times tap, and another network of 81-ohm and 9-ohm resistor to give the unity tap. The contact arm of the multiplier switch connects to one side of a 20-ohm potentiometer mounted in the eighth compartment, which is used as the final slide wire, giving a fine adjustment.

In the ninth compartment, the dummy antenna is located. A double shielded panel is used with guide bushings for the control shafts. All control shafts are broken by insulated couplings, eliminating any tendency for the controls to become "hot." Due



A close-up view of the five-frequency, crystal controlled, signal generator.

to the complete shielding, leakage from the attenuator is extremely small. The switches have "ball clicks" as well as marks engraved on the front panel, as this has been found to speed up the testing operation. A celluloid dial is used for the potentiometer, and the necessary passing marks are made with ink, allowing a change, if necessary, at a later period.

### *Test Connections*

Since the receiver to be tested with both the foregoing systems was one distinct unit, and the power pack and audio amplifier another; one power pack was installed permanently at each test position, and the receiver plugged into a connecting female plug on the testing panel. This panel also contains a detector plate-current meter, and the direct-current milliammeter measuring the current from a contact rectifier used as an output level indicator. A switch is available for connecting either the speaker or output voltmeter and dummy load in circuit. A UY-227 socket is mounted on the panel and connected to the amplifier which operates continuously. This device keeps the heater of the detector tube hot and avoids delay.

The line voltage for the entire testing system is maintained constant with an automatic induction regulator, and very little trouble is experienced from this source, as all loads are continuously in circuit. Any change in the primary current due to removing a radio set from the power pack circuit is quite small.

Tubes are the chief variable element remaining. All tubes are checked at least twice daily, and in addition, compensation for tubes below the average is made by changing the passing mark slightly. The spot check on sensitivity is constantly maintained in the test cage, and the Engineering Laboratory tests a number of samples daily, so that a close control of the product is possible.

At present, twenty positions are in service and the system is operating very satisfactorily. The leakage is of the same order of magnitude as that from a laboratory signal generator, and the testing operation has been speeded up slightly. The great advantage of frequency stability and the smaller number of checks required on the test position are noteworthy features of the system.

### *References*

K. S. Johnson — *Transmission Circuits for Telephonic Communication*. Chapter XII (New York,— 1927).

Bureau of Standards—*Circular No.* 74 (2nd edition) page 302 (March, 1924).

Rosa & Grover — *Bureau of Standards Scientific Paper No.* 169 (3rd edition) page 156 (December, 1916).

## *CLUB NOTES*

EDWIN H. ARMSTRONG, director and past President of the Radio Club of America, was among those who received honorary degrees at the convocation which celebrated the 175th anniversary of the founding of Columbia University, on October 31st.

In conferring the degree of Doctor of Science, Dr. Butler said:

"Edwin Howard Armstrong, E. E., 1913, Radio Engineer—Ingenious and skillful in scientific discovery and in finding new ways to make easier and more effective communication between men. * * *"

### *New Members*

The six new members elected at the November 26 meeting were:

Harry S. Johnson.

John A. King, Jr.

W. D. Loughlin.

Walter J. Roche.

Elmer O. Thompson

A. A. Van Orsdale.

A. W. Saunders is now with Electrical Research Products, at 250 W. 57th Street, New York, N. Y.

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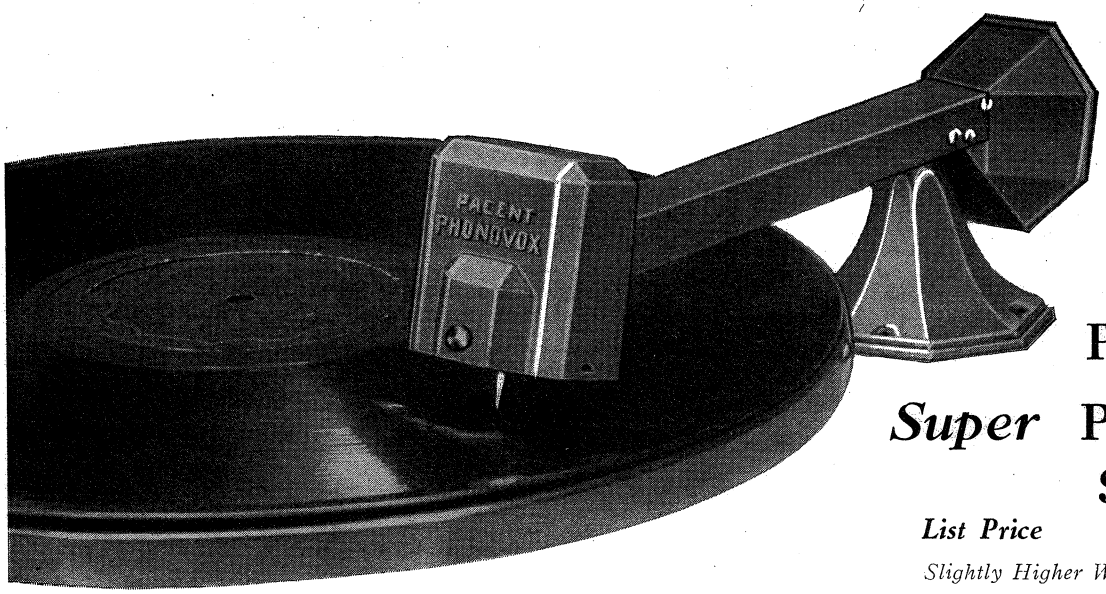

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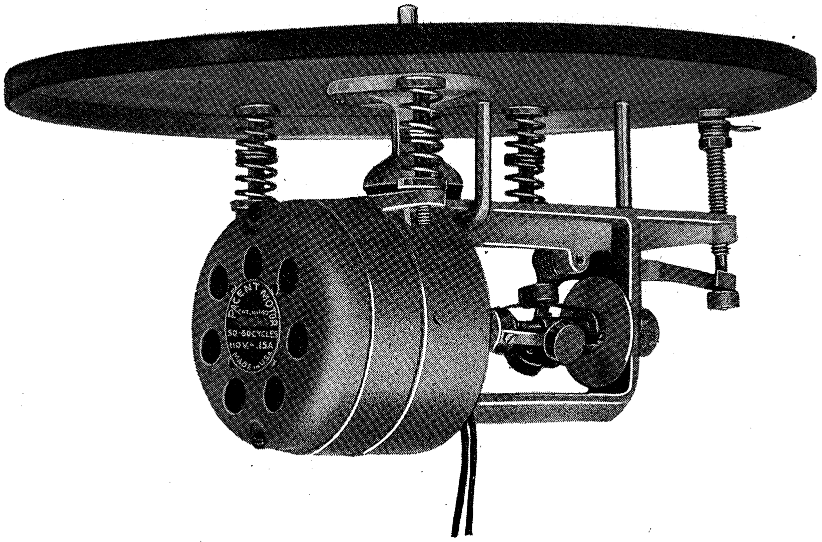

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