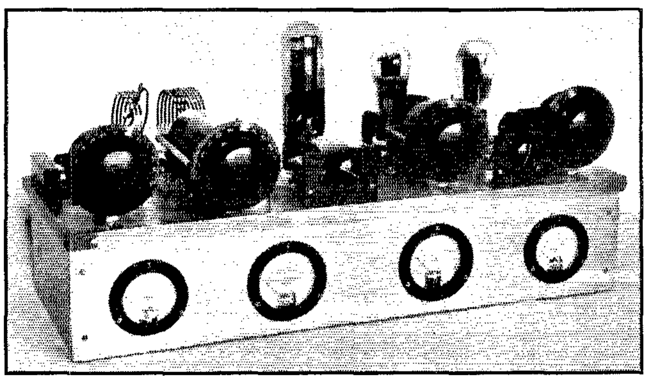
Modernizing the Three-Tube Transmitter

An Improved Version of One of QST's Most Popular Designs

By George Grammer, Assistant Technical Editor

TWO years is a long time in amateur radio, especially when new apparatus and new circuits follow on one another's heels at the dizzy pace attained in the past two twelvemonths. Yet, despite new tubes and special circuits, a few fundamentals have carried through unchanged. The basic design of the three-tube three-band transmitter first described in November, 1931, *QST*,[1] is a case in point; notwithstanding the fact that it antedates most of the new tubes, Class-B audio and single-signal reception—all of them so familiar now that they seem like old-timers—a recent overhauling of the old set indicated that few changes need be made to bring it up-to-date while still retaining the features which made it popular—good power output and efficient operation on three bands, economy of apparatus, and above all, simplicity and convenience in changing bands. The changes now to be suggested will not, perhaps, greatly increase the output of the transmitter; they will, however, increase the ease of operation and give the crystal a little less work to do. Both these features represent worth-while improvements.



THE REVAMPED THREE-TUBE TRANSMITTER

Electrical changes include the installation of a pentode oscillator and a new tank circuit in the final stage. The meter panel, also a recent addition, is convenient but not necessary to the operation of the set.

The changes recommended are quite simple—substitution of a 47 for the 10 originally used in the crystal oscillator circuit, and revamping the final amplifier tank circuit to use split-stator condenser. Both these necessitate a few minor modifications in the wiring, and a new set of amplifier tank coils may be required. We shall not go into the reasons for either of these substitutions here; the pentode oscillator was covered in February, 1932, *QST*,[2] and the benefits to be derived from rearranging the amplifier tank circuit were discussed in January of this year.[3] The transmitter also has been dressed up a bit to include a few meters, but it's still the same set.

OSCILLATOR CHANGES

The use of the 47 in the crystal oscillator circuit makes it necessary to install a 5-prong tube socket. The old bakelite sockets in vogue at the time the set was built are now unavailable, so one of the newer Isolantite ones was used. For the sake of appearance a similar socket was also installed in the doubler stage. Because of the change in sockets, blocking condensers of the type that can be fastened directly to the baseboard were substituted for the old ones at C_3 and C_4, Fig. 1. At the same time the capacity of the oscillator plate blocking condenser, C_3, was changed to 100 $\mu\mu$fd., chiefly because one of that size happened to be on hand, although the use of a low-capacity condenser in the pentode circuit is often advisable. The below-deck changes to the oscillator circuit include the addition of the screen dropping resistor R_4 and by-pass condenser C_{11}. The gridleak, R_1, was reduced from 20,000 to 5000 ohms, the latter value being more suitable for the 47, and a choke put in series with it to do away with r.f. losses in the resistor. Simultaneously, new chokes of the midget honeycomb type (National Type 100) were installed in both the oscillator and doubler plate circuits to replace the home-made chokes previously used. This step is largely for the benefit of those who may now be tempted to build the set for the first time, since the discarded chokes sometimes were ineffective in preventing feedback when the oscillator and doubler were operated from the same power supply, unless by-passed at the

[1] "More About Economical Crystal Control," November, 1931, *QST*.
[2] "Which Tube for the Crystal Oscillator?", February, 1932, *QST*.
[3] "Improving the Performance of the Neutralized Power Amplifier," January, 1934, *QST*.

