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LB-919

AN EXPERIMENTAL TRANSISTOR PERSONAL BROADCAST RECEIVER

RADIO CORPORATION OF AMERICA

RCA LABORATORIES DIVISION

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An Experimental Transistor Personal Broadcast Receiver

Approved

Stuart Wm. Seeley

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Introduction

This bulletin describes a laboratory model AM broadcast receiver which uses nine junction transistors and a compensating diode. It is operated from six small 1.5-volt dry cells (type C). The receiver has six of the laboratory-type, radio-frequency-amplifier transistors described in LB-915, *A p-n-p Triode Alloy Junction Transistor for Radio-Frequency Amplification*, and three transistors of the conventional p-n-p type selected for Class B audio drive and output service. By the use of Class B output, a total battery drain below 12 milliamperes (depending on program level) is attained. The battery life is therefore of the order of 500 hours, and the battery cost relatively small. The maximum audio power output is 150 milliwatts into a four-inch by six-inch oval speaker. The sensitivity and signal-to-noise ratio are comparable to that of conventional battery-operated receivers.

Although this receiver is only an experimental laboratory model designed without commercial considerations in mind, it indicates future possibilities in reduction of size and power consumption which may be expected by use of transistors.

General Discussion

The transistor for radio-frequency amplification described in *LB-915* makes it possible to improve the sensitivity and signal-to-noise ratio of an all-transistor broadcast receiver so as to compare with an all-tube receiver. By judicious design, relatively low cost dry cells can be incorporated in a transistor receiver so as to achieve an operating cost of 1/7 cent per hour. This is the same as the cost of operation of a 30-watt ac-dc receiver at 5 cents per kilowatt hour, and is less than 1/30 of the operating cost of all-tube battery receivers.

An experimental receiver of this type is shown in Fig. 1. Its size is smaller than that of so-called "personal" all-tube receivers, but a 4 inch x 6 inch speaker is used, which allows a sound quality found only in larger all-tube receivers. The receiver is, therefore, adapted for either portable or home use, yet requires no alternative connection to the home lighting circuit.

Size Considerations

The smallest cabinet which will house the 4-inch x 6-inch oval speaker is also large enough for the transistor receiver and six medium-size flashlight cells for power supply. The long dimension of the cabinet is about the minimum length for a satisfactory ferrite-cored loop. Experimental miniature oscillator coils and i-f transformers are used to further reduce chassis size.

