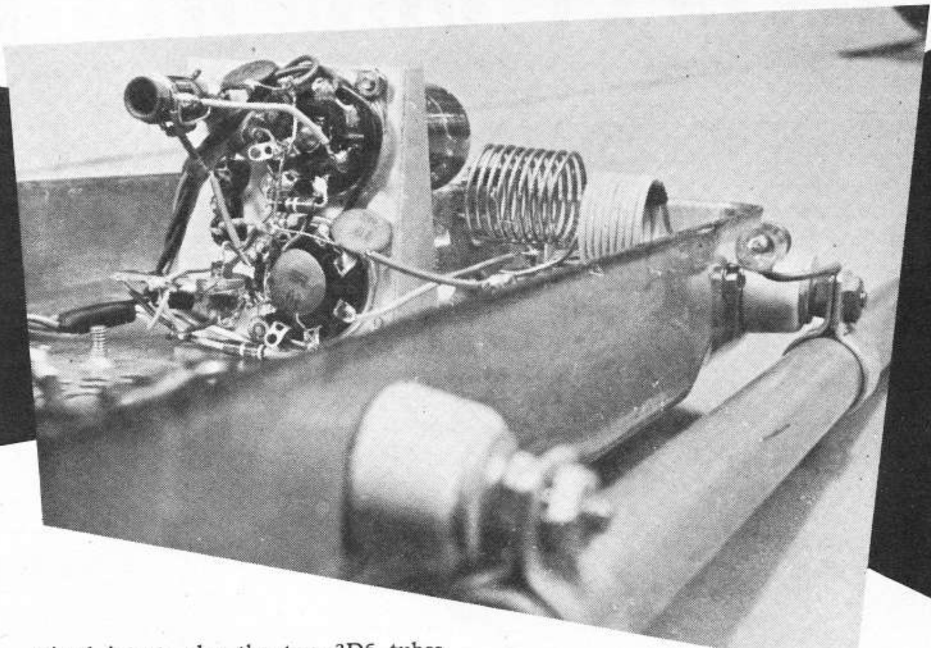
NUMAC-II

McEntee's famous Mac-II transmitter updated!



One of the most widely-copied transmitters ever presented to R/Cers, not only in the original form but in many other shapes and sizes—homebuilt and commercial—the Mac II is due for a face-lifting. Even if you don't have one of the originals, you can still use the circuit and info given here to make a potent and legal 27 mc R/C transmitter. The Numac-II circuit is a stable MOPA that treats the crystal gently, yet the one watt or more of RF that comes out will make plenty of splash in the ether, to control your models much farther than you can possibly see them.

■ There have been a tremendous number of Mac II transmitters built, many exact copies of the original (which appeared in the May '53 issue of *Air Trails*), others used the same circuit but different parts layout. Although the supply of PE 157 surplus power supplies upon which the set was based has long since dried up, batteries, vibrators, power transformers, 3D6 tubes, are still plentiful. A great many of the transmitters are still giving yeoman service and will doubtless continue to do so. However, the F.C.C. has stepped into the picture to an extent that we can't afford to ignore. The R/C rules which went into effect last September set up much closer frequency tolerances than the Mac II (and many other "high powered" 27¼ mc transmitters) can hold. The Mac II was based upon the premise of obtaining the maximum possible power from the simplest circuit—and it did just that. But even present users of this old workhorse will admit that nowhere near the 4½ watts or so that the Mac II operates at is really needed for reliable R/C operation.

You can still use the old-type transmitters until your F.C.C. license (if transmitter *and* license were obtained before Sept. 1958) runs out, of course. Some users will continue right to the bitter end; others will want to update their transmitters. For the latter, and for those whose licenses expire soon—and for all new builders who want a potent up-to-date transmitter—we dedicate this rig.

Our aim in the changeover was to use as many of the old parts as possible—a look at the photos will show that this has been done. Matter of fact, the job calls mainly for additions of small parts so little of the original investment is lost. The entire power supply is retained intact, also the two 3D6 tubes, mounting chassis, tuning condensers and so on. When our own Mac II was changed over to the Mac-50 (ATH, Aug., '54) the power supply was pepped up somewhat, and we suggest this be done, if you have the original Mac II. The changes made it possible to get quite a bit higher voltage out of the power supply.

