ANTENNA TUNING UNIT

Type BPA-10

INSTALLATION—OPERATION—MAINTENANCE

INSTRUCTIONS

Printed in U. S. A.

IB-30168—3-21-46

TABLE OF CONTENTS

ILLUSTRATIONS

TECHNICAL SUMMARY

ELECTRICAL CHARACTERISTICS:

Operating Limits:

Carrier Frequency .... 540 kc to 1700 kc

Transmitting Power (maximum) .... 10 kw

Antenna Resistance:

Output 5 kw or less .... 10 ohms to 1100 ohms

Output 10 kw or less .... 20 ohms to 1100 ohms

Line Impedance .... 50 ohms to 350 ohms

Antenna Reactance .... +j500 to −j500 ohms

Can be extended in a positive direction by the addition of a series capacitor; and in a negative direction if operating from a line of lower impedance than the antenna resistance.

Monitoring Rectifier:

Output Impedance .... to operate into 20,000-ohm bridging load

Output Level (program level—including bridging loss):

At 5-10-kw output .... — 9 vu

At 1-kw output .... —15 vu

Rectified current .... 75 ma d.c. maximum into a maximum of 1000 ohms

Frequency Characteristic .... substantially flat to 10,000 cycles

Power Supply .... 230 volts, 60 cycles

TUBE COMPLEMENT:

Rectifier .... one RCA-5V4G

MECHANICAL SPECIFICATIONS:

Dimensions:

Height .... 44 inches

Width .... 34 inches

Depth .... 23 inches

Weight (net) .... 330 pounds

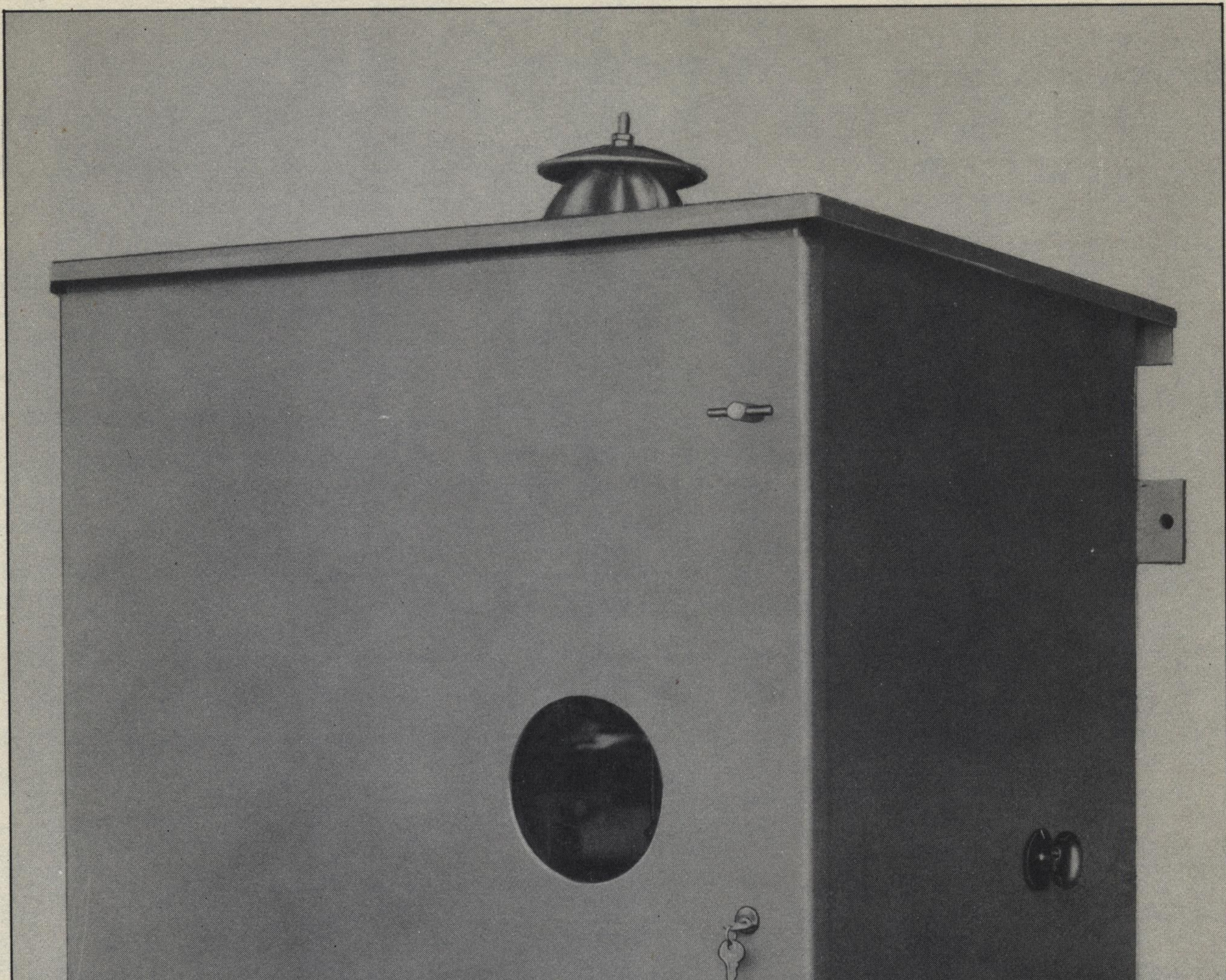

Figure 1—Type BPA-10 Antenna Tuning Unit (Exterior View)

Description

Purpose

The Type BPA-10 Antenna Tuning Equipment serves the double purpose of matching antennas of widely divergent characteristics to either concentric or open-wire transmission lines and of suppressing carrier harmonics on transmitters up to ten kilowatts (kw) output.

Construction

All parts of this equipment are enclosed in a weather-proof metal housing equipped at the front with a door affording ready access to the interior. This door is provided with a lock. The antenna ammeter may be read through a circular window in the door and is protected from lightning surges by a short-circuiting switch, which is operated by means of a knob extending through the side of the housing. A monitoring rectifier unit *(MI-7488-A) is contained within the housing to furnish, if desired, audio-frequency voltage for program monitoring and rectified carrier current for remote antenna current indication.

*MI-28902-B only. MI-28902-A does not contain monitoring rectifier.

Circuit

The circuit of this antenna tuning unit essentially consists of a single T-section low-pass filter which reduces the number of elements to a minimum. Referring to the schematic diagram, Figure 5, there will be observed two series inductors (L1, L2) which are employed to adjust independently the respective terminating impedances of the transmission line and the antenna circuit. The capacitive shunt leg, which is common to the two branches, is fixed at a value determined by the operating frequency of the station.

Signal energy for operation of the monitoring rectifier is obtained from a tuned pickup coil (L3) which is coupled to the antenna loading inductor (L2). This energy is rectified in a full-wave circuit using an 5V4G tube and the output is balanced to ground for excitation of a monitoring amplifier. Terminals also are provided for connection to a remote antenna ammeter and interlock relay located in the transmitter house. A 230-volt, 60-cycle power supply is required for energizing the rectifier filament transformer (T1).

Installation

Mounting

The unit is designed for mounting on a wooden platform or a steel angle cradle by means of the side flanges at the bottom of the housing. Rear mounting strips also are provided to permit mounting the unit on two upright posts. Dimensions are given in the outline drawing, Figure 6.

Care should be taken at installation to select a position where the antenna lead will be as short as possible. It is also important to insure adequate grounding by connecting the housing to the ground system through a heavy conductor or a copper bus.

R-F Connections

The antenna lead-in post is located on the top of the unit, and provision is made for mounting a similar post (MI-19413-1 bowl insulator) on the left-hand side of the housing in case an open-wire line is used. Concentric line when employed should be brought in through a hole in the bottom of the cabinet and connection made to the upper terminal of coil L1. In cases where a remote antenna ammeter is not used, terminals No. 5 and No. 8 should be connected together by means of a jumper.

Remote Metering and Audio Monitoring

An a-c supply of 230 volts, 60 cycles will be required to operate the rectifying equipment for remote metering. The associated filament transformer is tapped for operation at 190, 210, 230 or 250 volts and should be adjusted to the tap nearest the existing line voltage. Terminals No. 2 and No. 3 are used for connection of the power supply.

Static Drain

No provision for static drain is made in this unit. If no conductive path to ground exists elsewhere, a static drain should be mounted across the antenna horn gap, or at some other suitable place.

Tower Lighting

No complication as to tower lighting is introduced as the shunt arm is open circuit to power frequencies.

Tuning

CAUTION — REMOVE THE TRANSMITTER PLATE VOLTAGE PRIOR TO EACH ADJUSTMENT OF THE ANTENNA AND TRANSMISSION-LINE CIRCUITS. FULL POWER SHOULD NOT BE APPLIED TO THE LINE BEFORE PROPER ADJUSTMENTS HAVE BEEN COMPLETED. DANGEROUS VOLTAGES MAY OCCUR THROUGH IMPROPER TERMINATION AND RESULT IN DAMAGE TO THE LINE AND EQUIPMENT.

General Conditions

Although the network used in this unit serves the two functions of impedance matching and antenna tuning concurrently, it is desirable to consider them separately.