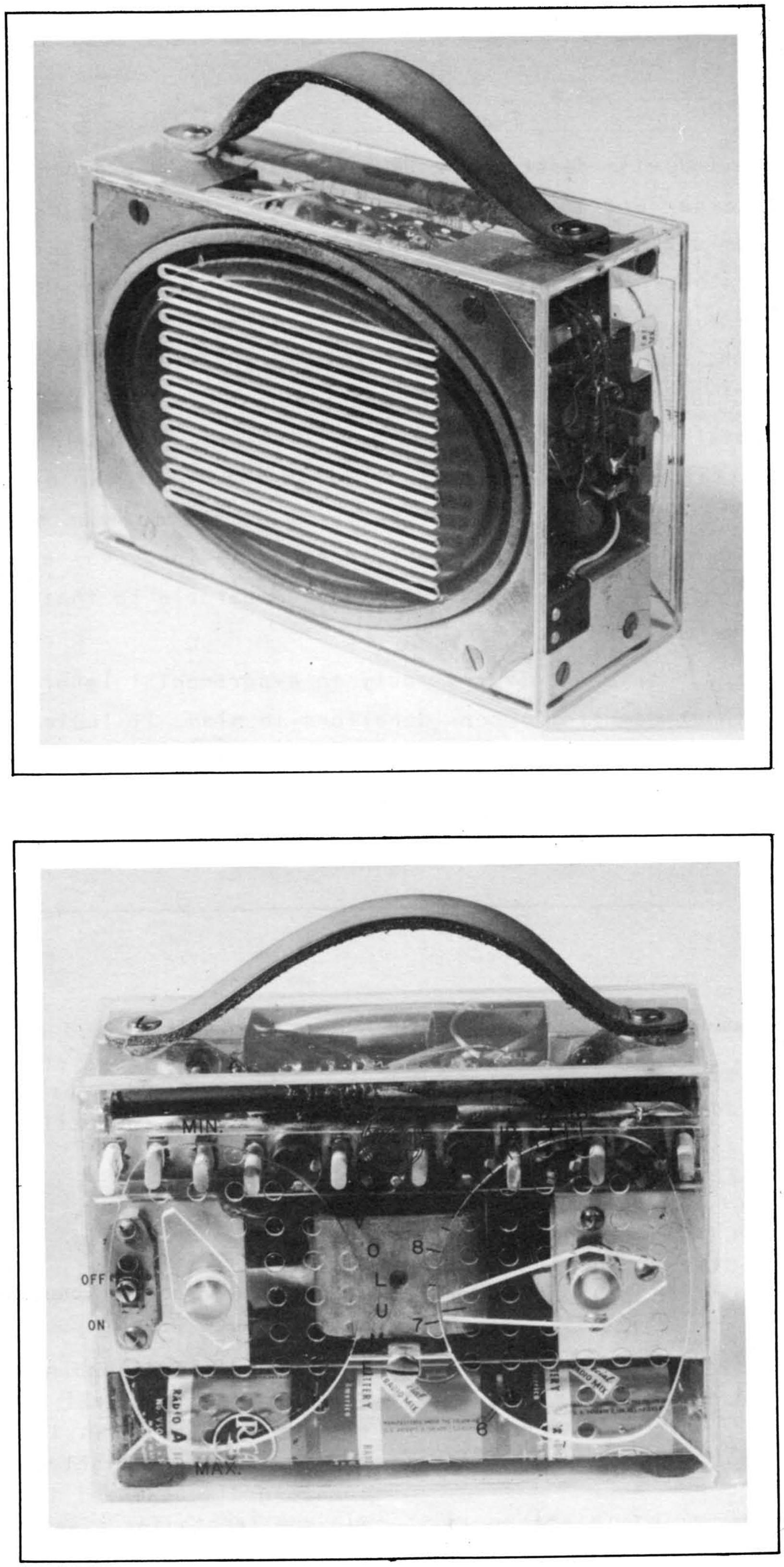

Fig. 1 - Front and rear views of experimental transistor personal receiver.

