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LB-931

MINIATURE IF TRANSFORMERS

RADIO CORPORATION OF AMERICA

RCA LABORATORIES DIVISION

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Miniature IF Transformers

Approved

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Introduction

This bulletin describes two types of single-tuned and one double-tuned 455-kc i-f transformers which employ specially processed ferrite materials. These transformers have been developed for use in transistorized miniature broadcast receivers.

One single-tuned transformer is a shell type which is 7/16 inch high and 11/32 inch in diameter. Its performance characteristics such as Q, tuning range, and stability with temperature and humidity have been studied and found to be comparable to those of much larger conventional transformers. Two such units are combined to form a double-tuned transformer. The other single-tuned transformer is a bobbin type which is larger and which has somewhat better performance characteristics.

Details of the special ferrite processing are included.

Description

An exploded view of the miniature i-f transformer is shown in Fig. 1, and the assembly drawing in Fig. 2. The spring washer, A, holds the ferrite cups B and C together in compression. The coil, D, is wound on a coil form and fits in the cups over the center cores. The leads are brought out together through a slot in the side of cup C. E is an insulating washer which serves to prevent the coil leads from coming into contact with metallic parts of the assembly. The mounting ring, F, is the last of the parts to go into the shield can, G. The assembly is held together by crimping or rolling the bottom edge of the can over onto the mounting ring. The side of the can is then punched into the slot in C to prevent C from turning when the transformer is tuned. Tuning is accomplished by rotating the top cup, B, with respect to the bottom cup. This varies the air gap in the center core and hence changes the inductance of the coil.

An assembled unit mounted beside a transistor is also shown in Fig. 1 along with a single cup in which eight nichrome pins have been molded; this cup plugs into a standard subminiature 8-pin socket. A complete transformer using one of these cups has been made. The leads were brought through the slot and spot welded to the pins.

Fabrication of Ferrite Shells

Magnetic Material

Several types of ferrite were used, but the following mix gave the best results -- especially in regard to temperature stability: 24.2 grams NiO, 49.1 grams ZnO, 127 grams Fe_2O_3, and 0.2 gram CoO are milled with 250 cc of methanol for four hours in a steel mill 4 inches ID, 5 inches OD and 4 inches inside depth charged half full of ½-inch diameter steel balls at 80 rpm. The milled material is dried thoroughly at 120 degrees C, then passed through a 20-mesh screen and calcined in fireclay crucibles at 950 degrees C for 1½ hours.