For antenna tuning, the coil L2 can be used to series-resonate the reactive component of a capacitive antenna; or, if the antenna is inductive, the reactive component can be thought of as being absorbed into the antenna tuning coil. In either case, only the resistive portion of the antenna impedance is left, and the impedance matching function can be regarded as taking place between purely resistive impedances, inasmuch as the characteristic impedance of most lines is resistive.

Under these conditions, the values of reactance employed are determined by the values of the impedances to be matched, with the phase shift through the network as a parameter. Since the circuit is a section of a low-pass filter, the phase shift may be anywhere between zero and —180 degrees, making possible a wide range of reactance values. However, it is not advisable to work too close to the —180 degree (or cut-off) point of the section, or with such low values of phase shift that the second harmonic will not be sufficiently attenuated, hence a value near —90 degrees will usually be found most suitable. These statements will become clearer upon examination of the equations relating to the reactances of the arms of the network and the antenna and line impedances. Referring to Figure 2, which shows a simplified circuit diagram, the reactances are:

$$X_1 = -\frac{\sqrt{R_1 R_2}\left[1 - \frac{\sqrt{R_1}}{\sqrt{R_2}}\cos\beta\right]}{\sin\beta}$$

$$X_2 = -\frac{\sqrt{R_1 R_2}\left[1 - \frac{\sqrt{R_2}}{\sqrt{R_1}}\cos\beta\right]}{\sin\beta}$$

$$X_3 = +\frac{\sqrt{R_1 R_2}}{\sin\beta} \qquad (1)$$

where: R_1 = Line impedance
R_2 = Antenna resistance
β = Phase shift through network

It will be appreciated that choice of β near zero or —180 degrees leads to large values of reactance in all arms since sin β approaches zero for these values. On the other hand, if we take $\beta = -90$ degrees, these equations simplify to:

$$X_1 = +\sqrt{R_1 R_2} \qquad (2)$$

$$X_2 = +\sqrt{R_1 R_2}$$

$$X_3 = -\sqrt{R_1 R_2}$$

If this leads to inconvenient sizes of X_1, X_2, or X_3, a new value of β can be chosen to yield better values for the desired reactance.

Tuning Procedure with R-F Bridge

The use of a radio-frequency bridge is recommended to insure accurate tuning adjustment and the application of this instrument will be assumed during the ensuing treatment of the tuning procedure. In cases where a bridge is not available, measurements can be made by a substitution method, also to be described.

To determine the values of inductance and capacitance to be used for proper line matching and antenna tuning, it is essential to know the impedance of the antenna at the operating frequency. For purposes of comparison, the resistances and reactances for various heights of typical insulated towers of the guyed-mast and self-supporting types are shown in Table I.