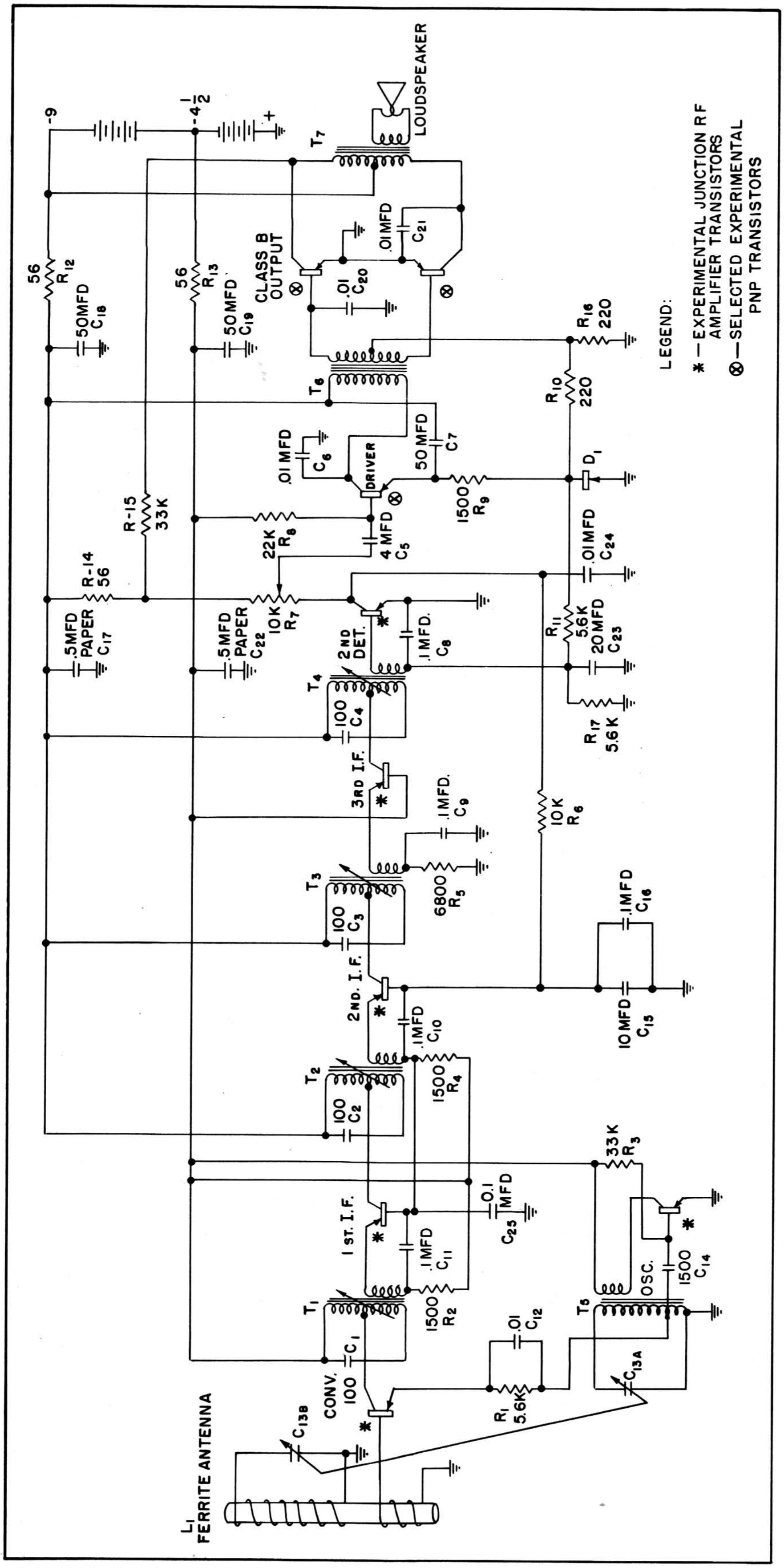

Fig. 2 - Circuit diagram for all-transistor broadcast receiver.

Circuit Features

The superheterodyne circuit diagram is shown in Fig. 2. The oscillator, the mixer, the three i-f stages and the detector each use one of the experimental p-n-p radio-frequency amplifier transistors described in *LB-915*. The oscillator and ferrite loop circuit are capacitor tuned, and each circuit is transformed down to allow base input connection of the mixer and oscillator transistor, respectively. In this way optimum selectivity is retained. The oscillator injection is on the emitter of the mixer. Single-tuned transformer-coupled i-f stages are used in emitter-input common-base circuits, and operate at 455 kc. With this type of circuit an i-f gain of about 22 db per stage is possible and no neutralization is required.

Automatic gain control (a.g.c.) is derived from the collector of the detector transistor and applied to the base of the second i-f stage. Variations of emitter current in this transistor are used to apply a.g.c. to the first i-f stage so the net effect is that of two gain-controlled stages. The audio system employs conventional p-n-p junction transistors which have been selected for driver and output service. Overall feedback, derived from the transformer-coupled Class B output stage is applied to the low end of the volume control. The 9-volt battery supply is center tapped to permit 4.5-volt operation of the r-f transistors and to obtain the necessary d-c conditions for a.g.c. and detection.

The compensating diode (D_1 of Fig. 2) is used for temperature compensation as discussed below.

Ferrite Loop and Oscillator Coil

The main winding of the ferrite loop consists of 120 turns of 15/43 Litz wire wound on a 6-inch by $\frac{1}{4}$-inch diameter bar. The mixer input winding has 6 turns wound on top of and near the low-potential end of the main winding. The unloaded Q was 200, and the final Q (connected to the mixer) was 100.

The oscillator coil consists of 110 turns of No. 36 double silk covered, enameled solid wire, tapped at 3 turns, with a 9-turn untuned secondary. The bobbin and tuning arrangement are similar to that described below for the i-f transformers. An unloaded Q of 110 was achieved and the frequency dependence upon temperature was satisfactory.

