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A Multi-Stage Crystal-Controlled Transmitter

By John M. Wells* and E. D. Tillyer**

The authors explain the construction and adjustment of a crystal controlled transmitter in which a thick crystal is used to control a low-power tube. Amplification is carried on through two low power stages operating on harmonics of the crystal oscillator. Such a transmitter gets around a lot of difficulties which may be experienced when using a relatively thin crystal, and amplifier stages operating at the crystal frequency.—Asst. Tech. Ed.

MUCH has been said and written lately on the subject of crystal controlled transmitters. It might not be amiss, however, to review briefly the distinct advantages of this form of transmission before going into details of the transmitter herein described.

In the first place when using crystal con-

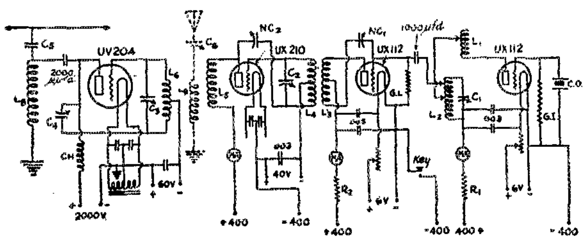

FIG. 1. THE THREE-STAGE POWER-AMPLIFIER CRYSTAL-CONTROLLED CIRCUIT

R1, R2 12,000 ohm Lavite units.
C.O. Piezo-electric crystal. About 320 meters for operation in 80-meter band; 160 meters for 40-meter operation. Using 2nd harmonics throughout.
L1 200 turns No. 24 D.C.C. wire on form 2¾ inches in diameter. Coil tapped at 5 places.
L2 13 turns No. 18 bare wire on form 3 inches in diameter, spaced 12 turns per inch, and tapped in the center and also 3 turns from one end.
L3 8 turns No. 26 D.S.C. wire wound over exact center of L4, Empire cloth insulation between. A tap is taken off at the center.
L4 8 turns No. 18 bare wire on 3 inch form, spaced 12 turns per inch with a tap at center.
L5 3 turns No. 26 D.S.C. wire wound over exact center of L6, Empire insulation, and tapped in center.
L6 7 turns No. 16 bare wire 3 inch form, spaced 6 turns to the inch and tapped in center.
L8, L9 Antenna inductance for antenna you use.
C1 G-R 500-μμfd.
C2 ditto 250-μμfd.
C3 Cardwell 450-μμfd. transmitting condenser.
C5 Small antenna coupling condenser for Hertzian antenna.
C6 Antenna series condenser, maximum of 100-μμfd.
NC1 Small neutralizing condenser.
NC2 Pyrex tube and brass rod condenser. Must stand oscillating voltage.
C4 Neutralizing condenser, maximum capacity around 70-μμfd. Use a G-R midget vernier immersed in automobile oil.
CH Radio frequency choke for parallel feed.
GI Varies with crystal. Usually around ¼ megohm.
GL About 1 megohm.

trol, the emitted frequency remains absolutely constant when the circuit is properly set up, irrespective of any changes in the antenna or tube circuits. The note in the receiver stays the same pitch, assuming of course, that the receiver stays constant. This means that the signals will be much more readable than is usually the case with the present day short-wave amateur transmitter.

In the second place, the use of crystal control is *very* helpful in obtaining a *splendid* note.[1] It is common for an amateur to find that, on short waves, his note becomes very rough and hard to read in spite of the fact that a direct current generator is being used, or a source of well rectified and filtered A. C. is on hand. Such has been the case at 1CAK. Using filtered motor generators the note has been reported as being anything from "fair A. C." to "raw A. C." at the receiving end. With the advent of crystal control the note has always been reported as "pure D. C." In fact many amateurs have asked if storage battery plate supply was being used. Since crystal control has been used at this station there has been no change in the previous plate supply.

The answer to this phenomenon is probably found in the fact that the cause of most poor notes on short waves is not necessarily

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1 Anyone who has heard NKF, 4BY, 2WC, 1AXA, 4FM, 4BK, 4XE as well as 1CAK will testify to the beautifulness of the crystal controlled note.—Asst. Tech. Ed.

in the poor plate supply but is due to *changes in frequency* in the transmitter. These changes take place for a number of reasons. Vibration of the building and the apparatus plays an important part. Any changes in the plate voltage tend to create variations in frequency. Probably irregular heating of the tube filaments by alternating current supply has an effect upon the constancy of the frequency. The use of crystal control obviates these effects. With crystal control and a moderately good source of plate supply, the note will be pure.