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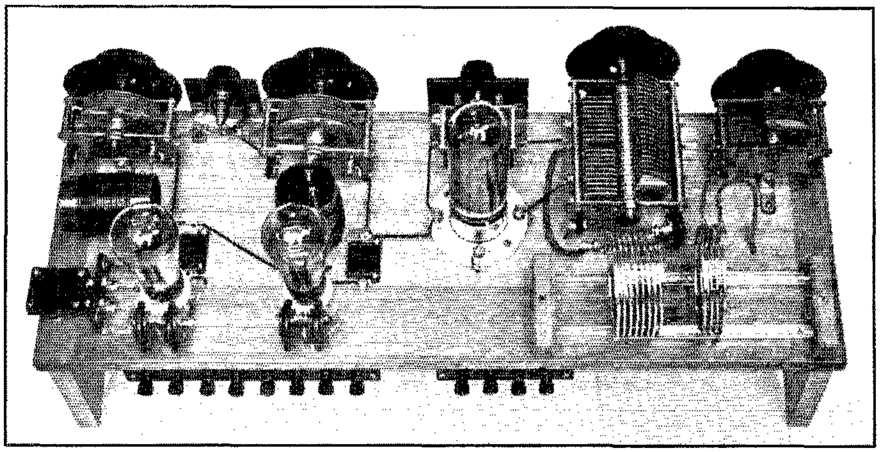
power-supply ends. This effect, mentioned in the original article,[1] happily is not present with the honeycomb chokes. As inspection of the bottom-view photograph will show, the chokes are mounted on some of the midget standoffs now being made by a number of manufacturers.



A TOP VIEW SHOWING THE NEW TANK CONDENSER AND COILS
Otherwise the layout is unchanged, the oscillator being at the left, buffer-doubler to its right, followed by the 203-A final amplifier.

Before testing out the pentode oscillator it was expected that maximum excitation would be secured with the doubler grid tapped down on the coil L_1. Actually, however, a trial of the setup showed that maximum excitation was secured with the doubler grid tap taken directly from the end of the coil, so it was left that way. The 47 is a great deal superior to the 10 formerly used because it is possible to use higher plate voltage on it with negligible crystal heating. This in turn means greater oscillator output. In this connection, to forestall repetitions of the suggestions that have been made many times by letter and in other magazines, perhaps we should say that we are fully aware of the fact that shifting the grid connections of the pentode around a bit will result in greater output. The catch is that doing it simply converts the pentode into a triode of sorts and the really good feature of the tube as a crystal oscillator—high output with little strain on the crystal—is thereby sacrificed. The only reason for using the pentode is to make life easier and longer for the crystal; otherwise one might as well use 350 volts on a 10 or 45, get plenty of output, and buy new crystals now and then.

Any of the power-pentode types, such as the 2A5 or 59, may be substituted for the 47, but it happens that the original layout of the set suits a filament-type tube. The fact that the 47 is ready for action almost immediately after the filament power is turned on often makes it preferable to the indirectly-heated types for transmitter work.

With 350 volts on the plate of the oscillator, the grid current in the buffer-doubler stage should be about 6 milliamperes, with no plate voltage on the doubler. Since this current flows through the 50,000-ohm resistor R_2, the bias on this stage is approximately 300 volts plus the battery bias, or nearly 400 volts in all. Under operating conditions, with the doubler exciting the final amplifier, the grid current drops to about 4 ma., representing a total bias of about 300 volts. Because of the high bias as well as the circuit used, the doubler efficiency is high. The plate and screen current to the 47 should total about 30 milliamperes under operating conditions.

THE FINAL AMPLIFIER

With the oscillator circuit taken care of, the scene shifts to the final amplifier. The buffer-doubler circuit may be left just as it was originally, except for the choke substitution mentioned above.

A split-stator condenser at C_7 replaces the original single-section tank condenser, a change particularly beneficial in this set from the convenience standpoint because with proper handling the amplifier will stay neutralized on all three bands with a single setting of the neutralizing condenser. A secondary, but nonetheless real, benefit is that the input capacity of the final stage is reduced with this type of circuit[3] so that it is no longer necessary to compromise on the position of the excitation tap on the doubler tank coil, L_2. It works best right on the "hot" end of the coil. The revised circuit is given in Fig. 1. It will be noted that there is no longer a tap on the final amplifier tank coil, nor is there any blocking or by-pass condenser in the plate circuit. Eliminating the tap makes coil changing a quite simple matter. No blocking condenser

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will be needed if the tank condenser has sufficient plate spacing to hold the d.c. plate voltage plus the r.f. plate voltage. The particular condenser used, a Cardwell Type 157-B, has not yet arced over with voltages up to 1500 on the plate of the 203-A.