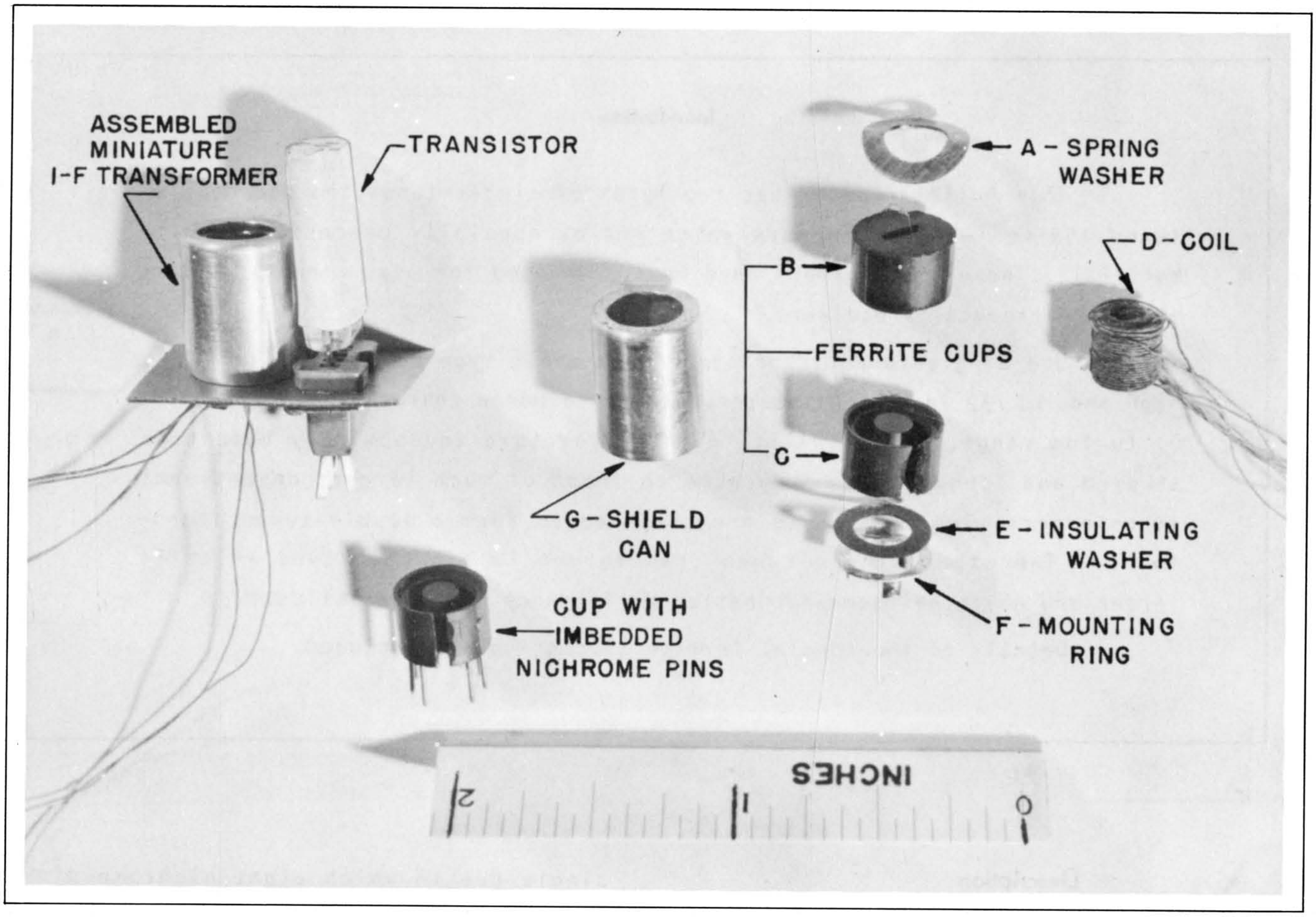

Fig. I - Assembled and exploded views of miniature i-f transformer.

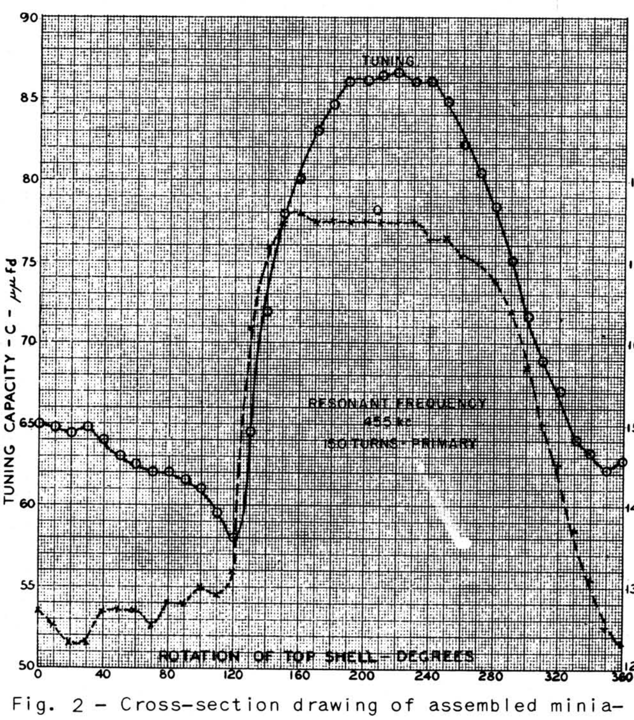

Fig. 2 - Cross-section drawing of assembled miniature i-f transformer.

It is then milled again with 150 cc methanol in the above mill under the same conditions for 22 hours. Thoroughly dried at 120 degrees C and passed through the 20-mesh screen, the material is ready to have binder added.

Binder

The amount and type of binder is very important to the electrical characteristics of the finished ferrite. The following ferrite-binder mix has been found to give satisfactory results. To every 100 grams of the magnetic material just described, 30 grams of water, 4 grams of Cerumul C wax emulsion, and 0.5 gram of trigamine oleate are added and thoroughly mixed. This is dried at 120 degrees C and passed through a 20-mesh screen. Enough carbon tetrachloride is then added to make a sloppy mixture. The solution is boiled and stirred until the CCl_4 is completely evaporated. The powder is passed through a 30-mesh screen and then dried at 120 degrees C for one hour before it is ready for molding.

