# RADIO AGE

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# The Should-Have-Been RCA Model 23K: Analysis of a 23-Tube Prototype Receiver

## Chapter 1 – The Magic Brain

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In this and subsequent articles I have the privilege of documenting a unique item, a 23-tube prototype receiver designed by RCA. As will be demonstrated, this is an enhanced version of the Model 15K, RCA's premier 1937 receiver and one of the largest radios ever produced by RCA.

This was the era of the Zenith Stratosphere, the Scott Allwave 23, and similar high-end sets. Bigger was better. I've elected to call the prototype the Model 23K since I believe it would have been marketed under that designation had it been put into production. (But that was not to be.)

My analysis will be presented in several stages. The final article will include a summary of features and specifications for the set, to the extent that I'm able to do so with confidence. I welcome and encourage comments and suggestions from our readers, particularly information regarding the original design of the 23K or the 15K. My contact information appears at the end of each article.

**Background**

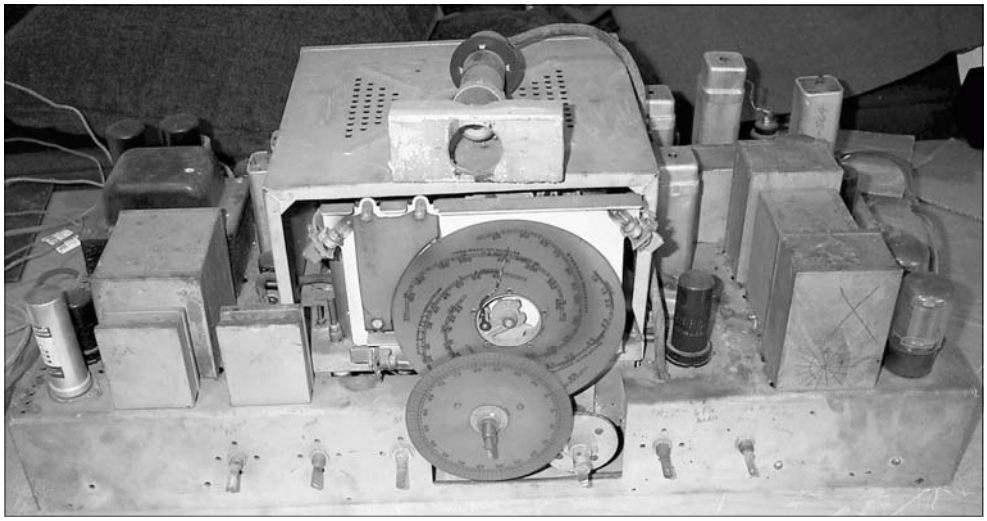
In a monumental case of serendipity, this receiver was spotted sitting curbside awaiting arrival of a trash truck to haul it to the dump. Had it not been for the sharp eye of Allan Ropper of Newton, Massachusetts, this episode in RCA history would have been forever lost. It took several months of discussion and investigation before we realized the true nature of the find. Allan generously donated this

*(Continued on page 3)*

**IMPORTANT NOTICE !**

**Meeting Place Change**
**See page X for details**

*(Continued from page 1)*
set to the Radio & Television Museum in Bowie, Maryland, where it will reside when my restoration is complete. It should be fully functional.



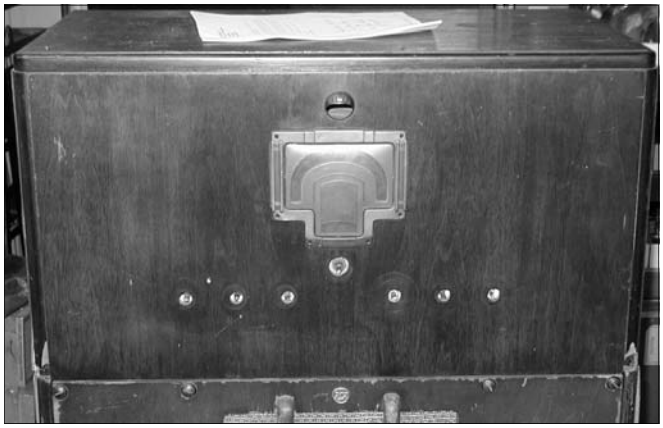
The Chassis of the RCA prototype receiver (the "23K").