To make the revision as foolproof as possible we decided to use a 13 mc crystal oscillator, and double in the output tube. With this arrangement there is no need to neutralize the output tube a task that is not at all difficult but very tricky for the uninitiated. With this sort of MOPA circuit, too, most any of the many versions of the Mac II can be changed over with good results with little or no chance of interaction between the two tubes, or oscillation of the output tube. Efficiency of a doubler is less than a straight amplifier, but you will still get plenty of wallop and the efficient antenna system will assure that this output is headed into the air toward your model.

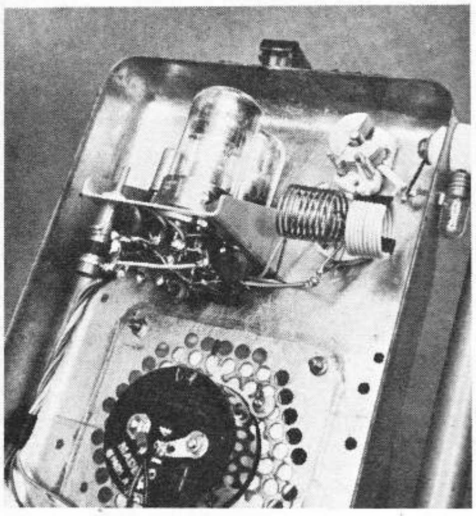
With the oscillator-doubler arrangement we found it unnecessary to change the tube location, so the original chassis was retained. It was first stripped of all wiring except for that to the filaments, but the filament dropping resistor was taken off (it was replaced with a tiny ½ watt wirewound unit). In place of the filament resistor went a coil form carrying L1, projecting downward. While this sort of MOPA is not too critical on parts placement it is wise to keep the oscillator and output coils separated as far as possible, and at right angles. We have done this. When wiring up, we utilized the unoccuped tube pins (4 and 5 on the 3D6) for tie points, also added a three-lug strip for the same reason. A wire was run between the center lugs of the two tube sockets and grounded; most of the ground connections are made to this wire. Plate lugs of both tubes (#2) are on the side toward the antenna, as they were originally. Keep the wiring compact and the parts associated with each tube grouped around same.

As we've stated, the circuit isn't fussy, but we might as well give it every reason for good behavior. The original plate coil of the Mac II can be used; cut it to 9 turns and take the tap off. This coil, L2 in the new circuit, should have the plate end nearest the tubes and the end to B plus nearest the antenna coil, L3. (It was the other way around in the Mac II.) Also, in the new setup the antenna condenser C8 was shifted to the ground side of L3 and the rotor grounded; this makes it less affected by hand capacity when tuning up.

You'll need a crystal exactly half the frequency of your output; for 27.255 mc this will come out to 13.6275. Most R/C suppliers now have these, but be sure you get one to the .005% tolerance. The F.C.C. allows use of .01% crystals if your input to the final tube is less than 3 watts. It runs just about this in the converted transmitter, but you are safer with the closer tolerance "rocks"; matter of fact, most of those now sold are to .005% anyhow.

When ready for the big trials, make temporary arrangements to open the screen grid lead to V2, while keying the V1 SG connections. You can monitor SG current by putting a meter in series with the keying lead. Connect a low range milliamp meter across resistor R4, which is put in the circuit for this purpose. A Zero to 5 ma meter is fine. With both tubes in the socket and a fully charged battery, turn on the power and tune the core in L1 till you see the grid current meter take a jump. Oscillator tuning is just like you would expect; starting with the core at the chassis end of L1, as you turn it in towards the open end, the grid current meter reading will slowly increase to a maximum then suddenly drop to zero; you must tune back from the point of maximum grid current. About .5 to .55 ma on the grid current meter is right. There is no particular need to monitor oscillator plate current. With L1 tuned correctly, V1 will draw around 7 ma plate current and .8 ma SG current.