Molding

Molding is done at very low pressure -- 9000 psi and in two stages. First, full pressure is applied to the bottom of the cup; then the walls and core are molded. The fill is done at one time.

Firing

The units are fired at 1050°C±20°C in air for 3 hours and allowed to cool with the furnace. The kiln atmosphere should be oxidizing at all times.

Coils

A satisfactory coil design consists of four 1/16-inch pies wound on 1/16-inch centers with about 35 turns of number 38SSE wire per pie. The coil form has a 10-mil paper wall and an OD of 0.150 inch. Best coupling is obtained by winding the 4-turn secondary with uniform spacing next to the coil form and with the primary pie windings on top. The coils are treated with Glyptal cement No. 1276.

Tuning

Fig. 3 shows the effect of rotating the shells with respect to each other on the Q and the capacity required to tune the transformer to 455 kc. The shape of these curves is quite variable from sample to sample as it is determined by the effective spacing between the cores of the shells. The effective spacing, in turn, is determined by the shape of the ends of the cores. The shape could be designed to give any desired tuning curve; however, to simplify the mold the ends of the cores used were straight bevels as shown in Fig. 2. The bevel was 0.007 inch.

Temperature Effects

The effect of temperature on the resonant frequency of the transformer is shown in Fig. 4.

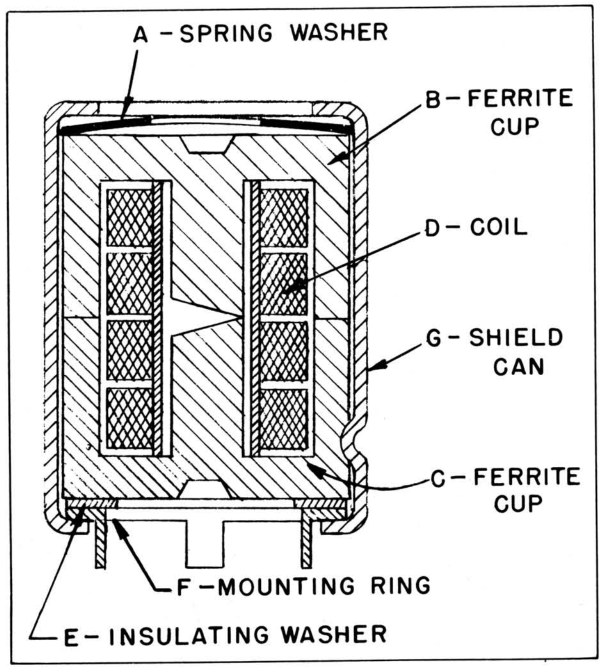

Fig. 3 - Tuning characteristic.

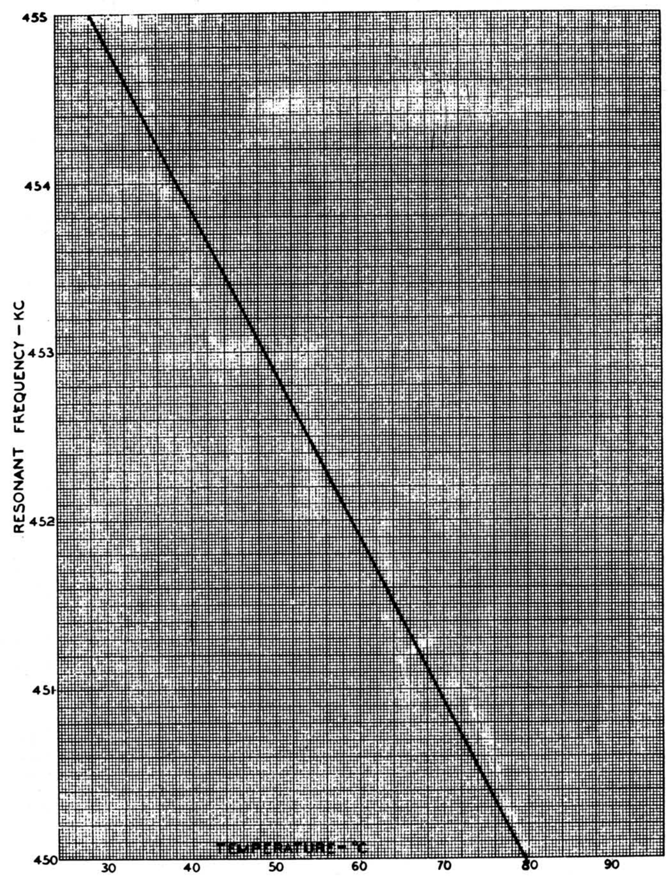

Fig. 4 - Temperature effect.