Some consideration was given to the use of parallel vs. series feed in the amplifier plate circuit, the former being preferred from the standpoint of convenience, since a centertap on the tank coil L_3 would be needed with series feed. Since the choke is usually the weak spot in parallel-fed circuits, tests were carried out to determine whether or not parallel feed would result in a loss of efficiency. These did not progress beyond trying the choke originally used in the old circuit, however, because the output and efficiency turned out to be exactly the same with either parallel or series feed on all three bands. So parallel feed it is.

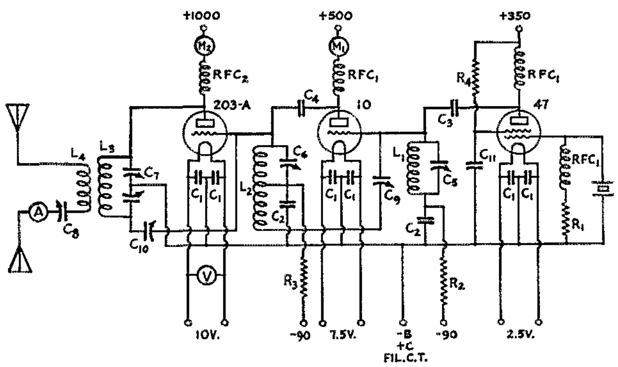

FIG. 1—MODERNIZED CIRCUIT OF THE THREE-TUBE TRANSMITTER

C_1—*0.004 μfd. (not critical).*
C_2—*0.002 μfd.*
C_3—*100 μμfd.*
C_4—*250 μμfd.*
C_5—*250-μμfd. variable.*
C_6—*350-μμfd. variable.*
C_7—*Split-stator transmitting condenser; total capacity, sections in series, 100 μμfd.*
C_8—*500-μμfd. variable.*
C_9—*50-μμfd. midget variable.*
C_{10}—*50-μμfd. transmitting variable (Cardwell 410-B).*
C_{11}—*0.002 μfd.*
L_1—*21 turns of No. 12 enamelled wire on 2-inch form, close-wound.*
L_2—*10 turns of No. 12 enamelled wire on 2-inch form, spaced slightly less than diameter of wire. Neutralizing winding consists of 6 turns, close-wound, ¼-inch from tank coil.*
L_3—*3.5 mc.: 20 turns of ⅛-inch copper tubing, coil diameter 3½ inches, spaced to make coil length 4 inches.*
7 mc.: 9 turns of ⅛-inch copper tubing, coil diameter 3½ inches, spaced to make coil length 1¾ inches.
14 mc.: 4 turns of ⅛-inch copper tubing, coil diameter 3½ inches, spaced to make coil length 1 inch.
L_4—*4 turns, construction similar to L_3.*
R_1—*5000 ohms, 2-watt rating.*
R_2—*50,000 ohms, 2-watt rating.*
R_3—*20,000 ohms, 10-watt rating.*
R_4—*50,000 ohms, 2-watt rating.*
M_1—*0-200 d.c. milliammeter.*
M_2—*0-300 d.c. milliammeter.*
V—*0-15 a.c. voltmeter.*
A—*0-2.5 r.f. ammeter.*

NEW COILS

A new set of tank coils to fit the amplifier tuning condenser had to be wound in this case because of the smaller capacity of the new condenser. Split-stator transmitting condensers of more than 100 μμfd. maximum capacity (sections in series) run to unreasonable lengths—unreasonable for this particular layout, that is—while the coils for the old circuit were based on a maximum condenser capacity of 220 μμfd. Because of the low capacity the 3.5-mc. coil has a large number of turns, so 1/8-inch tubing was secured in preference to the 3/16-inch size used for the old coils, and the coil diameter was increased to 3½ inches. Soft 1/8-inch tubing is easy to wind, but results in a "floppy" coil unless some method is used to strengthen it; accordingly a scheme suggested by W1FRQ was tried out and found to work splendidly. The turns, properly spaced, are cemented to celluloid strips after the fashion of the old low-loss receiving coils.