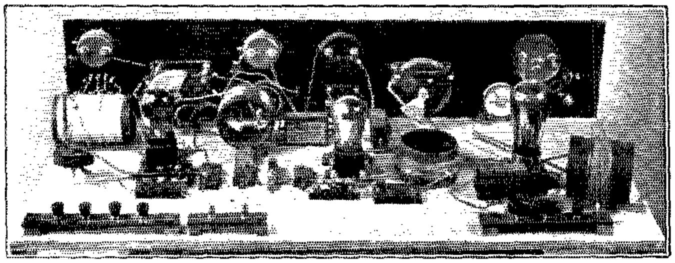


FIG. 2. CRYSTAL TUBE AT LEFT, 1st POWER AMPLIFIER STAGE IN CENTER AND SECOND AMPLIFIER AT RIGHT

There are several difficulties encountered when one constructs a crystal controlled transmitter. Some of these have been eliminated in the present set. First of all it is difficult to obtain satisfactory crystals for transmission purposes. They are expensive to buy and if one attempts to cut and grind them the work is difficult and the certainty of good crystals is not sure.[2] When one comes to crystals which oscillate in the 40-and 80-meter bands the problem becomes worse. Also at these frequencies the trouble of breakage becomes important. The trouble with thin crystals can be eliminated by the use of relatively thick ones even though the set is operated in the 80-40-and even 20-meter bands. For 40-and 20-meter work crystals oscillating around 160 meters are used, and for 80-meter transmission crystals having a wavelength near 320 meters are employed. As a matter of fact crystals oscillating around 320 meters or 240 meters can be used to work in the 40-meter band with slightly reduced outputs. Using a 320-meter crystal the writer has put 300 watts into a 250-watt tube on 40 meters.

2 In addition it is understood that quartz as found in the U. S. is not suitable for piezo-electric crystals. Most of the crystals we know of have been extracted from quartz coming from Brazil or Madagascar. The U. S. quartz is usually too full of flaws, cracks, bubbles, phantoms and twins.—Asst. Tech. Ed.

Another trouble experienced by a great many transmitter builders is that it is difficult to control a large tube with a small master oscillator. In the case of a crystal-controlled transmitter this can be done if the circuits are designed and set up with care. As will be shown later the transmitter used here is controlled by a 7½-watt oscillator which feeds a 250-watt power-amplifier with normal plate voltage but somewhat increased plate current in the oscillator tube.

Due to the fact that each power-amplifier tube (except the last one) is tuned to a harmonic of the preceding tube self-oscillation troubles are eliminated to a large extent. This makes the set unusually stable for a power-amplifier type of transmitter.

Contrary to expectations it was found to be quite simple to shift from one waveband to another, it merely being necessary to change the crystal and retune the circuits with the condensers. If content with slightly reduced output on 40 meters, the 320-meter crystal can be left in place and the shift from one band to another becomes even simpler. The only real difficulty in tuning is in the original set-up and proper adjustment of inductance and neutralizing condensers, which remain fixed (except in the last stage) when once properly tuned.

The Various Circuits

In order to set up a transmitter of this type there is only one way to proceed in order to get quick results. Take each tube circuit separately before starting to build the next one. Make the crystal oscillator work before you build any of the amplifiers,

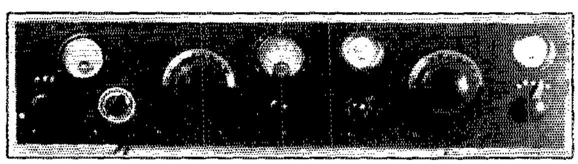


FIG. 3. FRONT VIEW OF SET SHOWN IN FIG 2. NOTE THAT ALL IMPORTANT CIRCUITS HAVE METERS

and after the C. O. is perking add a stage of amplification; after this is working put on another stage and so on. The photographs, diagrams and diagram explanations should be sufficient to give the constructional details. The complete circuit is shown in Fig. 1. The crystal oscillator is a UX-112 with 400-volt generator supplying plate voltage through a 12,000 ohm resistance. The second tube is also a UX-112 with the same plate voltage. The third tube uses a UX-210 with 400 volts direct to the plate. These three tubes are shown in Fig. 2. These three tubes in the circuit shown make a very excellent low-power crystal-controlled transmitter—one that anyone can afford to build. The unit comprising the circuit this far described should be the start of almost any kind of crystal-controlled transmitter. Any additional stages of amplification one desires can be added to this original unit. As a low power set this unit makes an excellent 'breaking into crystal transmission' layout. A 50-watter can be added later on, and can be substituted for the 204 power amplifier to be described later on. The antenna is coupled to the inductance L5, as shown in the dotted lines.