The straight line represents the average of the points taken, all of which lay close to the line. The return curve is not shown in Fig. 4 but the transformer returned to its original frequency each time for five temperature cycles. The frequency coefficient, then, is seen to be about 210 parts per million per degree C. The unloaded Q of the transformer dropped about 20 per cent for a 60-degree C temperature rise.

Loaded Resonance Curve

The resonance curves for two load conditions are shown in Fig. 5. In each case the output load was 101 ohms. The overall Q as determined from bandwidth measurements was 15.7 for an input load of 15,000 ohms, and 27.8 for an input load of 96,700 ohms. The efficiency of the transformer for both loading conditions was over 95 per cent. The actual turns ratio of the transformer was 12.5; the measured voltage ratio with the transformer loaded was 12.7. The coefficient of coupling, then, is close to unity.

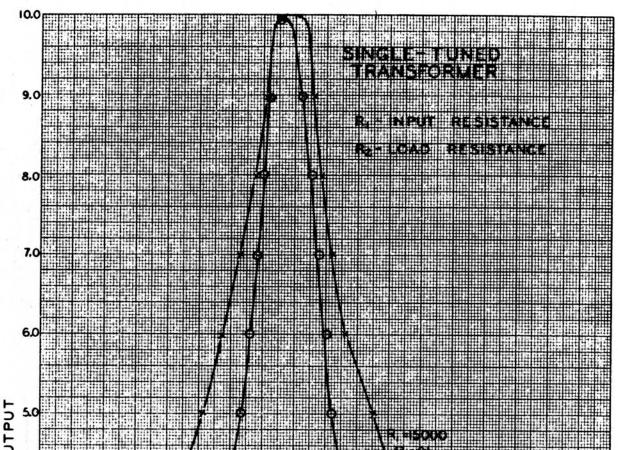

Fig. 5 - Resonance curves for single-tuned transformer.

Distributed Capacitance

The distributed capacitance of the primary winding without the ferrite shells at 26 degrees C was 8.25 μμf, and 8.95 μμf in the complete transformer assembly. At 82 degrees C the distributed capacitance of the completed unit was 9.78 μμf -- an increase of about 10 per cent. This would account for at least 2 kc of the total frequency drift with temperature shown in Fig. 4. The effective permeability of the ferrite shell is between 20 and 30.

Humidity

Humidity measurements were made in a closed polystyrene box in which an open container of distilled water was placed. The relative humidity in this chamber was of the order of 85 to 90 per cent. Fig. 6 shows the effect of humidity on the completed transformer. Measurements of the distributed capacitance

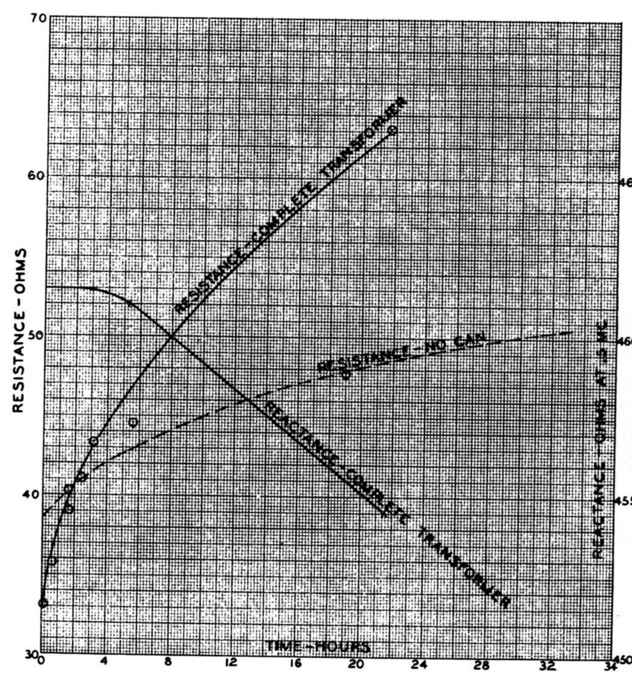

Fig. 6 - Humidity effect.

showed it to increase with time of exposure to humidity. This accounts for the drop in reactance with humidity shown in Fig. 6. The effect of humidity on the losses of the transformer without any can are shown by the dotted curve; the reactance of this unit changed a negligible amount, but the losses increased 36 per cent after a 4-day exposure to 100 per cent relative humidity. To determine how much the ferrite was being affected, the same ferrite shells were treated in Carnauba wax at 160 degrees C for 1 hour (the coil had been given a similar treatment when made), and assembled with the same coil. The losses increased 35 per cent after a 4-day exposure. The losses of the coil alone increased 10 per cent with a 16-hour exposure as compared with a 19 per cent increase over a similar period for the assembled unit less the can. Evidently most of the losses are due to distributed capacitance effects and very little to the ferrite absorbing moisture.