**Some Basics**

The radio uses 22 metal octal tubes and a 6E5 tuning eye. The block diaram (page 4) is based on pencil notes on the set, and physical examination. There are no connections shown for the two volume expander tubes because I haven't gotten that far in the analysis. I will connect them appropriately in a later revision of the drawing.

The 23K has six front-panel controls (plus tuning) rather than the four found on the 15K. Left to right they are: L. F. Tone (rotary switch) with AC power switch, Volume (potentiometer), AFC Off/On (rotary switch), Bandswitch, Expander (potentiometer), and H. F. Tone Min/Max (rotary switch).

The chassis measures 26 inches wide by 13-3/8 inches deep by 3-3/4 inches high, excluding control shafts. The "Magic Brain" (the RF front-end subassembly) is 9-5/8 inches wide by 9-1/4 inches deep (excluding shafts). It projects 5-7/8 inches above the chassis. The 6E5 tuning eye is mounted to the cabinet on a bracket above the MB (Magic Brain).



The cabinet of the prototype. The receiver portion is crudely made out of plywood, and sits atop a standard RCA speaker cabinet.

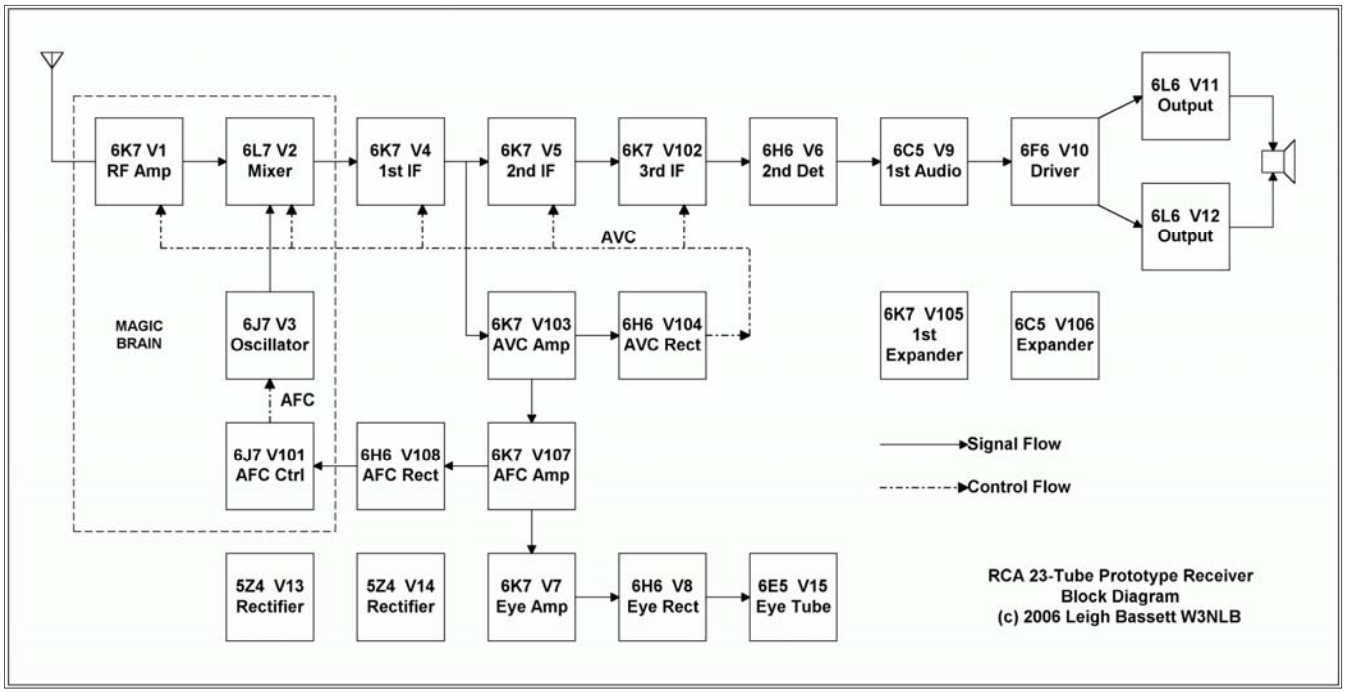
**Preliminary Investigation**

Unfortunately the set is not virgin. It was used in someone's home over a period of many years after it left the RCA labs. And, of course we cannot determine how many times it might have been modified during the time the RCA engineers were tinkering with it. The 1930s electrolytic capacitors have been replaced with modern parts and the originals were discarded. Most other components, including the dogbone resistors, appear to be original.