Going back to the circuit, the inductance L1 may have to be tuned with a variable shunt condenser in some cases. The grid leak may have to be varied, also, with some crystals. The crystal holder consists of two parallel brass plates between which the crystal is placed. About one quarter of a millimeter spacing is left between the crystal and the top plate. The original crystal holder was mounted to hang from a hook, suspended by rubber bands, but later this was found to be unnecessary.

The inductance L2 is tuned by condenser C1 to a harmonic of the crystal. When working in the 80-meter band, using a 320-meter crystal, this coil is tuned to 160 meters. For 40-meter transmission, with a 160-meter crystal, this coil is tuned to 80 meters. It can also be tuned to 80 meters when using a 240-meter crystal for 40-meter transmission. If a 320-meter crystal is used for 40-meter transmission we have found in practice that it is *much better* to use the following set-up: oscillator tube tuned to 320 meters, first amplifier tuned to 160 meters, second amplifier tuned to 80 meters and the final stage to 40 meters. As a crystal oscillator tube it was found that the UX-112 provided greater stability than 201-A when using full power.

The first amplifier also employs a UX-112 tube. For best results it has been found necessary to neutralize this tube in spite of the fact that only harmonics are being used. The grid leak value is not critical. Keying is done in the negative lead of the first amplifier. The fact that there is a high resistance in series with the plate of this tube makes keying relatively easy, and also helps to eliminate key clicks.

The second amplifier tube is a UX-210. The same 400-volt generator is used here with full voltage on the tube. The neutralizing condenser is a Pyrex tube with a brass rod inside and a copper sleeve outside. The condenser must stand considerable electrical strain. The inductance L4 is tuned by condenser C2 to some harmonic (usually the 2nd) of the preceding tube.

When using the 250-watt power amplifier in the last stage the power from the UX-210 is fed to the big tube by means of induct-

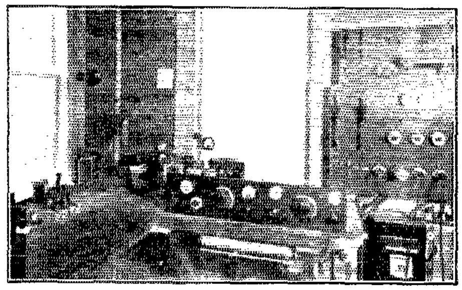


FIG. 4. COMPLETE TRANSMITTER AT 1CAK. THE 204 POWER AMPLIFIER STAGE IS IN THE REAR OF THE CRYSTAL-OSCILLATOR POWER-AMPLIFIER PANEL

ance L5. The antenna may be coupled to L5 through C6 and L9 for operation directly from the UX-210 stage. The last stage is the most difficult to put into operation. Great care must be used in the proper placing of the coils and the neutralizing condenser adustment is also very important.[3] This condenser is subjected to *very great* strains. The one used here consists of a General Radio midget vernier condenser immersed in a sponge glass full of automobile engine oil. If content with outputs of about 125 watts, the 250-watt amplifier stage can be tuned to a harmonic of the UX-210 by means of condenser C3 and inductance L6. If this is done the adjustments are much less critical. For full power, however, the last stage *must* be tuned to the wavelength of the 210 tube. With care power inputs to the 250-watter have been as high as 600 watts.

It might be interesting to outline the adjustment of a transmitter of this type for 40-meter operation when using a 160-meter crystal.[4] First make sure that the crystal tube is oscillating vigorously. This will be indicated by a sharp drop in plate current of this tube. Adjust L1 and the grid leak so that this drop will be as large as possible. Next tune the first amplifier to approximately 80 meters by means of condenser C1. Vary this condenser gradually until the plate current in this tube drops to a *minimum* with the condenser set to tune the coil to exactly half the wavelength of the crystal tube. This is with grid leak control of the grid bias.