IF Transformers

The tuned i-f transformers provide both selectivity and impedance matching. The average emitter input resistance of the experimental transistors used in the i-f stages is about 50 ohms at 455 kc; their output resistance is about 50,000 ohms. On the basis of these impedances, miniature transformers were designed with a tapped, single-tuned primary and a closely-coupled untuned secondary. Fig. 3 shows

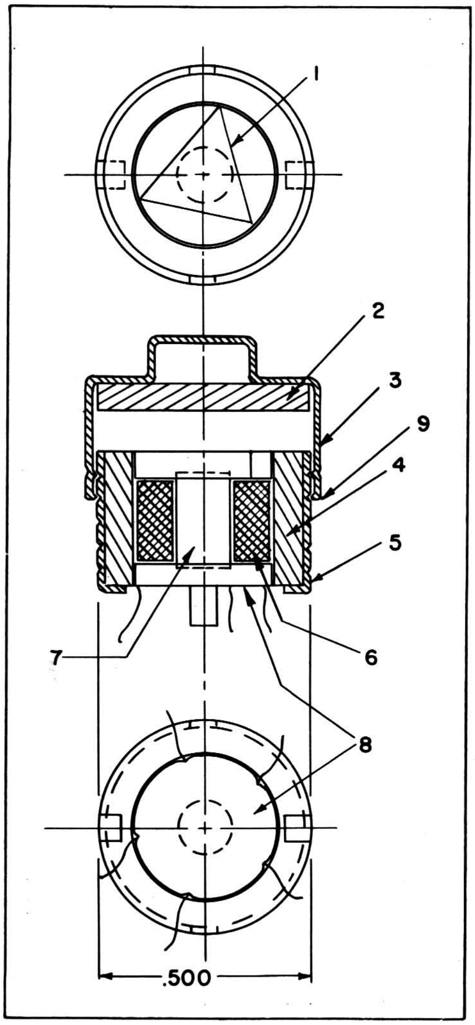

Fig. 3 – I-f transformer assembly.

details of the transformers. The coils are wound on a ferrite bobbin *7* and are surrounded by a cylindrical ferrite sleeve *4*. At the bottom of the bobbin and sleeve, a ferrite wafer *8* completes the magnetic circuit. At the top, however, a triangular wafer *1* is used so that the winding is securely held but the magnetic circuit is not fully complete. Tuning is accomplished by motion of a separate circular top wafer *2* of ferrite, which alters the inductance.

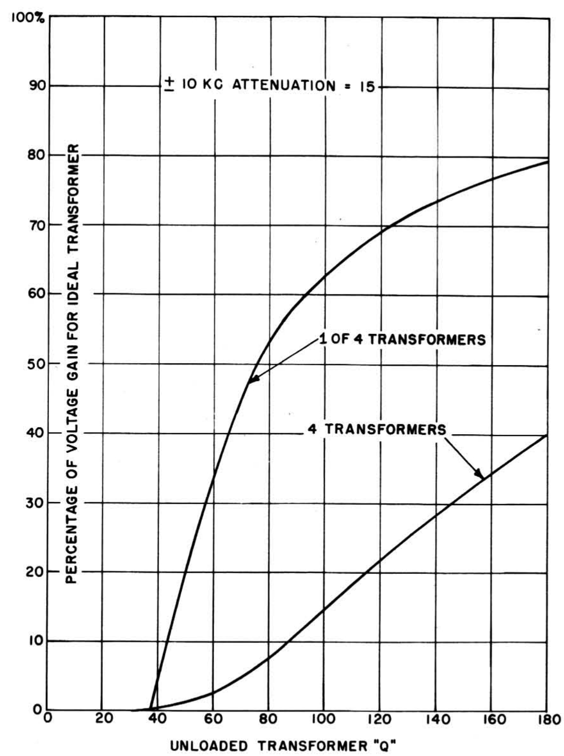

Fig. 4 – Transformer loss characteristics.

The coil bobbin, with its surrounding sleeve and top and bottom wafers, is cemented into a threaded metal sleeve *5* of ½-inch diameter, which serves as a chassis mounting support. The coil leads pass through notches in the bottom wafer *8*. The tuning wafer is mounted in an internally-threaded metal cap which can be screwed on to the lower metal sleeve to vary the tuning.

The transformers are small and compact and were found to have satisfactory temperature stability.