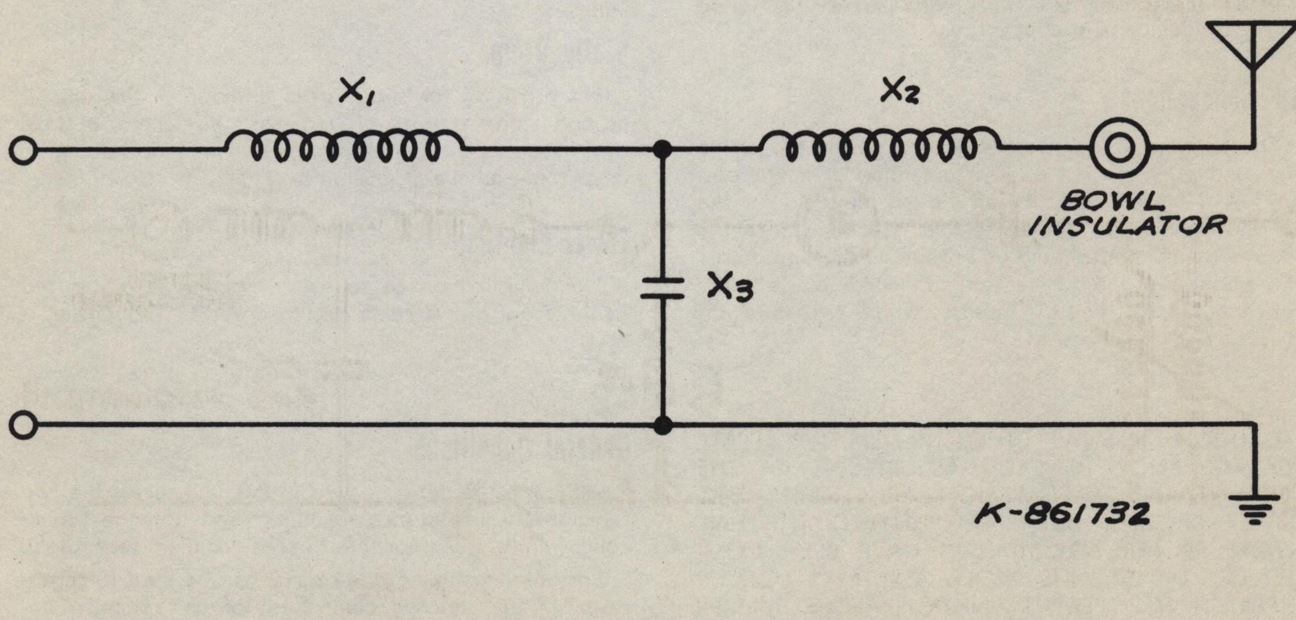

Figure 2—Simplified Circuit Diagram

TABLE I

Antenna Height * in Electrical Degrees	Self-Supporting Type		Guyed-Mast Type	
G	R	jX	R	jX
50	7	−j100	8	−j220
60	9	−j 70	13	−j170
70	14	−j 25	19	−j 75
80	20	+j 11	28	−j 28
90	40	+j 35	36	+j 0
100	60	+j 80	80	+j140
110	90	+j 90	140	+j320
120	175	+j 80	220	+j500
130	190	+j 15	370	+j600
140	165	−j 70	660	+j480
150	130	−j 85	1100	+j 0
160	82	−j 55	550	−j250
170	60	−j 25	280	−j450
180	40	−j 5	180	−j500
190	28	+j 25	120	−j430
200	23	+j 50	80	−j400

* Height in electrical degrees = Height in feet × frequency in kilocycles × 1.016 × 10^{-6} × 360.

Substitution of the resistance components of line and antenna impedances in the equations (1) gives the values of X_1, X_2 and X_3 necessary for the impedance matching function. Examination of the reactive components indicates the reactance necessary for tuning. For example, suppose we have a 60-ohm line and a 120-degree antenna with 175 ohms of resistance and +j80 ohms of reactance. Substitution of the values 60 and 175 ohms in equations (2) gives the value of 102.5 ohms for X_1, X_2 and X_3.

To tune out the antenna reactance in this case, it is only necessary to assume that this reactance is a part of the required value of X_2. Subtracting the 80 ohms of antenna reactance from 102.5 ohms leaves 22.5 ohms to be obtained in the coil L2. When the other arms of the network have been adjusted to the proper value of the 102.5 ohms, there will exist a condition of impedance match between the line and the antenna resistance and the antenna reactance will have been removed as a cause of loss.

In making these adjustments, the line should be disconnected and the impedance bridge connected across the input terminals to determine when the desired value of 60 ohms has been obtained. When measurements show that the input impedance of the tuner with the antenna connected is 60 ohms resistive, the line may be reconnected for a final check before turning on full power.

Calculations of the current in the capacitive branch are made to insure that the rating of the capacitor is not exceeded. Proper capacitors are supplied on the basis of information received with the order.

To enable intelligent estimates to be made of the inductances obtained by tapping down on coils L1 and L2, it should be mentioned that their maximum inductance is 120 microhenries.

Tuning Procedure Without R-F Bridge

If no impedance bridge is available, a simple substitution method may be used to determine when a proper adjustment has been obtained. To do this, it is necessary to arrange to switch the line from the tuner to a resistance equal to the line impedance, noting the change in line current accompanying the switching. When no change occurs, the tuner is in proper adjustment. Because it is not desirable to apply full power to the test resistor, which will usually have a rating of a relatively few watts, connection should be made to a low power stage in the transmitter during this adjustment. To make the adjustment simple, a coupling circuit and a series tuning capacitor can be used, as shown in Figure 3.