Now you can connect up the doubler screen circuit again; a 10 ma meter in the keying lead will give a valuable check on operation of this tube. Set C7 at about midpoint, connect a blue bead pilot lamp (#44 or 46) from antenna post to case, and set the antenna condenser C8 at about ⅓ capacity. There should be a meter in the plate circuit



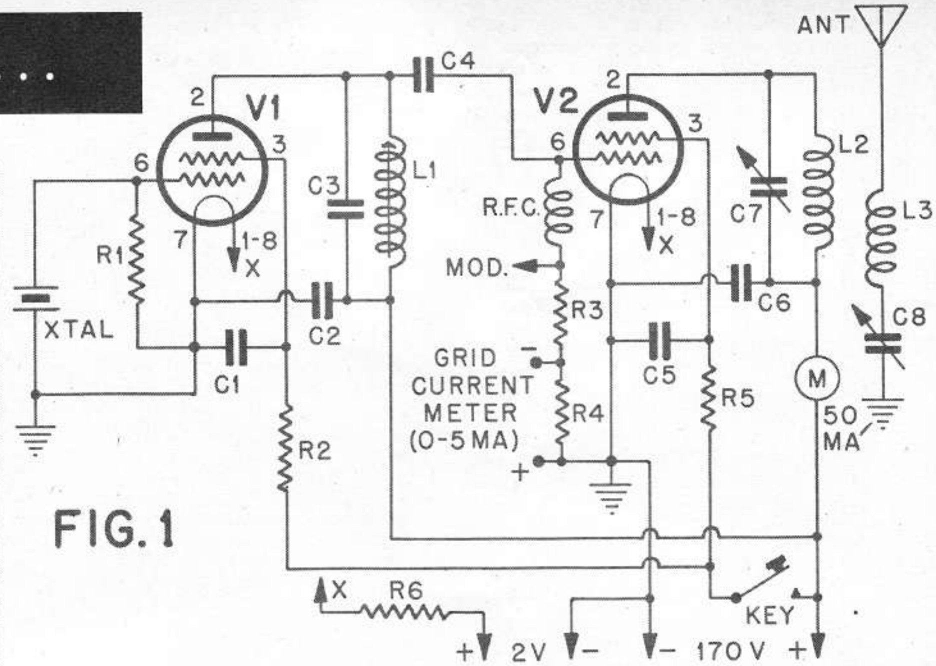


FIG. 1

Numac-II circuit uses many parts from the earlier, and fabulously-successful Mac-II. Rig now meets latest FCC rules regarding radio control operations.

of V2, of course; this is the principal meter of the set and can be any value from 35 to 50 ma. Turn on the power, punch the key and turn C7 rapidly back and forth; the plate meter reading should at some point drop a bit and the bulb might show a little brilliance. One thing you have to watch at this point—it is possible to tune V2 to triple the oscillator frequency instead of double. Operating as a tripler, output will be very low, plate current will be high, C7 will be near minimum capacity (plates almost fully open) and you will be far from the correct frequency. You can check this if you have a *tuned* type of field strength meter.

If you are not familiar with MOPA circuits and it is possible to do so, have a more experienced modeler tune the transmitter for you the first time. They *are* more tricky than the old power oscillator type of transmitter; with a little experience you will have no trouble tuning or retuning.

With the crystal stage tuned properly, you will never have to retune it, unless you change the crystal or either tube. On our test set, it was possible to get a maximum of about .7 ma grid current on V2, before the crystal quite working. The set is normally used with the slug backed off (in the opposite direction from that where the crystal stops oscillating *abruptly*) to give about .5 ma grid current. With V1 tuned this way, the plate current of V2 will only rise to 20 ma or so when C7 is not tuned to resonance; we find output is best when V2 is loaded so that it draws about 16 ma plate current. If loaded more heavily output drops. With the crystal not oscillating, V2 plate current jumps to 35 ma or so; don't hold the key down with this much current more than a second or two (to see if you can get the crystal back in action) or the tube will be damaged. This is why we recommended opening the V2 screen grid lead (to socket terminal 3) when first tuning up the oscillator; with no voltage on the screen the tube will draw no plate or screen current at all and you can play around with the oscillator as much as you want. Because of the very large resistor in the V1 screen circuit, V1 will not draw excessive current under any conditions, so you need not worry about it.