To strengthen coils by this method, first slide the loose turns on a form just large enough to distend them somewhat so they will set firmly. The form on which they were wound will do quite well if a "filler" is put on to occupy the space left by the natural springing of the coil after it is wound. The filler may be a piece of corrugated cardboard wound around the tube or form. Then three half-inch-wide celluloid strips, slightly longer than the finished coil is to be, should be slid under the turns longitudinally, spaced equidistantly around the circumference of the coil. The next step is to straighten out the turns so that they are evenly spaced, and then fill in the spaces between the turns along the celluloid strips with Duco Household Cement.

The coil should then be left alone for an hour or so until the cement sets; then another coat can be applied and similar celluloid strips cemented on top of the coil over the first ones. These top strips give the bracing a finished appearance, as well as increasing its strength. The cement should be given plenty of time to dry—overnight if possible—after which the coil may be removed from the form. The bracing will have ample strength to withstand ordinary usage—with 1/8-inch tubing it is possible, in fact, to bend the turns in relation to each other without loosening them from the strips.

The new coils have been fitted out with small G. R. plugs as terminals, mounted parallel to the coil axis. These plug into G. R. sockets which are soldered to pieces of heavy flexible cable connecting to the stationary plates of C_7. This flexible

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mounting, which is visible in the top-view photograph, is much easier to make than a fixed type of mounting, and permits the coil to rest properly in the glass-rod supports.

The antenna coil, the size of which will of course be determined by the antenna tuning system used, is of the same construction as the tank coils. The coupling coil shown is kept from tumbling over by short pieces of No. 14 wire soldered to two of the turns and hooked around the supporting glass rods. When the flexible leads are clipped on the coil, it will sit nicely in one position with no tendency to move out of place under ordinary jars and vibration. The antenna leads are brought out to a pair of stand-off insulators mounted underneath the baseboard at the rear edge.

Further additions to the set include plate milliammeters for the doubler and final amplifier stages, a filament voltmeter for the 203-A, and an antenna ammeter. They are all mounted on a 5-inch wide strip of plywood running the length of the baseboard. It is convenient to have the meters installed as shown because it is easy to see the effect of each adjustment. This method of mounting also keeps the meters at a reasonable distance from the r.f. circuits.

It should be noted that the amplifier grid resistor, R_3, is specified as 20,000 ohms. This is a compromise value, designed to insure plenty of bias so the tube will operate with fair efficiency when doubling to 14 mc. Slightly greater output can be secured on the 7- and 3.5-mc. bands by reducing this resistance to the old value of 5000 ohms, in which case it is desirable to insert more resistance or increase the fixed bias when working on 14 mc. For all-round work the use of the 20,000-ohm resistor is preferable.

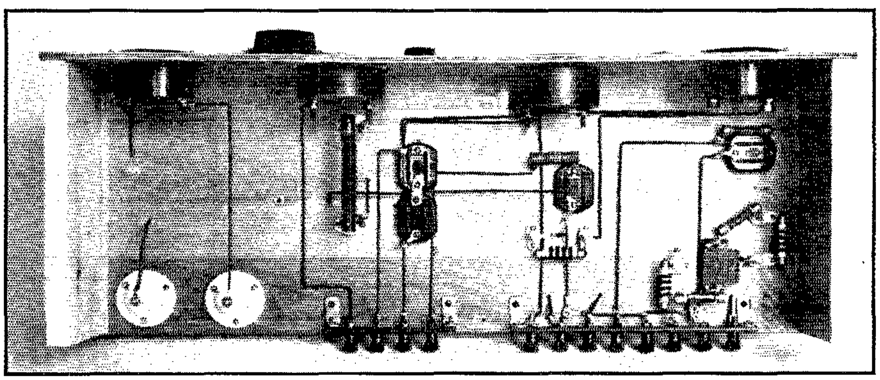
TUNING

Tuning and neutralizing are much the same as with the old layout, except that less of it is required when changing bands. We shall run through the procedure for the benefit of those who may be making their first acquaintance with the transmitter.