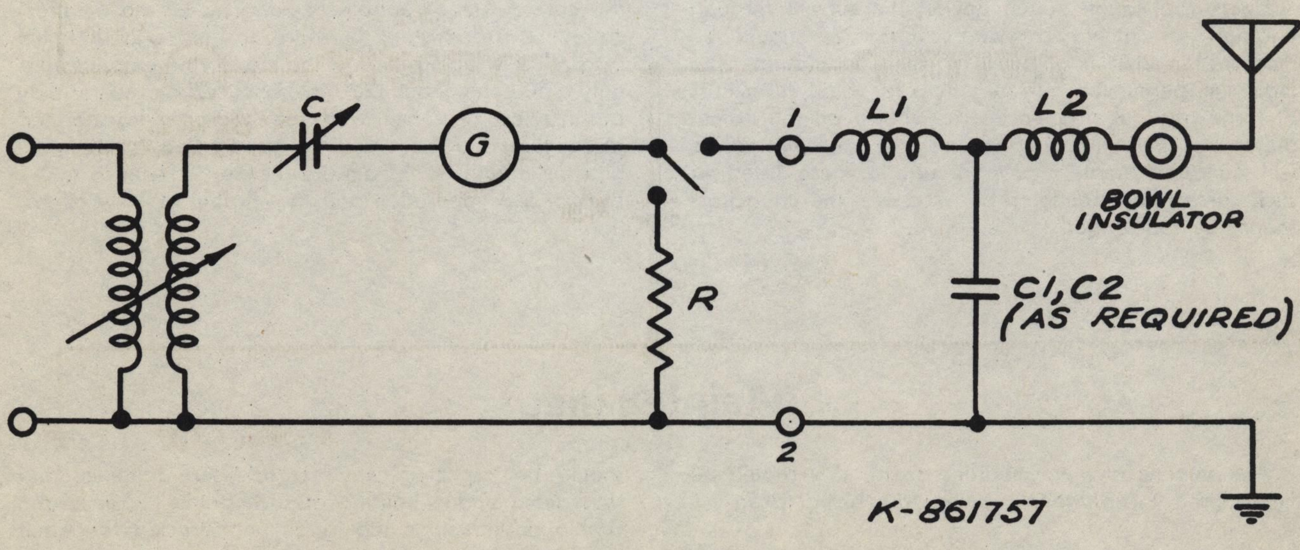

Figure 3—Coupling Circuit and Tuning Unit

With the switch in the resistor position, capacitor C can be tuned for a maximum current reading in meter G. Then, on switching to the tuner input, the direction in which capacitor C must be turned to increase the current again to a maximum indicates the sign of the reactance in the antenna circuit. If the capacitance must be increased, the load is capacitively reactive; if the capacitance must be decreased, the load is inductively reactive; if no change is necessary, the load is resistive. Similarly, if the current reading at resonance is greater than before, the load resistance is less than Z_0; if that reading is less than before, the load resistance is greater than Z_0; if there is no change, the load resistance is equal to Z_0.

CAUTION—Remove unused jumpers.

This method may be used to determine unknown resistances simply by using a calibrated test resistor; likewise, unknown reactance values may be determined by using a calibrated condenser at C.

Final Check

Upon completing the tuning procedure as outlined in the preceding paragraphs, the adjustments should be checked before full power is applied to the line and antenna. The recommended method of check is described in the following paragraph.

With the measuring equipment disconnected from the tuning unit, attach the transmission line and insert a low-range thermal milliammeter in the ungrounded side at each end of the line. Apply sufficient power to provide a readable deflection on each meter and note the current values. These values should agree within 15 per cent when the tuning adjustment has been correctly performed. Under such conditions, full power may be applied to the line after removing the millammeters.

Upon application of full power, the current through each of the tuning capacitors (C1, C2) should be measured under conditions of full modulation. The maximum permissible current values for these capacitors at three nominal frequencies are shown on the nameplates. At intervening frequencies, the maximum values will be approximately proportional to those listed. If such currents are found to be excessive, the capacitors should be rearranged in the circuit.

Remote Metering Equipment

The antenna tuning unit embodies the necessary equipment to enable the installation of a remote meter for measuring antenna current and also furnishes audio-frequency energy for operation of a monitoring amplifier. The method of remote antenna-current indication as outlined herein has been approved by the Federal Communications Commission.

The remote meter should require 25 to 50 ma direct current for full-scale deflection and should have a scale corresponding to that of the antenna ammeter (M1). It should be equipped with a shunt adjusted so that the deflections of both meters are identical. In most cases, a 5-ohm variable shunt will be satisfactory for this purpose.

As shown by the schematic diagram (Figure 5), terminals No. 5 and No. 8 are used for connection to the remote meter and transmitter interlock relay. Sufficient output for proper deflection of the remote meter may be obtained by adjusting the coupling between the antenna loading inductor (L2) and the monitoring pick-up coil (L3) and by tuning the latter to the carrier frequency. A wide tuning range is afforded by the six taps on the pick-up coil and by the use of two capacitors (C4, C5) which may be employed singly, in series, or in parallel. Jumpers are provided to facilitate interconnection of these capacitors.

Maximum output will be secured as the pick-up coil is tuned to resonance. It is not advisable, however, to approach resonance too closely since the increasing selectivity of this circuit will seriously impair the audio-frequency response characteristic. At resonance, the response at 10,000 cycles will be down approximately 4 db. Under no conditions should the current through the series resistors (R1, R4) be allowed to exceed 75 ma d.c.