Increasing the Tuning Range

The tuning range can be increased by lengthening the cores to the point where the shells are in contact only when the beveled ends of the cores are matched as shown in Fig. 7a, and are separated when the bevels are opposed as in Fig. 7b. Tuning ranges of ±20 per cent can be obtained easily in this way. However, a 35 per cent reduction in Q develops in the minimum inductance position due to flux leakage into the shield can from the air gap between the shells. This drop in Q can be nearly overcome without more than a 10 per cent reduction in tuning range by providing a lap joint for the shells as shown in Figs. 8a and 8b. This last design worked well but the shells are more difficult to make than those finally adopted. See Fig. 2.

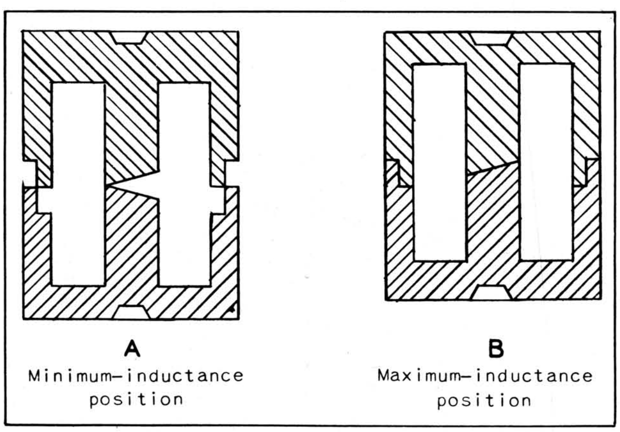

Fig. 7 - Cross-sectional view of lap-joint ferrite shell.

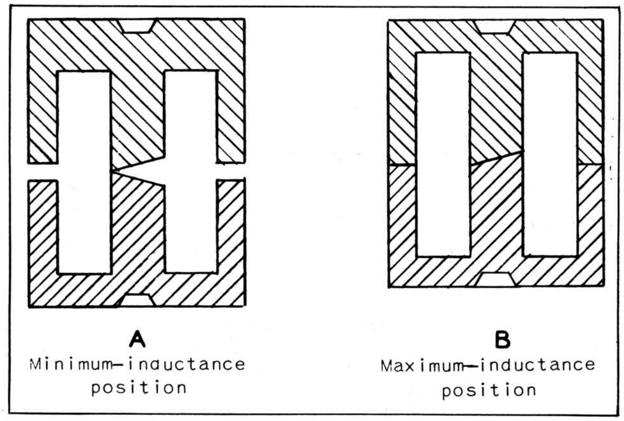

Fig. 8 - Cross-sectional view of butt-joint ferrite shell.

Temperature Compensation

The permeability of the ferrite has a positive temperature coefficient. Compensation for this can be provided by causing the ferrite shells to move apart as the temperature is increased. There are at least two ways by which this can be accomplished as shown in Fig. 9 and Fig. 10. In Fig. 9a, H is a corrugated washer

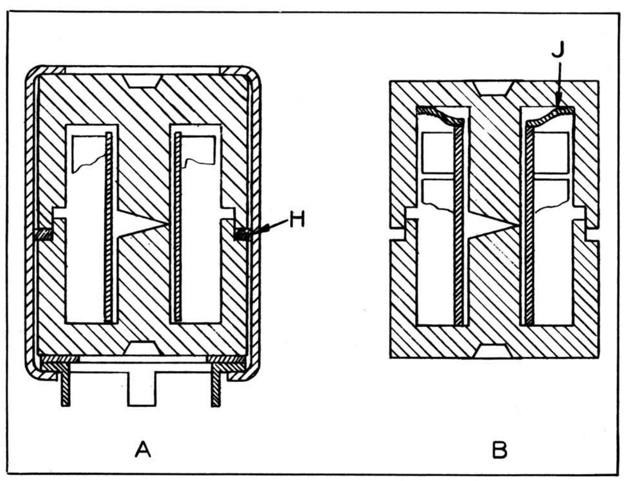

Fig. 9 - Cross-sectional view of temperature-compensated transformer construction.