Now tune the UX-210 circuit to approximately 40 meters by varying condenser C2. This condenser is also varied until the plate current in this tube is at a *maximum* with

3 We desire to point out again that complete shielding (when *not* operating on harmonics) is very desirable. More complete neutralization can be had, and the adjustments are much easier to make.—Asst. Tech. Ed.

4 See also *QST* for May, page 43.—Asst. Tech. Ed.

the condenser set to tune this circuit to 40 meters, or the 4th harmonic of the crystal. The grid bias in this stage is obtained from a C-battery.

Tune the 204 circuit in the same manner as the UX-210 was tuned. In this case, however, the antenna circuit should also be tuned at the same time as its tuning has some

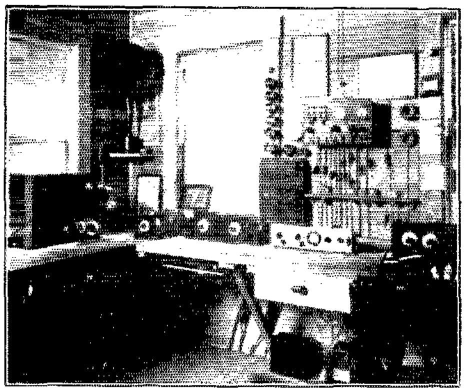


FIG. 5. A CORNER OF THE OPERATING ROOM AT 1CAK. TRANSMITTER NOT SHOWN BUT IS AT EXTREME RIGHT ON TABLE

effect on the tuning of C3. After all of these adjustments have been made, return each of the circuits by means of C1, C2, C3 and C5, beginning with C1, to get maximum antenna current.

It must be understood that before any of the preceding tuning can be done, the neutralizing condensers must be adjusted and the correct location of the taps on coil L2 must be found. Once set, these controls do not have to be changed, with the possible exception of the neutralizing condenser C4 which is very critical.

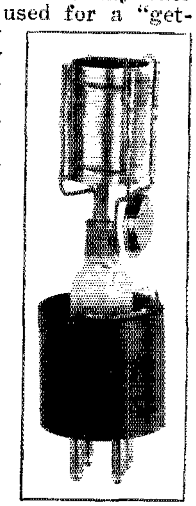
This set is still in the experimental stage. It has not been operated very many times. During the few hours it has been on the air, however, very enthusiastic comments have been received from all amateurs worked. Two French stations have been worked on 40 meters. Their reports were "R7-R8, pure D. C. very steady". bz2AB has been worked and GVC was communicated with when he was 1,500 miles north of Ottawa. Numerous U. S. and Canadian amateurs have been worked also.

The time spent in building and adjusting a crystal controlled transmitter of this type will repay itself many many times over for there is a great satisfaction in knowing what your note will be like at the receiving end, and in knowing that if the signal is strong enough to copy at all, the receiving operator will have no trouble in reading you.

The UX-874 Regulator Tube

WE present herewith photograph of the UX-874 regulator tube which was described in detail in the "new tubes" story appearing on page 33 of our May issue. The photographs were not available at that time.

As can be seen the tube contains a reinforced tubular plate supported from the glass stem by several wires. Attached to the lower rim of this plate is a sort of tiny frying pan which contains the chemical "getter" used to complete the exhaust, or perhaps some material which generates gas of a kind and amount suited to the requisite glow action of tube. In the samples that have been examined this frying pan has its lid firmly fastened except at the lower edge which is open somewhat so that gases could escape into the tube. At any rate phosphorus is seemingly used for a "getter" since a momentary phosphorus fire of tiny proportions occurred on the stem next the little pan when the glass of the tube was broken away. This accounts for the missing corner of the stem, which the little pinpoint of flame managed to crack off. Don't be alarmed, though—the fireworks were almost too small to be seen and probably would not happen in most tubes—besides which one isn't in the habit of breaking tubes into a powder keg.



Looking at the top view of the tube we can see the central stem inside of which is the other electrode—a wire of small diameter. This wire is surrounded by an insulating sleeve of some such material as lavite but projects a quarter inch or more. Almost touching this projection is a wire from the plate, leaving only a small gap across which the glow discharge starts—shifting immediately to the plate and with increasing loads covering larger areas of the plate as described in the writeup previously referred to.

—*R. S. K.*

Strays

3LD fell from the top of his 80 foot mast without even scratching himself. He says he was wearing his light fall coat.