In a transformer of this type the unloaded Q is important since it determines the insertion loss of the transformer. Fig. 4 shows the theoretical effect of unloaded Q on overall gain for one and for four cascaded transformers, when designed so that the loaded-Q attenuation is 15 times at ±10 kc. With the transformers made as described above, an unloaded Q of 150 was obtained. Fig. 4 shows that each stage can therefore be expected to have 75 per cent of the theoretical maximum gain.

The following table indicates the turns used for each of the transformers and the final loaded Q. Number 36 double silk covered, enameled solid wire was used for all windings in these transformers.

Table I

Unit	Primary Turns	Primary Tap	Secondary Turns	Final Q
T1	150	75	3	35
T2	150	50	3	35
T3	150	50	3	35
T4	150	50	5	35

Other Circuit Considerations

The circuits are arranged to reduce effects of temperature variations in the transistor. This is achieved by current-limiting resistances which tend to maintain constant emitter current. The converter gets excessive oscillator voltage but the resistor R_1 (Fig. 2) acts to limit the effective negative swing of the base of the converter. For instance, the oscillator peak voltage needed at the emitter for best operation of the converter transistor is about 0.3 volt at room temperature and at zero bias between the emitter and base. However, about 1 volt peak of oscillator voltage is applied to the emitter of the converter resulting in an emitter current through R_1 to produce a bucking bias of about 0.7 volt d.c. The net peak positive oscillator swing of the emitter is then about 0.3 volt. Because of the self-biasing nature of the R_1C_{12} circuit, the converter collector current is kept essentially constant with variation in temperature and transistors. The bias limiting resistors for the i-f transistors are those in series with the emitters.

A resistor in the emitter lead of the audio driver maintains essentially constant collector current to the driver transistor, independent of temperature. These compensating bias voltages also permit interchangeability of transistors. This type of compensation cannot be used for the second detector and for the Class B output transistors. Bias for these transistors will be discussed below.

Second Detector and AGC

The collector voltage supply for the two a-g-c i-f transistors (first and second i-f) is the upper half of the 9-volt supply battery. The base bias current for the second i-f transistor is obtained through the audio volume control, second-detector load potentiometer R_7, and the audio isolation resistor R_8. Consequently, the bias for the second detector must be such that, for no signal, the collector voltage is more than 4.5 volts above ground. The difference between this voltage and 4.5 volts through R_8 is the bias for the second i-f transistor. The second-detector collector voltage is approximately constant as the temperature increases. This is because its bias from the diode D_1 through $R_{11}R_{17}$ voltage divider changes with temperature. D_1, which provides temperature compensation, is an experimental germanium diode having a low forward resistance.

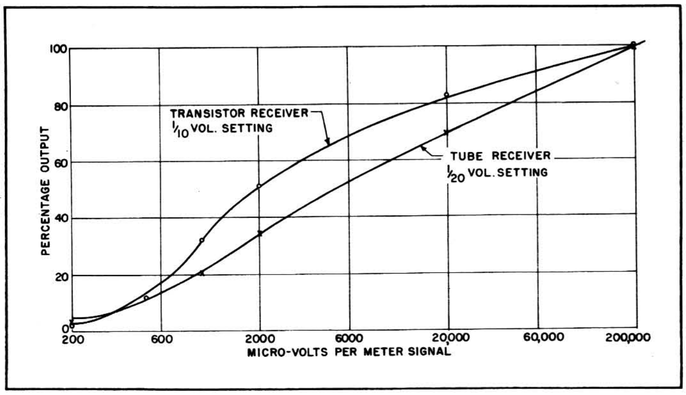

Fig. 5 - AGC characteristics.

The bias for the first i-f transistor is obtained from the resistor R_4 in the emitter circuit of the second i-f transistor. Since the first i-f transistor can have a small bias after its gain becomes a minimum, its gain will be a minimum before the emitter current of the second i.f. and the gain of the second i.f. becomes a minimum. Consequently, the gain of the second i.f. cuts off last and follows the stage that has the earlier cutoff. This sequence is necessary to keep distortion to a mimimum.

The a-g-c characteristics of the receiver are shown in Fig. 5, where they are compared with those of a conventional tube receiver of the personal portable type.

Audio Output System

The audio output system is a Class B power-output amplifier using a transistor driver coupled to the output transistors through a transformer T_8 as shown in Fig. 2. The turn ratio of the primary to each side of the secondary is 4 to 1. The driver and output Class B junction transistors were specially selected for the circuit and output requirements.