For 3.5 mc.: With plate voltage disconnected from 10 and 203-A, but with all filaments running and bias batteries connected, apply plate voltage to the oscillator and set C_5 for oscillation. This setting will be found near the minimum-capacity end of the scale. The plate current should be 25 to 30 milliamperes. Oscillation can be checked by the familiar dip in plate current or by a neon bulb or tuning lamp. Temporarily insert a milliammeter in buffer grid bias lead and readjust C_5 for maximum grid current.

With the oscillator working properly, tune C_6 to resonance (resonance will be found near the maximum-capacity end of the scale) and then find the setting of neutralizing condenser C_9 for which no indication of r.f. can be obtained in the buffer tank circuit when C_6 is swung through resonance. Adjustments to C_9 will affect the tuning of the oscillator tank circuit, so C_5 should be readjusted to keep the oscillator running each time the setting of C_9 is changed. When the 10 is properly neutralized C_6 may be swung through resonance without affecting the reading of the milliammeter in the grid circuit. After neutralizing, plate voltage should be applied and C_6 adjusted to resonance, indicated by minimum buffer plate current. The minimum current should be about 40 milliamperes if the filament of the 203-A is lighted.

The milliammeter should now be shifted to the



THE SUB-BASE CONNECTIONS

The buffer-doubler and final amplifier grid bias leads are now brought out to separate terminals so that grid current can be measured conveniently in each and also so that the bias on each stage can be individually adjusted. The screen dropping resistor and by-pass condenser for the 47 oscillator are near the terminal strip in the lower right-hand corner. The new r.f. chokes for the two low-power stages are mounted near the plates of the tubes. The choke for the final stage is mounted with its "hot" end away from the meter which it faces in the photograph. The two porcelain standoffs in the lower left corner are for the antenna or feeder terminals.

amplifier grid-bias lead and C_6 adjusted for maximum grid current, which should be between 15 and 20 milliamperes. Neutralize the amplifier, following the same procedure as in the case of the doubler; that is, find the setting of C_{10} which permits swinging C_7 through resonance without showing an indication of r.f. in the amplifier tank circuit (on a neon bulb or tuning lamp) and without causing a sharp change in the amplifier grid current. After neutralizing, the amplifier plate voltage may be connected and C_7 adjusted to resonance, again indicated by minimum plate current. Without the antenna load, minimum plate current should be about 20 milliamperes. With the antenna connected and tuned to resonance, the coupling between L_3 and L_4 should be adjusted to make the 203-A draw rated plate current—about 150 milliamperes. Both C_7 and C_8 should be readjusted to resonance each time a change is made in the coupling between L_3 and L_4.

For 7 mc.: Tune oscillator and buffer as before, then set doubler plate tank for second harmonic; resonance on the second harmonic will be found near the minimum-capacity end of the C_6 scale. Grid current to the final amplifier should be the same as before—15 to 20 milliamperes—and the doubler plate current should be about 50 milliamperes. If the final amplifier has been neutralized previously on 3.5 mc., it should be neutralized on 7 mc. as well, provided both tank coils (L_3) are designed so that resonance is reached with C_7 set at half capacity or more. If the amplifier has not been previously neutralized follow the procedure given above for 3.5 mc. Minimum amplifier plate current, when the plate voltage is applied after neutralizing has been checked, should be about 20 milliamperes without the antenna.

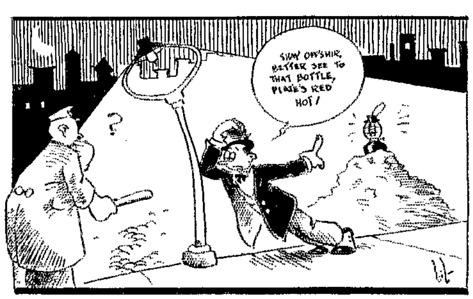
For 14 mc.: Tune oscillator and doubler as in 7-mc. operation. Amplifier should have been previously neutralized on 7 mc. With 14-mc. coil inserted at L_3, apply plate voltage and adjust C_7 to resonance as indicated by a minimum plate current of about 60 milliamperes. Do not change the setting of C_{10}.