inserted between the ferrite shells as shown. The assembly is the same as in Fig. 2 except the spring washer A has been omitted. H holds the ferrite cups apart and tightly against the ends of the shield can. Since the shield can has a higher coefficient of expansion than the ferrite cups the net result is that as the temperature is increased the ferrite cups are moved apart. An uncompensated transformer drifted 19 kc up to 90 degrees C; while the same transformer when compensated drifted only 10 kc up to 90 degrees C. Using a better ferrite the temperature drift of a compensated transformer was cut to 2 kc at 600 kc up to 92 degrees C. The ring H, made of phosphor bronze, decreased the unloaded Q of the transformer from 150 to 50. By splitting the ring, the Q was brought up to 95. The bad effect of this ring on the Q prompted the design shown in Fig. 9b. The function of this unit is the same as that shown in Fig. 9a except the cups are held apart against the ends of the shield can by a shaped fiber washer J. Since this washer is not metallic it does not affect the Q or tuning of the unit. The temperature stability of this unit was the same as that of the first design.

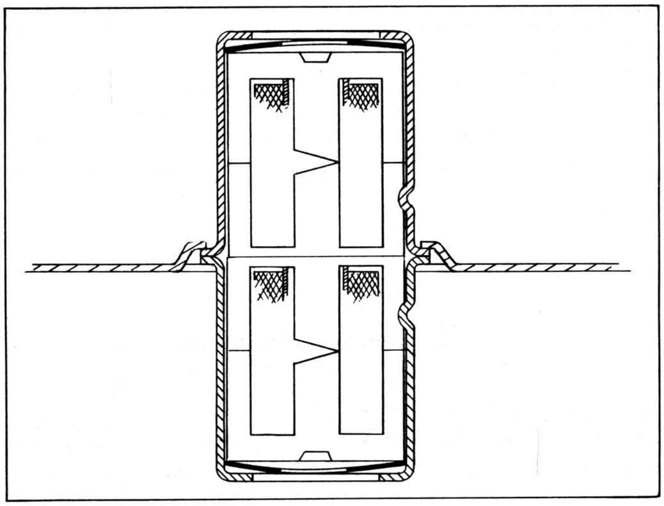

Fig. 10 – Cross-sectional view of double-tuned transformer.

Double-Tuned Transformer

Fig. 10 shows two pairs of cups and coils mounted end to end. The magnetic coupling between the coils is adjusted by varying the thickness of the ends of the inside ferrite cups. The shield cans are flared and are held together by the lances thrown up from the chassis. The magnetic parts are held tightly together by the action of the spring washers A (see Fig. 2). A photograph of the assembly is shown in Fig. 11. The circuit and resonance curve are given in Fig. 12. The unloaded Q was about 150 for both the primary and secondary.

Bobbin-Type Single-Tuned Transformer

This type of transformer has been mentioned previously in LB-919, *An Experimental Transistor*