When an audio monitor is to be used, an output level of approximately +17 dbm is available from this source, the circuit of which is balanced to ground and may be used to feed a 500-ohm load. The load in this case must be capable of handling 25 ma of direct current. It is desirable, therefore, to feed a 20,000-ohm or greater bridging load. If the monitoring amplifier has only a 500-ohm input, a 20,000-ohm carbon resistor may be inserted in series with the 500-ohm transformer. Under this condition, the direct-current flow is negligible and the output level from the rectifier is reduced to —1 dbm at 5-kw operation and to —7 dbm at 1-kw operation.

Maintenance

The antenna ammeter shorting switch (S1) should be kept closed except when readings are being taken.

All connections, especially the coil connector clips, should be inspected regularly to insure tightness and thus avoid undue heating at such points. Screens and ventilation openings should be unobstructed to permit free circulation of air.

PARTS LIST

Symbol No.	Description	Stock No.	Dwg. No.	Symbol No.	Description	Stock No.	Dwg. No.
A1	Rectifier, monitor		K-891875	M1	Meter (frequency determined)	See MI-19465	
C1	Capacitor (frequency determined)	See MI-7444-C		R1	Resistor, 6.4 K, 90 W	17899	K-890162-2
				R2	Resistor, 10 K, 90 W	17900	K-890162-3
C2	Capacitor (frequency determined)	See MI-7444-C		R3, R5	Resistor, 250 ohms, 10 W	17901	K-891887-2
				R4	Resistor, 125 ohms, 10 W	17902	K-891887-1
C4	Capacitor, 300 mmf	69860	P-32221-532				
C5	Capacitor, 200 mmf	69864	P-32220-683	S1	Switch, 250 V., 30 amp.	90038	K-890957-1
C6	Capacitor, 1000 mmf	42335	P-722009-547				
				T1	Transformer	17897	K-900433-501
L1, L2	Coil		T-611579-501				
L3	Coil	17898	M-415903	X1	Socket, vacuum tube, octal	18007	K-844041-501