This extended lifetime presents some interesting problems when analyzing the set. Some changes were obviously routine maintenance, but others seem related to its original purpose as a testbed. Where the changes appear to relate to the radio design, I've attempted to document all identifiable configurations.

One unique feature of this set is the numerous pencil notations on the chassis and on individual components. The tube types and their functions, as shown on the block diagram, are based on these labels. All front- and rear-panel controls were similarly labeled in pencil.

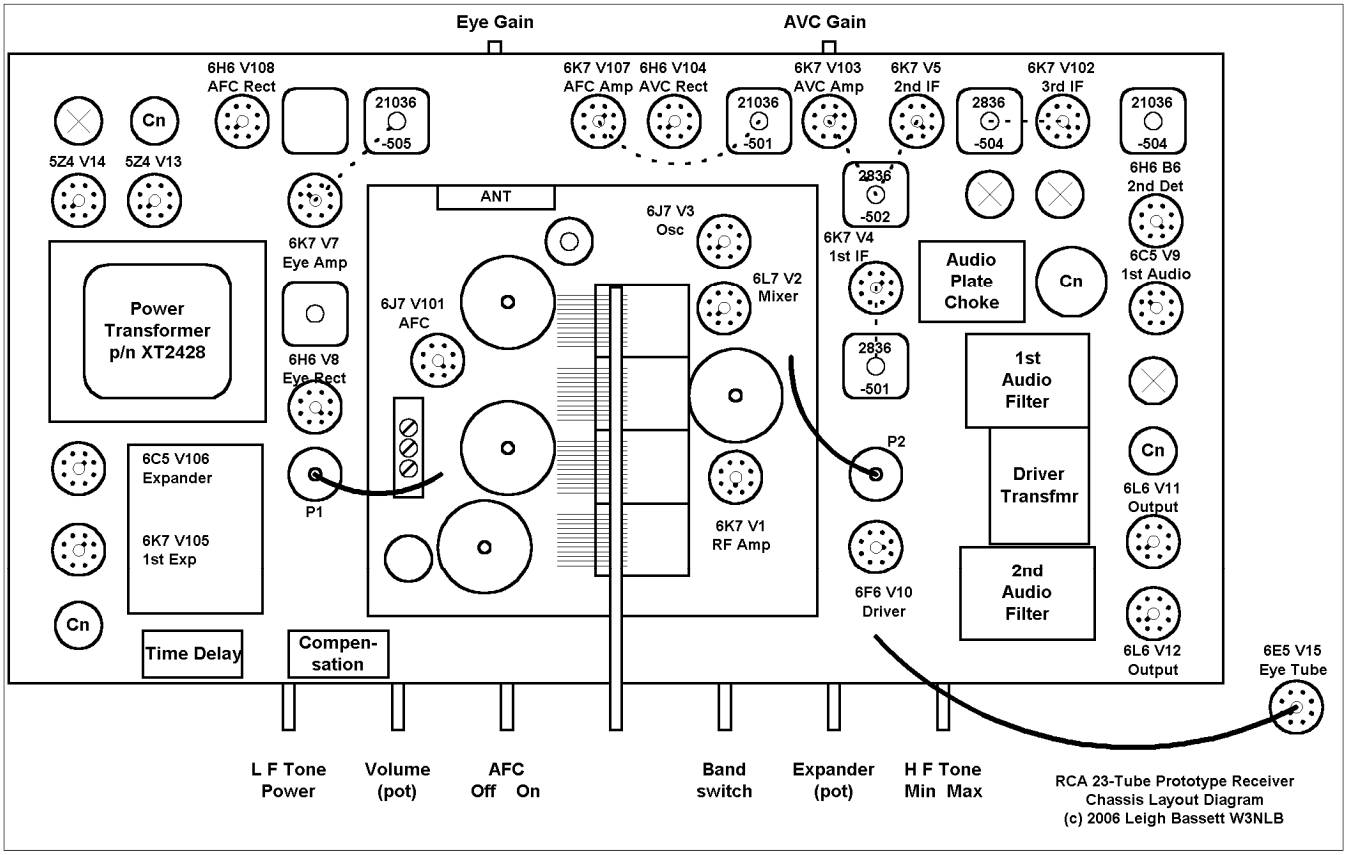
## In This Issue




Block diagram of the prototype receiver.

The values of electrolytic capacitors, and of individual sections of the two Candohm resistors, are written under the chassis.

