Active SSB Modulators

Staff

An earlier portion of this series of articles on sideband might have led you to believe that *only* diode modulators are used in modern sideband circuitry.

Tain't so. "Active" modulators—those involving tubes or transistors, and thus capable of providing some amplification of the signal instead of mere loss—are also widely used.

It's common knowledge, of course, among active sidebanders, that active modulators are used. But many active sidebanders seem to believe that only a few such circuits exist.

This ain't so either. A search of the literature going back to the earliest days of the current sideband boom (early 1948) revealed a minimum of 15 circuits. Each of these, of course, is subject to an infinite number of minor variations as well.

Before we dive into the intricacies of these 15 circuits, though, let's make some comparisons between active modulators and those of the diode variety. You just might not want to wade through all the active-modulator circuits —and then again you might.

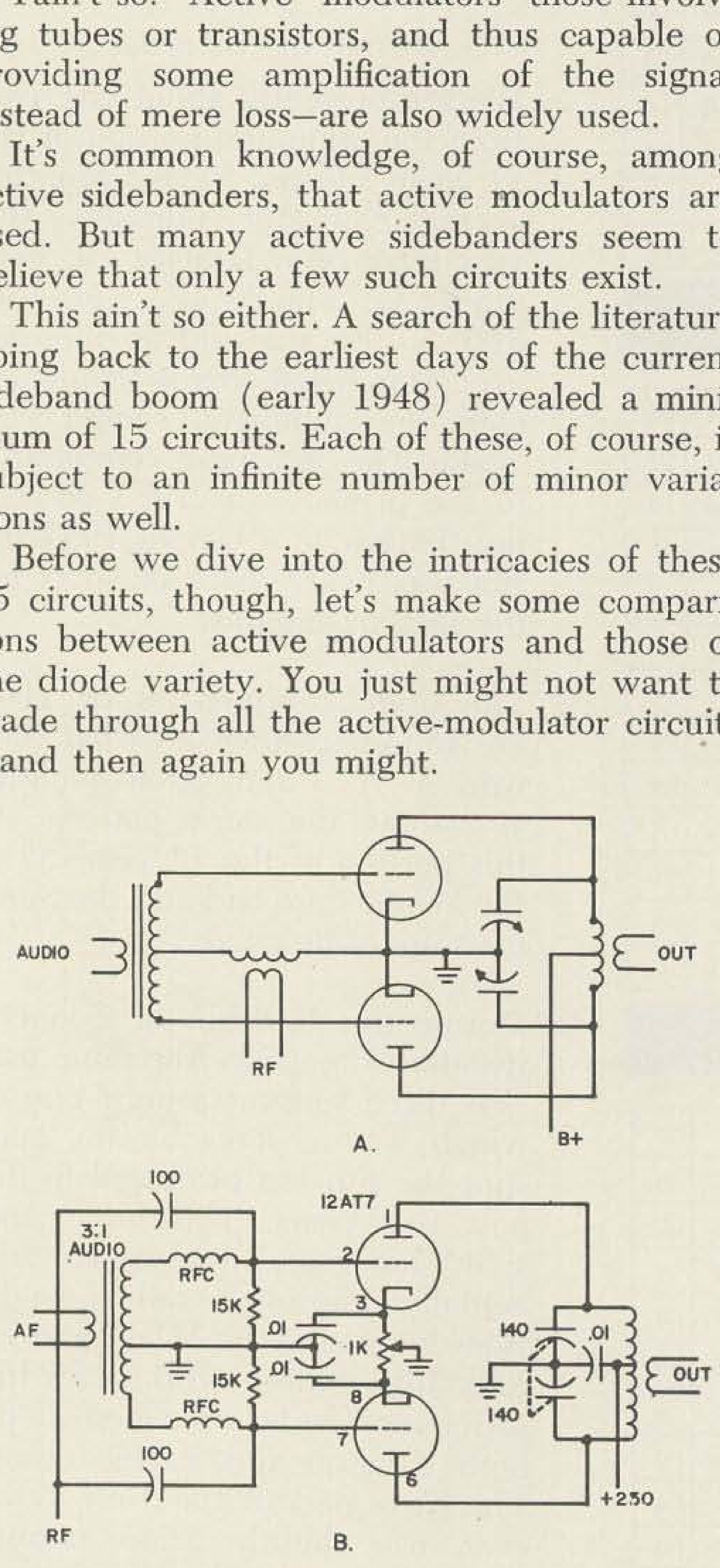


FIG. 1

A. Basic Circuit
B. Practical Circuit
Push Pull Balanced Modulator

The major characteristics of the diode modulator are its simplicity, low number of components, absence of power-supply requirements, and relative freedom from aging.

The active modulator, on the other hand, has (in addition to the opposite of all the characteristics just mentioned) the capability of amplifying the signal instead of just producing losses.

For a given amount of rf output power, you're going to have to use about the same number of active devices. The real choice, then, becomes one between a diode modulator plus an extra linear amplifier, or an active modulator without the amplifier.

And viewed in this light, it becomes one of those things about which there is much difference of opinion. Some people prefer to battle it out with the amplifier, while others prefer to fight their problems with the modulator.