AMPLIFIER TUNING NOTES

The permanence of neutralizing will depend considerably on the capacity balance in the two sections of C_7; if the two sections are not exactly identical the neutralizing may be slightly off when coils are changed. This is one reason for recommending that the amplifier tank coils be made so that C_7 will always be set at half capacity or more at resonance, because the capacity balance at the higher-capacity end of the condenser is likely to be more nearly exact. If the condenser is not perfectly balanced, tuning C_7 very far off resonance will cause the grid current to change slightly during the neutralizing process, if the grid milliammeter is being used as an indicator of neutralization. In such a case the aim should be to find the setting of C_{10} which results in practically constant grid current as C_7 is varied a little on each side of resonance, with a gradual—not jerky—change in the reading as the condenser is tuned farther away from the resonance point. It is also desirable that both sections of the condenser have the same capacity to ground or other objects; in other words, the condenser should not be mounted too close to other parts of the set.

In tuning both the buffer-doubler and amplifier stages, take care that the tank circuits are off resonance for the very minimum of time when the plate power is applied. Both tubes will take rather husky plate currents when the tank circuits are detuned, and such treatment is ruinous to a thoriated filament. It is a good idea to have a key in the filament center-tap of the stage being tuned so that the plate power can be applied momentarily until the correct settings have been determined. If the plate supply to the last stage is connected and the rectifier filaments are lighted, but with the plate transformer shut off, a current of the order of 10 to 20 milliamperes generally will flow in the plate circuit if C_7 is off resonance. At resonance this current will drop to zero if the tube is properly neutralized. This indication is useful in determining the resonance setting before plate voltage is applied. It is particularly helpful in finding the 14-mc. setting of C_7, in which case the 203-A is operating as a doubler and hence cannot be neutralized in the normal fashion.

In connection with tuning the antenna to the final amplifier, one point which many amateurs seem to overlook is that a change in coupling or antenna tuning will affect the setting of the amplifier tank condenser. The amplifier tank condenser always should be reset for minimum plate current as the last step in the antenna tuning process. When the coupling is correct, the minimum plate current will be approximately the rated plate current of the tube, although a higher minimum plate current can be drawn if the additional loading produces a corresponding increase in antenna current.



KEYING

From the standpoint of maximum stability,

(*Continued on page 86*)

Myrl Jones, of the Squinch Owl fame, brought out the interesting points of the army-amateur net. Many matters of importance were discussed under the leadership of fieldman Hebert at the open meeting.

Dr. H. O. Phillips, W4BZG, as toastmaster; talks by Major Van Nostrand of Atlanta; Mr. Perkins Prewett, chamber of commerce; Hebert and Reinartz, plus a fine entertainment from the broadcasting studios under the direction of John Connelly left nothing to be desired.

The convention closed with the distribution of prizes and a dance. Onward to Mobile, Alabama, in 1934, and thanks of the delegates to the committee for a great convention.

—*A. A. H.*

Modernizing the Three-Tube Transmitter

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center-tap keying in the final stage is recommended. For key-click elimination, however, it is more desirable to key in the center-tap of the buffer-doubler stage. This puts a variable load on the oscillator which may result in a slight change in frequency as the set is keyed, particularly if the oscillator is worked right at the critical setting of C_5. In such a case a slight detuning of C_5 on the high-frequency side will be beneficial. The 90-volt fixed bias specified for the final amplifier will be sufficient to cut off the plate current of that tube during keying spaces if the buffer-doubler tube is keyed.

A Universal Antenna Coupling System for Modern Transmitters

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NETWORK EFFICIENCY

Small diameter inductances have come very much in vogue in high frequency transmitters within the last year or so. Their use is well justified in multi-stage transmitters because they have very small external fields and eddy current losses in shielding, etc., are reduced to a minimum. A well-designed small coil will usually have a much higher Q than a large coil of heavy copper tubing. But it is very difficult to couple inductively to one of these small inductances because of their small field and because of mechanical difficulties and losses in the pick-up coil form. Repeated measurements have shown that the power in the antenna is usually increased from 20% to 30% when an impedance-matching network is substituted for a pick-up coil. This increase is accounted for by the inherent high-efficiency of the network and by the elimination of the losses which might have been introduced by the pick-up coil. Another reason for the better output is the fact that the antenna impedance can be precisely matched to the plate of the final amplifier tube, obtaining exactly the right relationship for optimum output with true resonance so that the voltage neither leads nor lags the cur-