As can be seen from the photo on page 3, the radio is housed in a very cheap and uninteresting plywood cabinet fitted atop a commercial RCA model 64-A PA speaker. The panel hardware is identical to the 15K,




Chassis layout of the RCA 23K.


Pencil markings on the chassis helped me determine the functions of the radio's components.

including the dial scale cover and escutcheon, and the escutcheon around the tuning eye. However, there are no labels on any of the controls, nor any other labels or logos on the front panel. The contrast between the beautiful burled walnut of the 15K cabinet and this plywood housing is quite remarkable. It's obvious that this set was never sold to the public.

While it would be possible to present the numerous similarities between this set and the 15K in tabular form, I think it is more interesting and informative to discuss each in its proper place in the overall narrative. There are several major enhancements. For example, the 23K's Magic Brain RF assembly has four tubes, compared to only three in the 15K. The extra tube provides AFC (Automatic Frequency Control) on the standard broadcast band. The 15K did not have AFC.

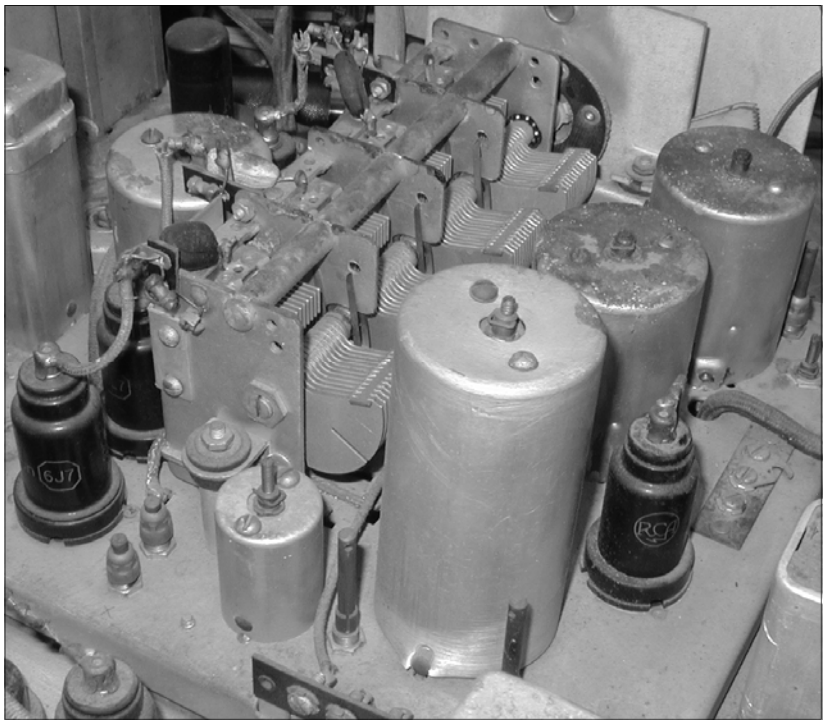
A note regarding circuit designations (V1, R22, etc.): The accompanying schematics use two distinct styles for designators. Those with one or two digits are derived from the 15K schematics for components in the 23K which are identical in location and function and have the same or similar values. Unique 23K components have three-digit part numbers. This is an experiment. I originally intended to use a completely new set of designators for the 23K, but realized that matching the two designs would be easier if I identified identical components when possible.