The output transformer T_7 loads each output transistor with about 200 ohms during the active half cycle. The bias needed for the output transistors is somewhat critical and varies with temperature. As the temperature increases the required bias decreases. A low forward resistance germanium junction diode D_1 may be used for a temperature-compensated bias as shown in the circuit diagram, Fig. 2 and, as indicated above, may also supply bias for the second detector. A germanium diode is used in order that the temperature coefficient will vary in the same manner as the transistor. The constant current of 2 ma to 3 ma to the driver transistor through the diode D_1 produces a diode voltage of about 0.24 volt. This voltage is divided by R_{10} and R_{16} for a bias of about 0.12 volt, the needed bias for the output transistors at normal room temperature. If the temperature decreases, the bias increases; the bias decreases for a temperature rise. The power supply for the rest of the receiver is isolated from the Class B output for stability reasons by means of the $R_{12}C_{18}$ and $R_{13}C_{19}$ circuit elements.

Audio response curves of the receiver with and without the feedback connection from

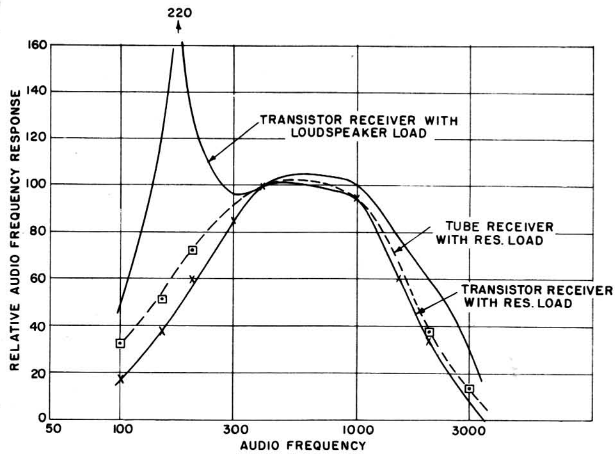

Fig. 6 - Audio frequency response without feedback.

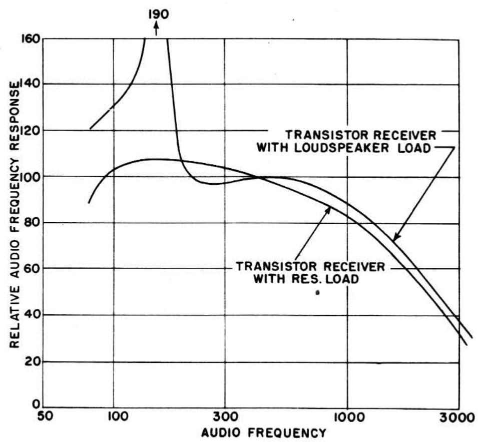

Fig. 7 - Audio frequency response with feedback.

the Class B output to the bottom of the volume control are shown in Figs. 6 and 7. In Fig. 6 a comparison is made with the audio response of a typical personal all-tube set. Into resistive loads, it is seen that the responses are about the same. When feedback is included in the transistor set (Fig. 7) it is seen that the low-frequency response is greatly improved.

Because the feedback is connected to the low end of the volume control, it is gradually reduced as the volume-control setting is increased.

Sensitivity and Noise Measurements

The sensitivity was 100 microvolts per meter for an output of 5 milliwatts. The signal-to-noise ratio was approximately 4 db less than that of a conventional battery-operated personal portable receiver.

Power Output and Battery Life

The following table gives further comparisons of the transistor receiver with a typical tube receiver.

Table II

	Tube Receiver	Transistor Receiver
Total d-c Power from "A" and "B" batteries (on average program)	920 mw	100 mw
Max. power output	75 mw	150 mw
Battery life (approx.) depends upon use	80-100 hrs.	500 hrs.
Batteries used	special	6 medium flashlight
Approximate battery cost per hour	5 cents	1/7 cent
Size of speaker	2 x 3 inches	4 x 6 inches
Weight with batteries	3 lbs. 14 oz.	2 lbs. 12 oz.
Dimensions	9 x 6 x 2¾	6½ x 4½ x 2½
Volume	140 cu. in.	73 cu. in.

Loy E. Barton

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