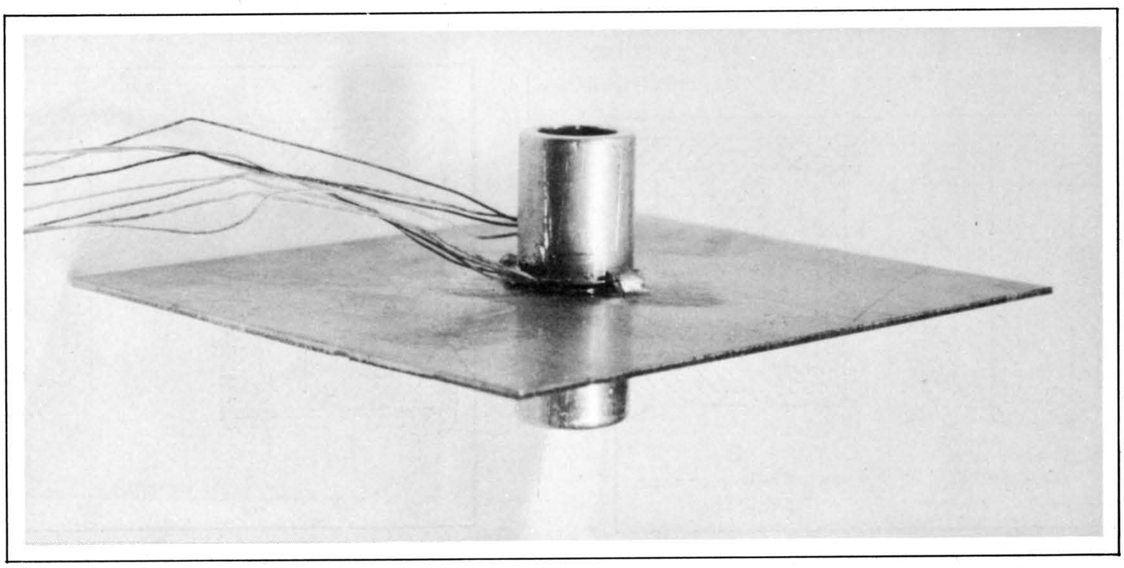

Fig. 11 – Photograph of double-tuned transformer.

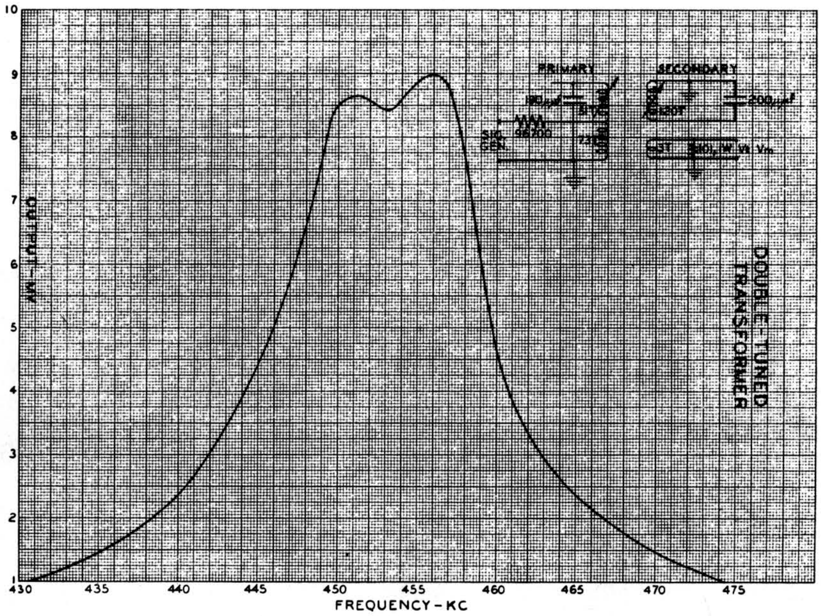

Fig. 12 - Circuit and resonance curve for double-tuned transformer.

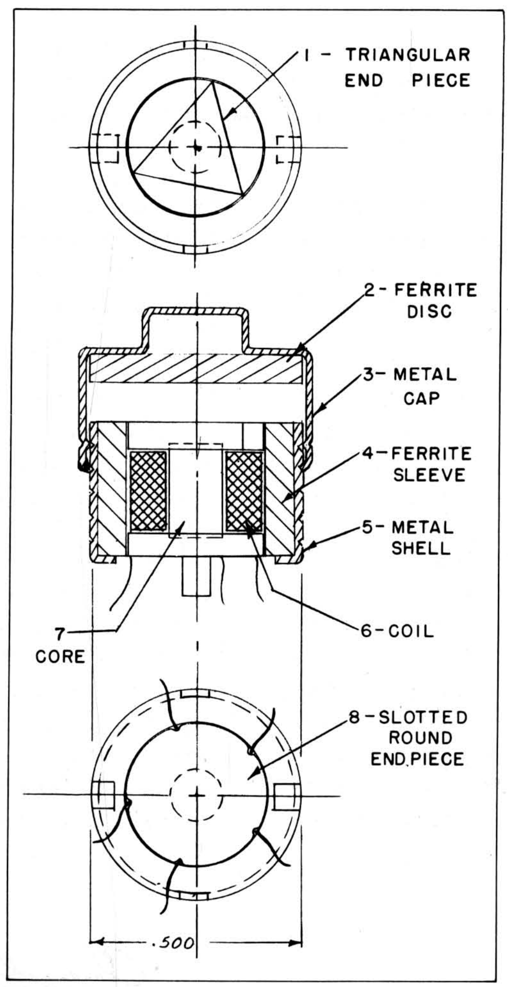

Fig. 13 - Cross-sectional view of bobbin-type i-f transformer assembly.