**The Magic Brain**

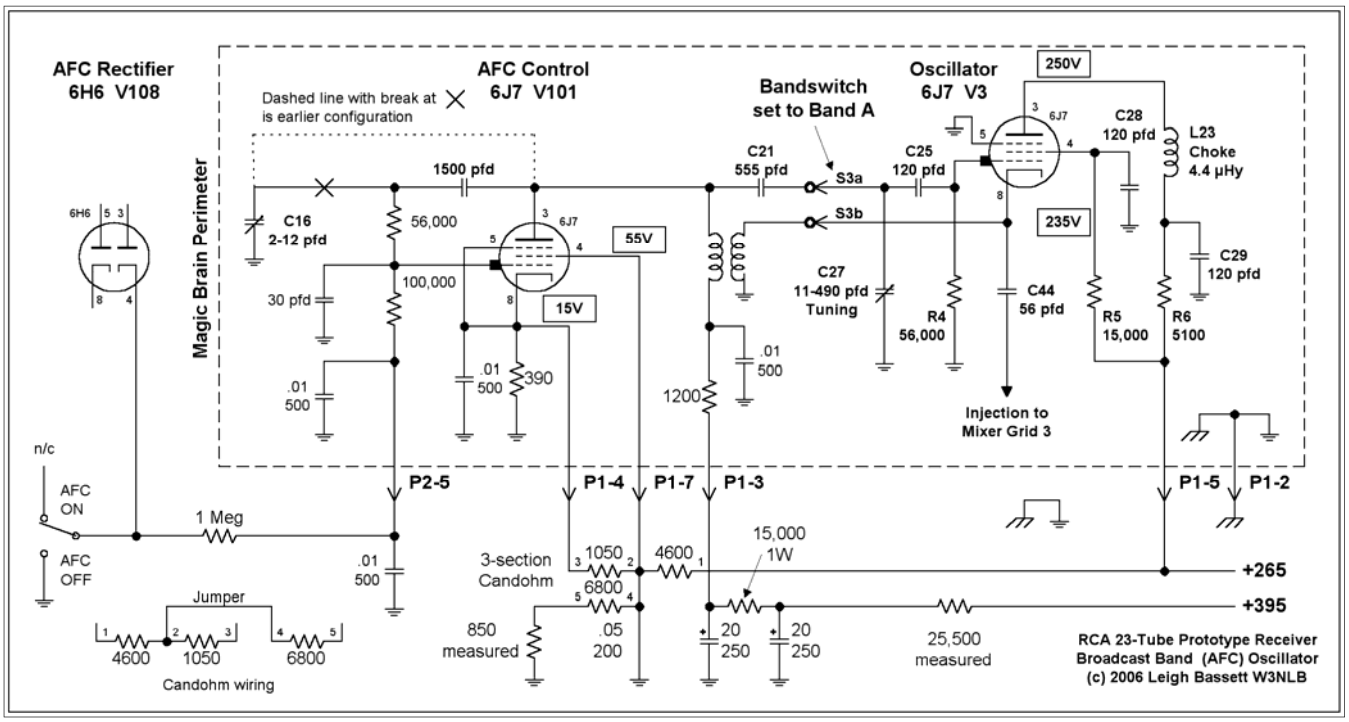
My analysis has been greatly facilitated by the fact that I have a Model 15K stripper set (devoid of power transformer and other significant components). But its Magic Brain is intact, which provides a good reference for the following discussion.

The 23K covers the same five frequency bands as the 15K, namely Long Wave (Band X, 150–410 kHz), Standard Broadcast (Band A, 530–1,800 kHz), Medium Wave (Band B, 1,800-6,400 kHz), Short Wave (Band C, 6,400-23,000) kHz), and Ultra-Short Wave (Band D, 23,000-60,000 kHz). The tuning dial and mechanism are identical to that on the 15K, and have the same part numbers.

The "standard" Magic Brain, as used in production models 9K through 15K, is a removable subassembly completely self-contained up to the plate of the mixer




The Magic Brain section of the radio is shown here. Note the four-gang tuning capacitor.