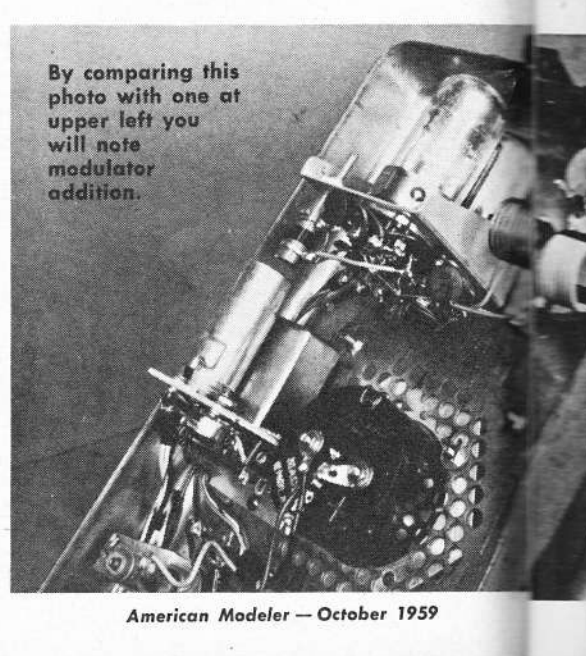
Total current drain of the transmitter is less with the MOPA circuit than in the original Mac II, so battery drain is also less. It will run around 5 A or so. Even so, we suggest that you use one of the higher current storage cells; they can be had with ratings from 20 to about 32 ampere-hour (all are the same external size). RF output is lower, too. However, the 1 to 1.3 W you can get out of your Numac-II is not to be sneezed at! You won't get this much unless you have about 175 volts under load, as our set provides from the power supply with a fully-charged battery.

These changes will give you a more stable transmitter (you can grab the antenna and the set will keep right on perking—though at lower output, of course . . . don't try this with any power oscillator, including the old Mac II!). You'll have a transmitter that is legal under the new rules and that puts out a very clean stable signal. It's worth the small amount of work involved.

This might be the end of the story—except for some other requests involving the Mac II that we have had. Many readers have asked about modulating the transmitter, for use with tone receivers. We had never done anything about this, as we took a dim view of modulating the old power oscillator circuit. But when we came up with a nice MOPA the modulating possibilities came to mind so a little experimenting was done. It turned out to be very simple, using the "cheap and dirty" multi-vibrator oscillator and modulator circuit shown in Dwg. 2. The added parts were mounted on a little shelf attached beside the plate meter. Originally it was thought a transformer might be needed, and this is seen on the modulator unit shown; however it was not needed or used. A possible use for it will be explained later, however. The single 3A5 tube is supplied filament power through a separate 2 ohm resistor; for tone operation, the transmitter tubes V1 and V2 operate continuously, and the entire DC input voltage to V3 is keyed. If you use this modulator in a transmitter other than the Mac II original, it is wise to keep it separated from the RF output circuits as much as possible, as RF can cause odd actions in the multi-vibrator circuit. Parts of the modulator circuit itself are not at all critical in placement, but leads should be kept short, particularly those running to the grids of V3.

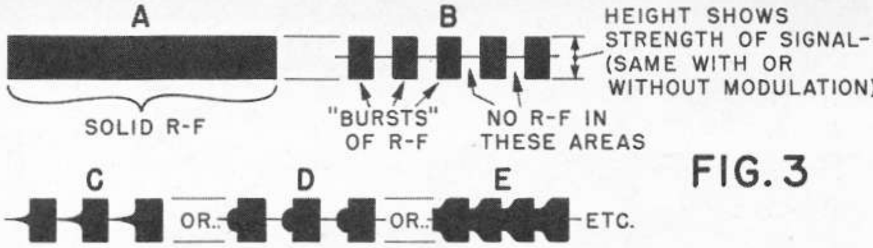
The modulator circuit shows a variable control R11, which shifts the audio frequency over a range from about 360 to 1650 cycles, making the modulator adaptable to most receivers of the untuned tone type (most single channel jobs, in other words). Output of this modulator was found ample for 100% modulation of the revised Mac II, and should do for many other transmitters as well. If the Mac II is revised as we've shown and the modulator built as the circuit indicates you can pretty well be sure of 100% modulation (which most R/C receivers much prefer). If used on other transmitters, it would be smart to check the output with an oscilloscope.