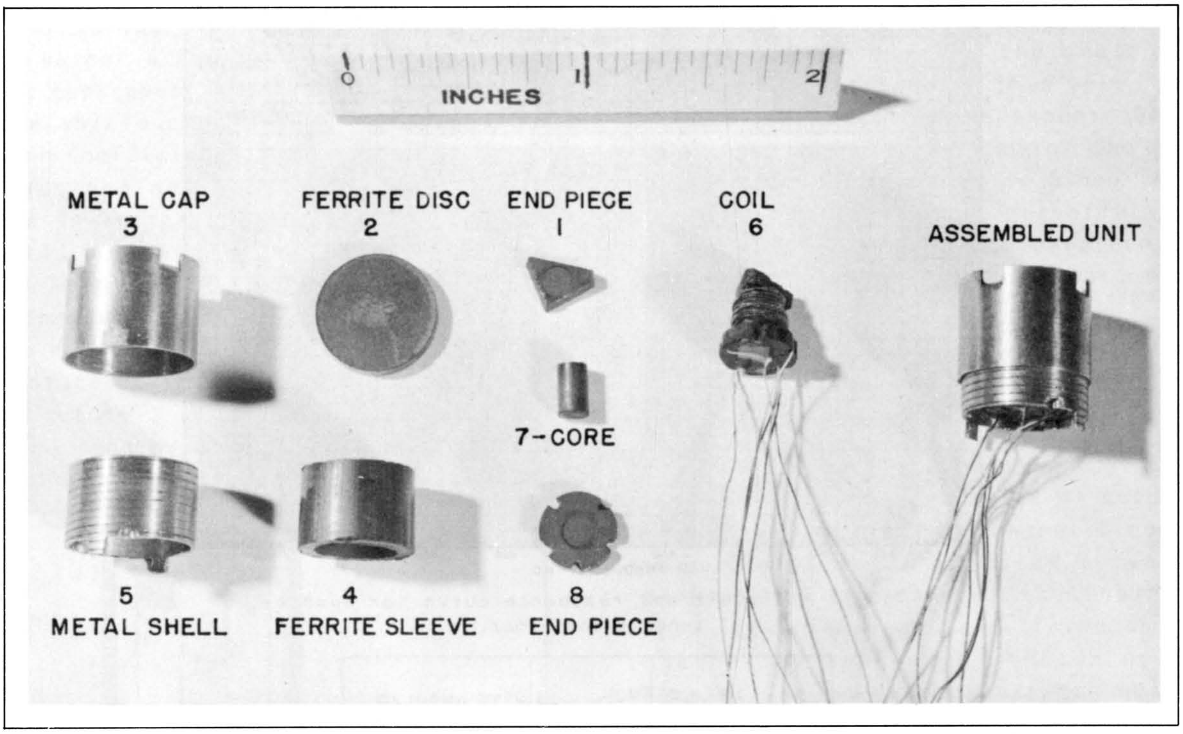

Fig. 14 - Assembled and exploded views of bobbin-type i-f transformer.

Personal Broadcast Receiver. An assembly drawing is shown in Fig. 13, and an exploded view of the parts in Fig. 14. The unit consists of a ferrite sleeve (4) which is glued into a metal shell (5). A ferrite bobbin made up of a slotted round end piece (8) and a triangular end piece (1) glued to a core (7) carries coil (6). This bobbin assembly fits into the sleeve (4) and is held in by gluing (8) to (4). The coil leads are brought out through slots in (8). The outside of this metal shell (5) is threaded and a metal cap (3) carrying a ferrite disc (2) is screwed down over the shell (5). As the cap is screwed down, the ferrite disc (2) is brought up to the triangular end of the bobbin, thus changing the inductance of the coil. The tuning range thus affected depends primarily on the fit of the triangular end in the sleeve, but it is also affected by the size and shape of the piece. If the corners of the triangular end are sharp and the end just fits in the sleeve (4), a tuning range of ±10 per cent in inductance is obtained. If the fit is fairly loose, a range of ±20 per cent can be realized. The tuning range is spread over 2 turns with 45 per cent completed at the end of the first ½ turn.

The Q of the bobbin-type transformer is about the same as that of the shell-type previously discussed. However, the temperature characteristics are better because of the compensation obtained from the unequal expansion of the cap (3) and ferrite sleeve (4). The effect of humidity is about one half as much as on the shell-type transformer; this is due to slightly lower distributed capacitance. While the bobbin-type transformer is not as simple to manufacture, it offers some advantages in stability which might make it attractive for certain applications.

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