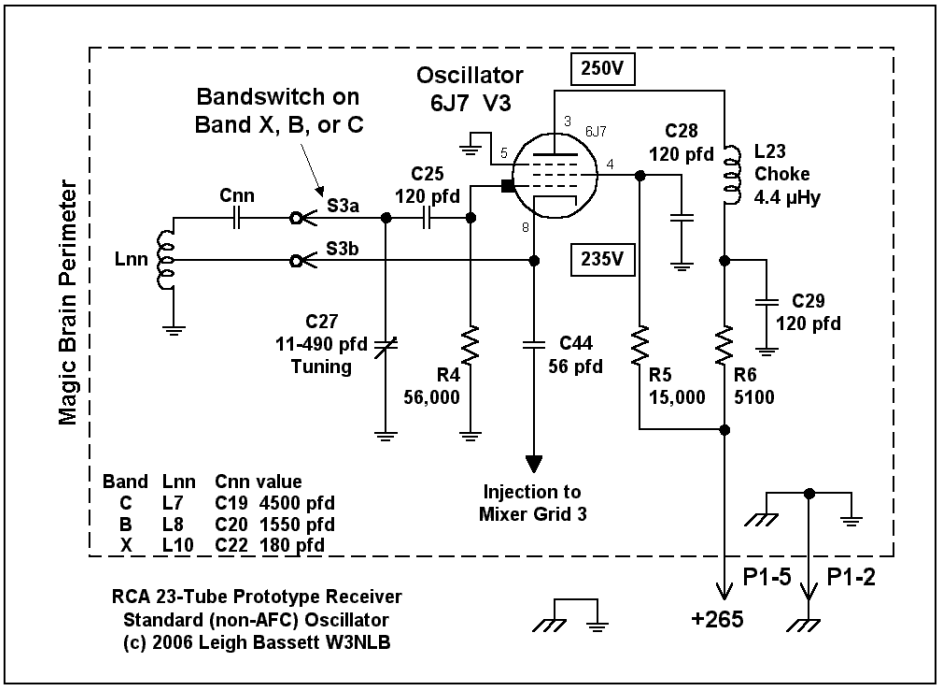

Broadcast band (AFC) oscillator schematic. Components outside the Magic Brain perimeter were measured and may not reflect the exact circuitry in the set.

tube, which connects to the primary of the first IF transformer located on the main chassis. There is one mechanical difference: The 15K MB bandswitch is controlled by a chassis-mounted shaft, so the linkage must be disconnected in order to remove the Magic Brain unit. The 23K has an integral shaft for this function.

Connection between the 15K's Magic Brain and the main chassis is via a single integral eight-conductor cable with an octal plug on the radio chassis end. Due to additional interconnections the MB in the 23K has two cables, one on each side, each with an octal plug. The first cable is fully populated with eight conductors. The second has only three conductors including the two filament lines and the control voltage for the AFC circuit. Although the low side of the filaments are grounded in the MB, the design uses twisted wires to feed filament voltage from the chassis.

## The Oscillator Circuit

The 15K Magic Brain has three tubes: a 6K7 RF amplifier (V1), a 6L7 1st detector (mixer) (V2), and a 6J7 local oscillator (V3). The Magic Brain in the 23K has a fourth tube, a 6J7 control tube (V101) which




Bands X, B, and C (tapped coil) oscillator schematic.

provides automatic frequency control (AFC) to the local oscillator when operating on the broadcast band. This tube, operating under DC control, in conjunction with fixed capacitors, provides a variable capacitive reactance in shunt with the trimmer capacitor, tuning capacitor, and oscillator coil, thus directly controlling the local oscillator frequency. The design is similar to one described by Charles Travis [1], who had worked at the RCA Licensing Laboratory. This circuit is similar to that used in the RCA 816K. The 816K also features Magic Brain circuitry, but it's built on the radio chassis, not on a separate subassembly.

The AFC function required a change in the design of the oscillator coil, adding a control winding and an additional solder terminal. The oscillator circuit used on most bands in the radio has a single tapped coil with the low end grounded, the tap going to the oscillator tube cathode, and the top end capacitively coupled to the oscillator tube grid and the tuning capacitor. The AFC configuration uses two coils, one untuned in the cathode circuit, and a tuned coil in the plate circuit of the control tube which connects to the oscillator tube and tuning capacitor.

One design change appears in this circuit. The trimmer capacitor was originally connected to the control tube plate, at its junction with the coil winding. This would put it in parallel with the controlled reactance. The connection was moved to the other side of the reactance capacitor.

The control tube must have been very sensitive to hum on the plate supply line, because it has its own filter circuit on the main chassis, comprised of two 20 µF electrolytics with an interposed 15,000 ohm, 1-watt resistor. This filter feeds only the control tube plate circuit, not its screen.

**The Antenna Circuit**

The tuning capacitor in the 23K has four sections, compared with three in the standard Magic Brain. It appears that RCA had originally intended to have AFC control on the tuned RF input (antenna) circuits as well as on the local oscillator, but this feature is not functional in the prototype. The components are in place to support it, but the wire that would carry the control current to the coil is cut off and wrapped around a spare terminal to keep it from flopping about. I can speculate that the RCA engineers did try to make it work, but found it impossible to have the antenna and local oscillator circuits track with sufficient accuracy, and dropped the idea.

Antenna can with ferrite shield.

To support the RF AFC feature, the antenna coil of the standard Brain was replaced by two new coils mounted in separate aluminum cans. The added section of the tuning capacitor was used only for tuning the broadcast band with its associated AFC circuitry.

The new coils sport a unique feature: They are shielded by ¼-inch thick ferrite sleeves inside the cans, extending 2 inches above the chassis (the cans are 2-3/4 inches tall). Three center-punch dimples hold the sleeve in place inside the can. The modified cans have three mounting screws rather than two, arranged in an asymmetric triangle, so the cans can only be installed in one particular orientation. These two cans were hand-made, as evidenced by machinist scribe marks on the surface.