If you have wired correctly, there is no problem to getting the modulator going. Just hitch it up and turn on the



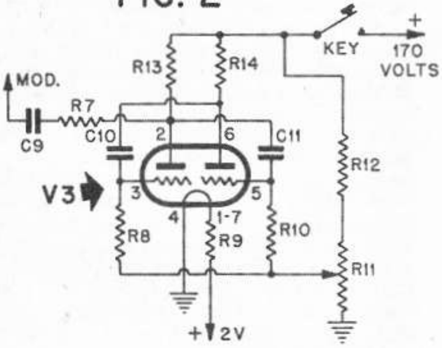
By comparing this photo with one at upper left you will note modulator addition.

power. You can check it with headphones connected to the output lead, for operation and frequency. It is connected to the RF section by simply clipping the output to the RF choke as indicated on Dwg. 1. No other changes are needed in the transmitter. If all is well, when you key the modulator, the plate current of V2 will drop quite a bit (from 16 to 10 ma on the test transmitter); a power output load bulb on the transmitter will dim considerably and a FSM will show a lower reading. Don't fret too much at this—it *doesn't* mean your signal is dropping in strength! What happens is seen in Dwg. 3; at A is the steady RF signal that goes out with no modulation. When you turn on V3, holes are chopped out of the RF signal as at B, but note that the total *height* of the signal does not change, which means the *strength of RF is the same.* Should you be able to look at your signal with a scope, it should appear as in Dwg. 3B; if the blocks of RF have tails as in C or D, you need more modulation (though such a signal would probably work your receiver OK)—E is not so good.



IMPERFECT MODULATION PATTERNS–(LEFT AND CENTER ARE NOT TOO BAD--RIGHT ONE SHOWS VERY LOW MODULATION PERCENTAGE).

FIG. 2



The load bulb, FSM and plate current meter all show lower readings with this modulator on because of the periods when no power is being transmitted (the meter drops because where each of those gaps shows in the scope pattern, V3 is drawing zero plate current, and the meter shows the *average* plate current of the tube), and they average out the total amount of power the transmitter emits.

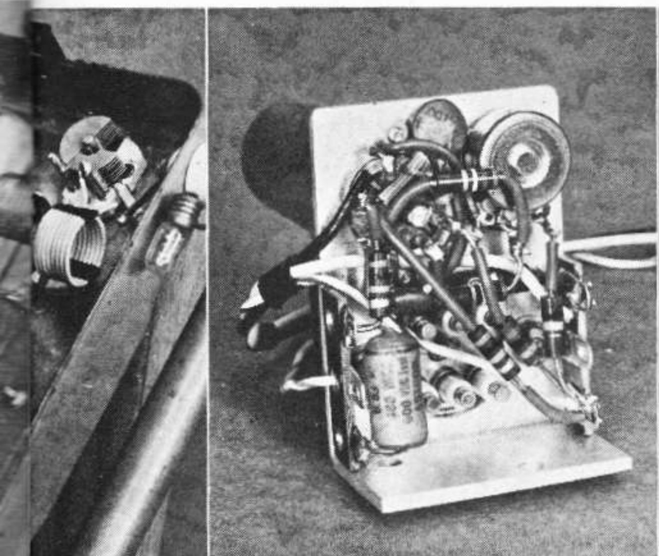
The modulator shown draws about 6 to 8 ma (depending upon setting of the frequency control). Heavier modulation can be had by lowering the value of R7, but you should not go too far in this direction as this resistor isolates the modulator from the RF circuits to a considerable extent. As noted, RF can cause trouble in V3; to check for such problems, turn on power to V3 with the RF section *not* powered; connect high resistance phones through a condenser to the junction between R7 and C9. Note the tone, then turn on the RF section. If the tone changes greatly you are getting RF in the modulator. In the earlier Mac II the tone will change a *little* when you do this, as the high voltage drops considerably when the RF section is connected. RF troubles in modulators can sometimes be cleared up by connecting low value condensers (100 mmf or so) from the multi-vibrator grids to filament, keeping leads as short as possible; the best cure is to separate the AF and RF circuits.