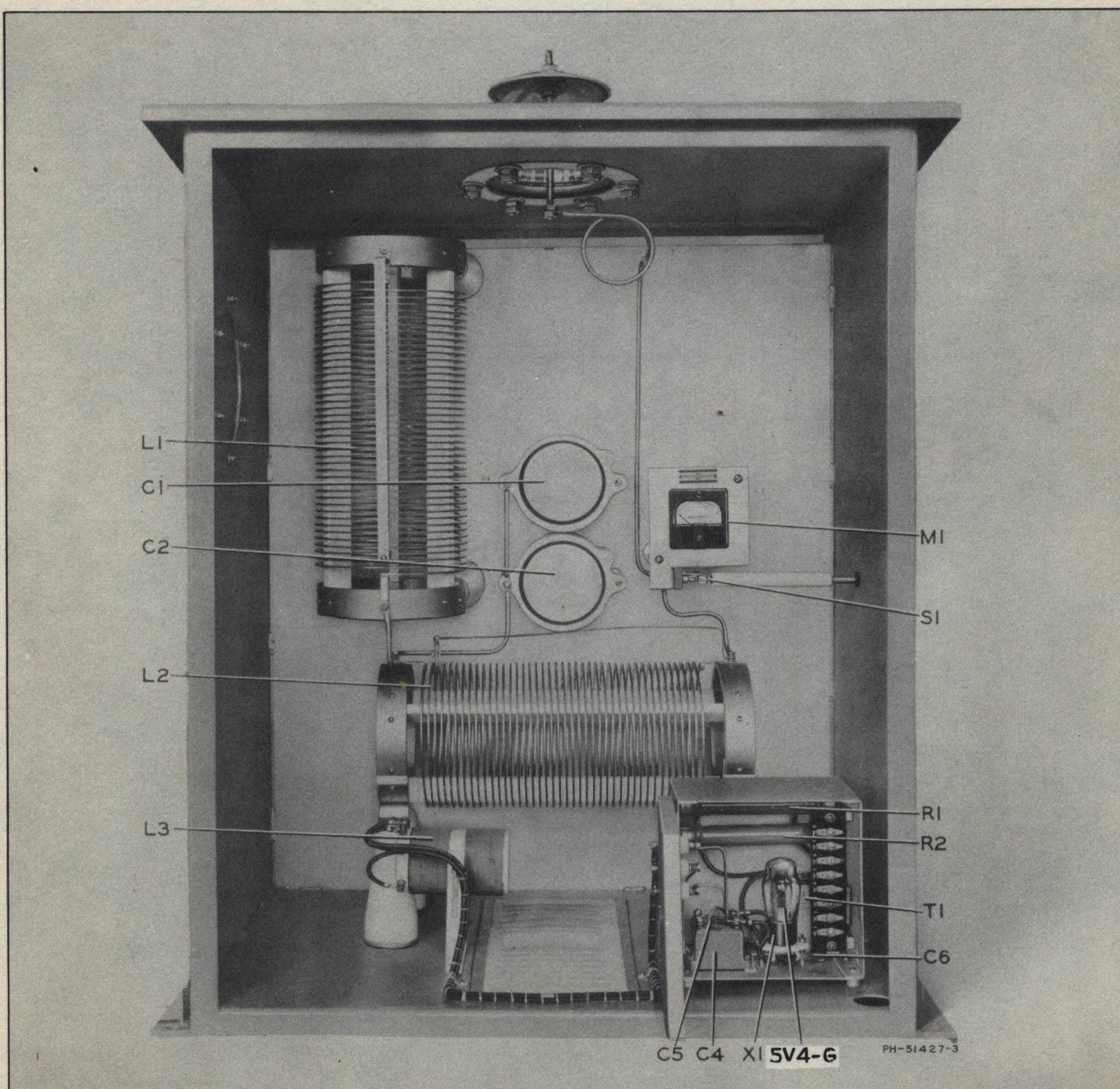

Figure 4—Antenna Tuning Unit (Interior View)