The mounting holes for these cans were originally punched for the two-screw (unshielded) configuration. Three more screw holes were added later to accommodate the shielded cans. Whether this represents a design change or simply a fabrication convenience cannot be determined.

**The Mixer Grid**

The tuned circuits in the mixer grid are the same as those in the 15K with one exception. In the 23K a capacitor has been inserted between the detector coil and the junction of the bandswitch and tuning capacitor. The reason is unclear.

**Bandswitching**

The bandswitching in the Magic Brain is quite complex. In fact, the *Service Lecture* booklet for the standard Magic Brain [2] devotes four full pages and five diagrams just to the switching circuitry. Unfortunately, that of the 23K is even more complicated. I've drawn simplified diagrams of the three switched circuits, but I must emphasize that these are not complete, and intentionally so. I was more interested in presenting the essence of the functions rather than their specifics. Scans of the standard MB *Service Lecture* booklet pages will be available on my website.

**Unimplemented Features**

There are two features of the 23K Magic Brain that apparently were never used.

- There is a vacant mounting hole for a coil can. There is no evidence that anything was ever mounted there, so it must be for a feature that was never implemented.

- There is a three-position screw-terminal strip that was not wired. I believe it was to have provided the means to enable or disable the antenna circuit AFC by connecting the control lead to the middle terminal, control voltage to one outer terminal, and ground to the other. By moving the center link, the function could be enabled or disabled. The control wire that is cut off would easily reach the middle terminal.

**Electrical Changes**

The electrical component changes relative to the standard Magic Brain are summarized below. Added components are not mentioned.

- The new oscillator coil has an additional winding and one more solder terminal.
- Two new antenna coils replace the single original.
- Resistor R6 in the oscillator B+ line was changed from 5,600 ohms to 5,100 ohms.

**Mechanical Changes**

There were a few mechanical changes in the 23K Brain.

- The antenna coil for Band D (consisting of L13 and L14) was moved from the vertical interstage shield to the chassis, thus rotating it 90 degrees. Its axis was originally parallel to the bandswitch shaft. This move was required because the bandswitch wafer was moved closer to the shield, leaving no space to mount the coil on the shield.
- Antenna trimmers for Bands X and A were moved closer to the bandswitch to make way for the extra coil mounting hole (unused).
- A three-position terminal strip was mounted near the antenna coil circuitry but was never wired.
- The chassis was extended forward, providing mounting space for the additional antenna coil and the added wafer on the bandswitch.
- An extension on the front apron provided a mounting point for the bandswitch control shaft, so the Brain is now completely self-contained mechanically as well as electrically.
- The Brain is now shock mounted, having rubber grommets at the four mounting screws. This is most likely the reason for incorporating the bandswitch control shaft on the subassembly.

**Restoration and Test**

Since the MB is a complete subassembly, I elected to restore it and test it separately from the main radio chassis. This proved to be very easy. All of the capacitors were good, which surprised me. They all measured over 50 Megohms leakage resistance, and the values were quite close to nominal. The resistors had drifted a bit, but I decided to test the unit with them as found rather than replacing them.

A regulated bench power supply provided B+, and its 6.3-volt AC output powered the tubes and pilot lights. The B+ was set to 265 volts, yielding oscillator plate and screen voltages of 250 and 235 volts respectively. These agree exactly with the values given in the service data for the 15K.

The local oscillator works fine on all bands, dying at about 40 MHz on Band D. I suspect a weak tube, but have not ruled out other possible causes. The tuning capacitor rotor contacts were dirty, and repeated application of De-Oxit contact cleaner did not completely cure the problem. This caused some dropouts as the dial was tuned across the band. This would clear up with use.