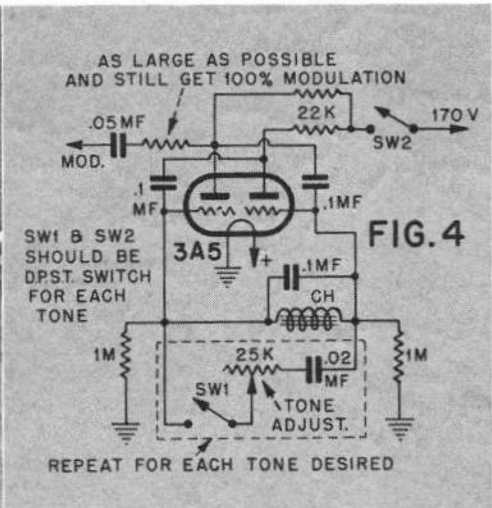
As a final check, note the change in screen current of the RF tubes when the modulator is keyed. It should rise no more than a milliamp or so, and probably won't even go up this much. Without modulation the total screen current of the two tubes should be no more than 5 ma.

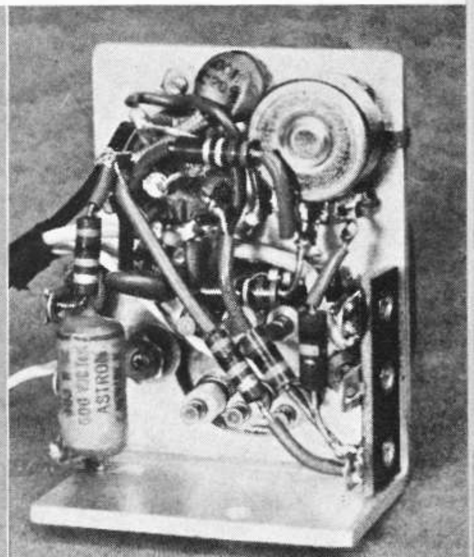
The multi-vibrator is amply stable for single channel tone transmitters and probably for most using tuned filters too (such as the Marcytone). However, it is *not* recommended for use with reed receivers. There is an "out" here, though we didn't go too fully into it. By addition of a high Q choke to the modulator circuit, as seen in Dwg. 4, a fair degree of stability may be had. Ideally such a modulator should be operated at a rather low level, and its output fed into a modulator tube, the latter doing the actual modulating. Brief experiments indicated that the circuit would do a pretty good job directly, however, and it's worth looking into, for those interested in reed work with their present transmitter. The recommended choke only costs a couple of dollars; note that most chokes will *not* do here; many commercial reed transmitters use toroids costing up to $10 apiece. Most problems with reed transmitters stem from change of tone frequency with shifting B voltage. The circuit shown changed only about 4 cycles, when voltage was dropped from 175 to 80—a much greater drop than normally experienced, of course. It is felt this circuit with the low cost AF choke has real possibilities, for the experimentally-inclined.

Parts List for circuit in Dwg. 1. Xtal—13.6275 mc (Aristo Craft or equiv.); L1—CTC LS3 form, red core, 16T #28 En. wire, closewound; L2—9T #14 wire ¾" I.D., ⅞" long; L3—8T #20 insulated wire close wound; RFC—Miller 250 uh choke (Ace). Condensers: C1, C2, C5 and C6—.01 mf ceramic, at least 500 volt (Ace); C3—25 mmf ceramic (CRL type DD); C4—100 mmf ceramic (CRL DD); C7—35 mmf APC type variable (Ace); C8—50 mmf variable (Ace). Resistors (all ½ W): R1—15K carbon; R2 and R3—.15 meg 5%; R4—2K; R5—4.3K 5%; R6—1 ohm IRC BW-½. Two 3D6 tubes with loctal sockets (Gyro); 3-lug strip, xtal socket.

For circuit in Dwgs 2 and 4 (latter is experimental, with all parts shown on ckt, except Ch which is ESSCO type GH-3853-2, connect to terminals 1 and 2). V3—3A5 tube with miniature 7 pin socket; C9—.03 mf, 600 volt; C10 and C11—820 mmf ceramic (CRL DD); R7, R12, R13 and R14—22K 5% ½ W carbon; R11—miniature 100K variable; R8 and R10—.68 meg; R9—2 ohm IRC BW-½.







Modulator circuit above; unit is seen in photos at the left and right.