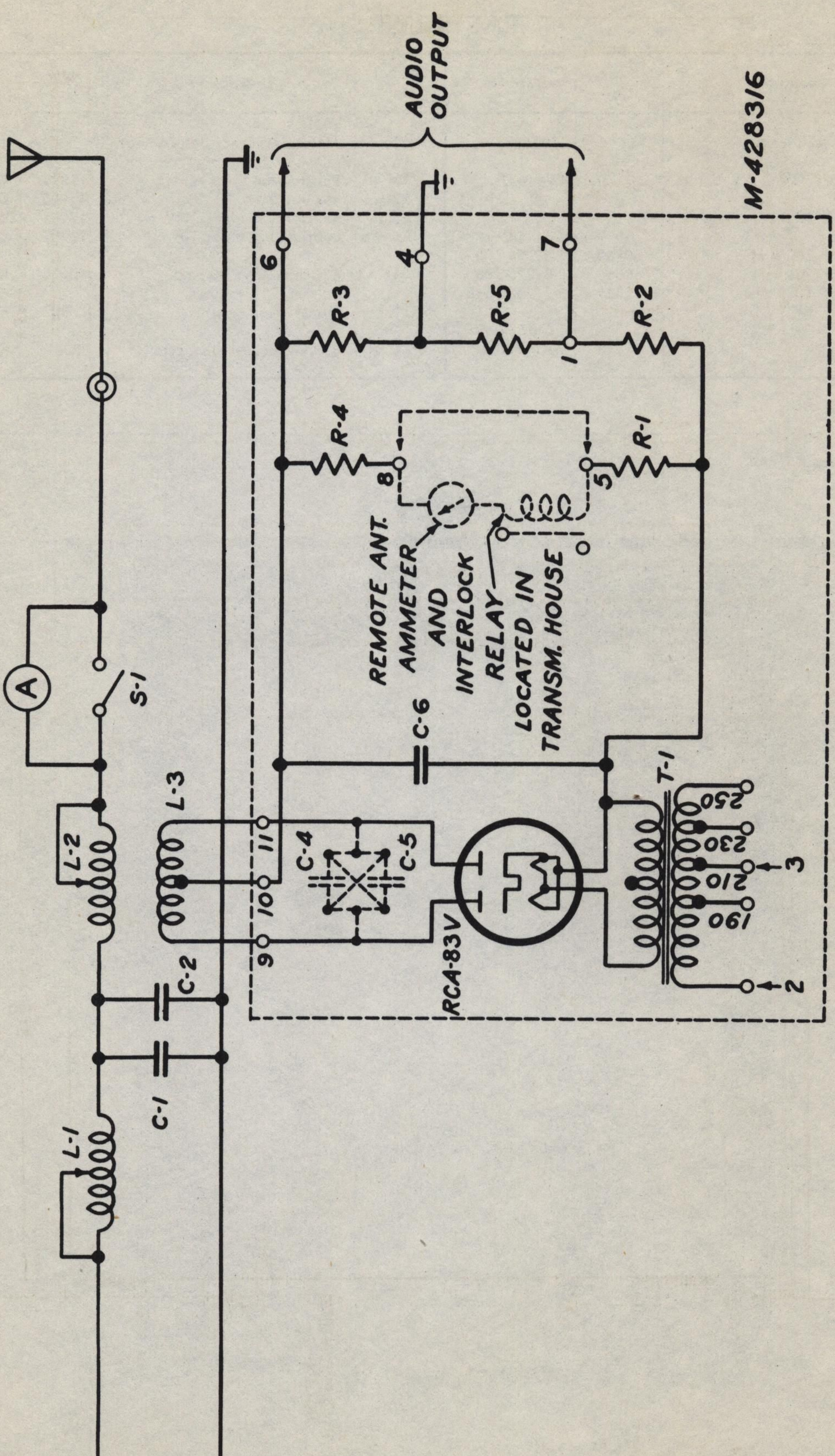

Figure 5—Antenna Tuning Unit Schematic Diagram

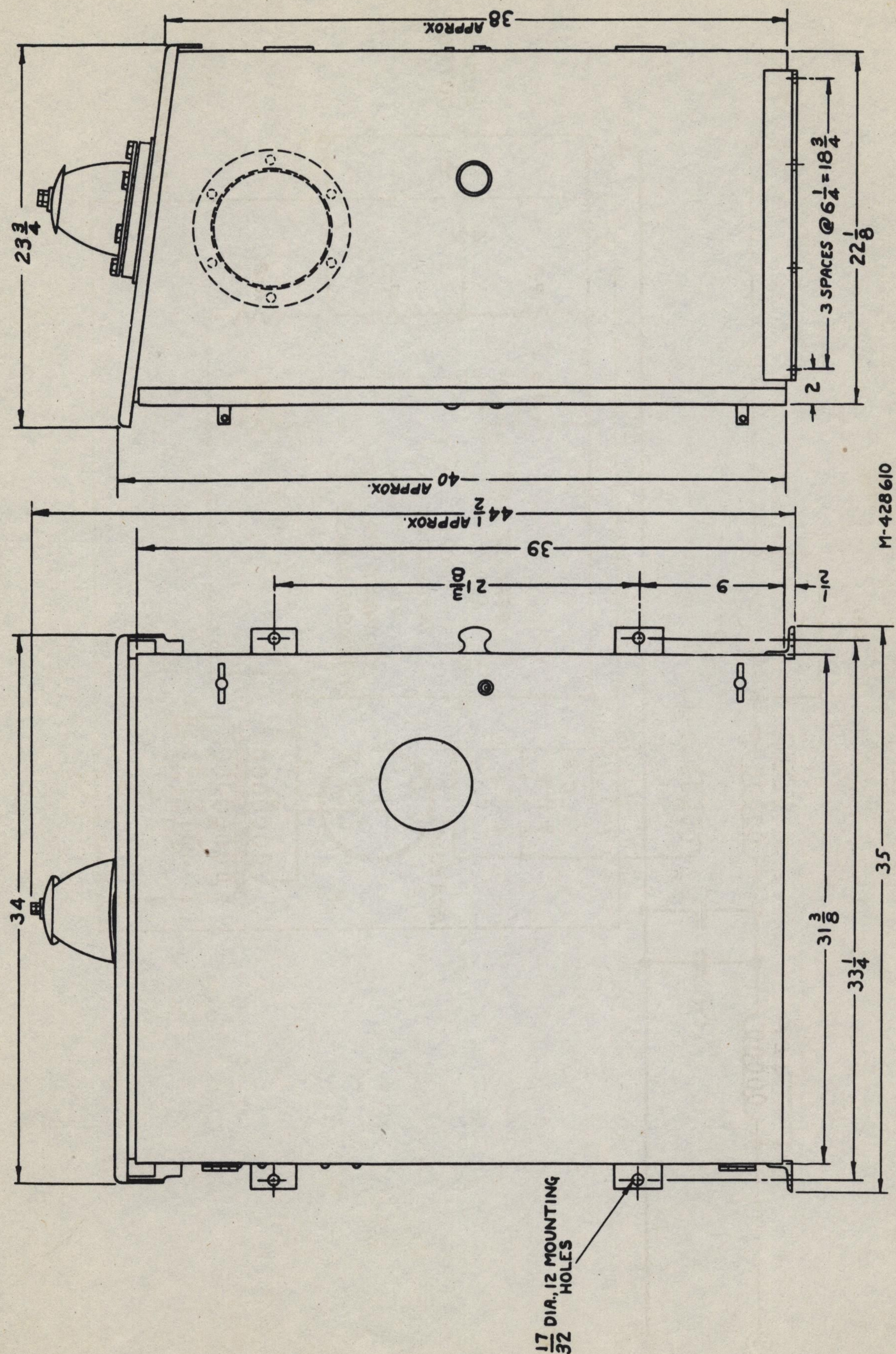

Figure 6—Antenna Tuning Unit Outline