The oscillator was very stable on all bands, exhibiting almost no supply voltage sensitivity. Changing the B supply from 165 to 265 volts moved the A-band signal only 150 Hz (0.01 percent) at 1.455 MHz. The output amplitude at 165 volts decreased by 1.5 dB compared to the higher supply voltage. I did not evaluate the

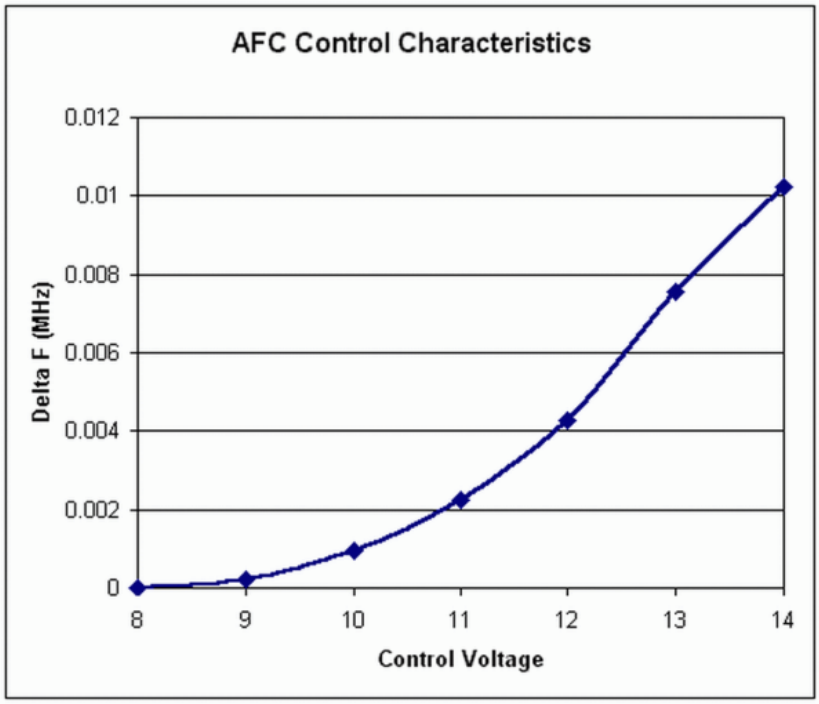



Chart of AFC control characteristics as measured.

oscillator for sensitivity to mechanical shock or temperature change. I don't believe either would be a concern in normal operation, considering the shock mounting arrangement.

**AFC Functional Test**

Of course the most interesting feature was the AFC circuit, and I elected to test it in a stand-alone mode by simulating the external supply and control voltages. The 15K service data is moot on this point since the circuit didn't exist in that radio. I built an external resistor network as shown on the schematic to duplicate the circuitry in the radio itself. The values are based on measurements in the set.

With some circuit analysis I determined that the screen voltage should be about 55 volts, and the cathode voltage about 15 volts. I didn't know what the plate voltage should be, so I used 200 volts as a safe value. Once the complete radio is operational these data may be revised. I built up the external resistances shown on the partial schematic in a box and connected the Magic Brain to it.

To my utter amazement, the circuit worked! The screen measured 54.7 volts, and the cathode 14.6 volts. I slewed the control voltage from 0 to +14 volts, stopping just below the positive bias point. This produced no frequency change up to 8 volts, then an approximately logarithmic change up 10 kHz maximum over the range from 8 to 14 volts, as shown in the chart. The measured current through the AFC transformer control winding varied from 11 microamps at 8 volts to 620 microamps at 14 volts. I tested the oscillator circuit for sensitivity to changes in control tube plate circuit voltage. Raising the voltage from 180 to 220 volts (20 percent) increased the frequency by 3.7 kHz (0.25 percent) at a center frequency of 1.455 MHz.

Needless to say I'm extremely pleased by the results. The 10-kHz AFC range is just right for the broadcast band. But it brings up an interesting question. Analysis of the circuit, and the observed performance, show *unidirectional* control, not symmetrical as would be expected. This remains to be investigated.

**Summary and Conclusions**

This installment has described the 23K Magic Brain, the self-contained subassembly that incorporates the receiver front-end circuitry and generates the IF signal. Inclusion of Automatic Frequency Control for the broadcast band may be the first attempt at this feature in the RCA product line.

The next installment of this series will describe the IF chain and associated circuitry, including the AFC discriminator which generates the control voltage for the AFC circuit in the Magic Brain.

**Contact and Further Information**

Additional material will be found at http://AntiqueTechService.com/Articles/. Please direct all comments, suggestions, and questions to the author: Leigh@AntiqueTechService.com.

**Endnotes**

1. C. Travis, "Automatic Frequency Control," *Proceedings of the IRE, Vol. 23,* October 1935, p. 1125.

2. "Technical Features of 1937 RCA Victor Receivers," *Service Lecture—Magic Voice Series—Fall 1936*, RCA Manufacturing Co., 1936.

*(To be continued.)* ■