If you're interested in going *double* sideband instead of single, then the active modulator is recommended. You can build one of these to operate at a kw if you like, and avoid *all* amplifiers (such a circuit, although for a more practical power level, is included in our list).

Ready to look at circuits? Let's get with it.

One of the most basic of the active modulator circuits is that shown in Fig. 1, the push-pull balanced modulator. Fig. 1B shows the practical version of the circuit, including balance control and means for routing rf and audio to their proper places.

This circuit works something like an electronic switch, turning the carrier off and on under the control of the audio (or other modulating signal—wherever "audio" is mentioned in this article, rf of a different frequency than the carrier can be substituted equally well and then the circuit becomes a "mixer").

Thus, when the grid of the upper half of the tube (in Fig. 1) becomes less negative, more of the carrier flows through this tube. At the same time, the lower grid becomes more negative, cutting off carrier flow through this half of the tube.

The carrier is eliminated because it affects both grids equally and plate current in both halves of the tube goes in the same direction at the same time. This current flow cancels itself out in the push-pull tank circuit.

However, incoming audio drives one grid positive while the other goes negative, allowing current to flow more through one half than the other as mentioned earlier. This flow, being different in the two halves of the tank circuit, does *not* cancel out—it shows up instead in the output as the sidebands, less the carrier.

The *modified* push-pull balanced modulator of Fig. 2 works the same way. Carrier is injected into the cathodes of both tubes, in phase. Audio is injected into only one; it affects the other because, for audio, the two tubes form a "long-tailed-pair" phase inverter circuit.

This phase inverter is worthy of special mention. The secret of its success is the 33K resistor in the common cathode circuit. In addition, the resistive loads in the plate circuits are necessary.

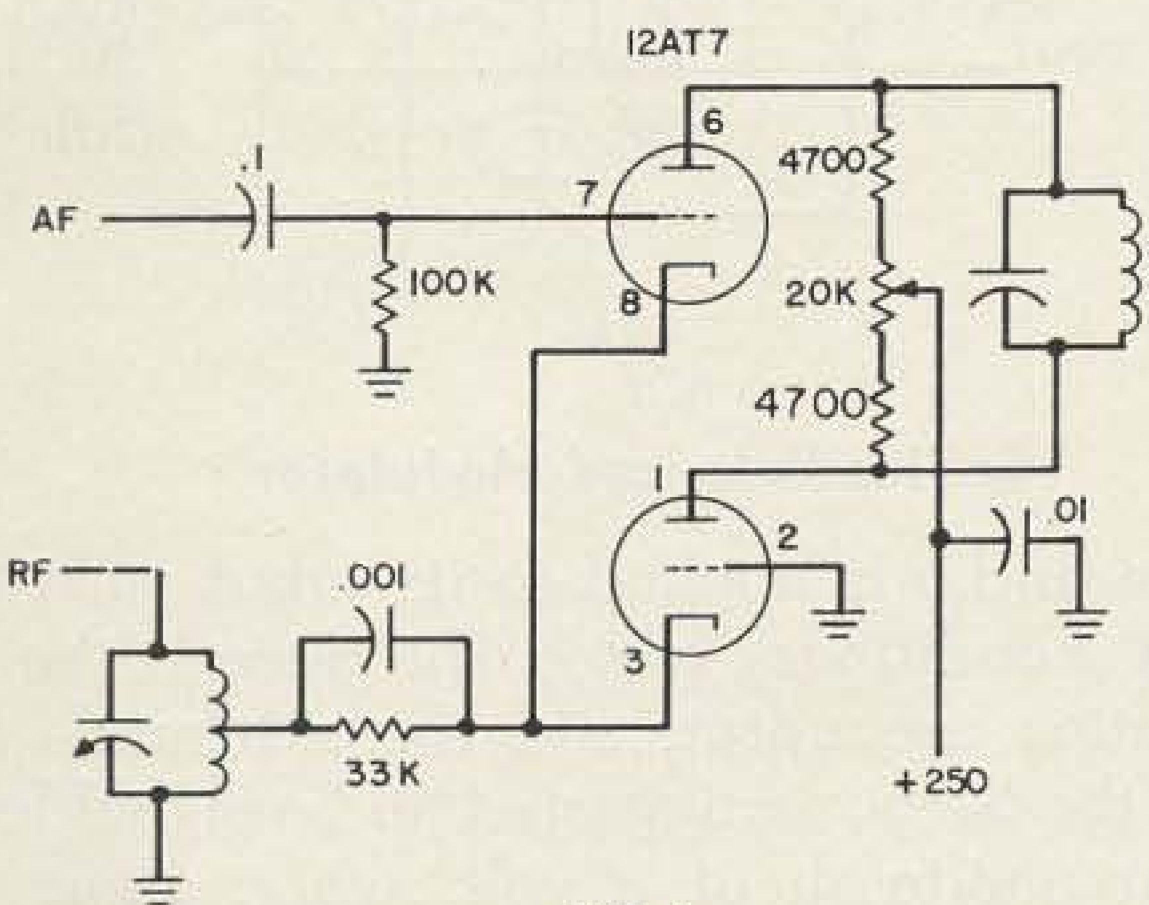


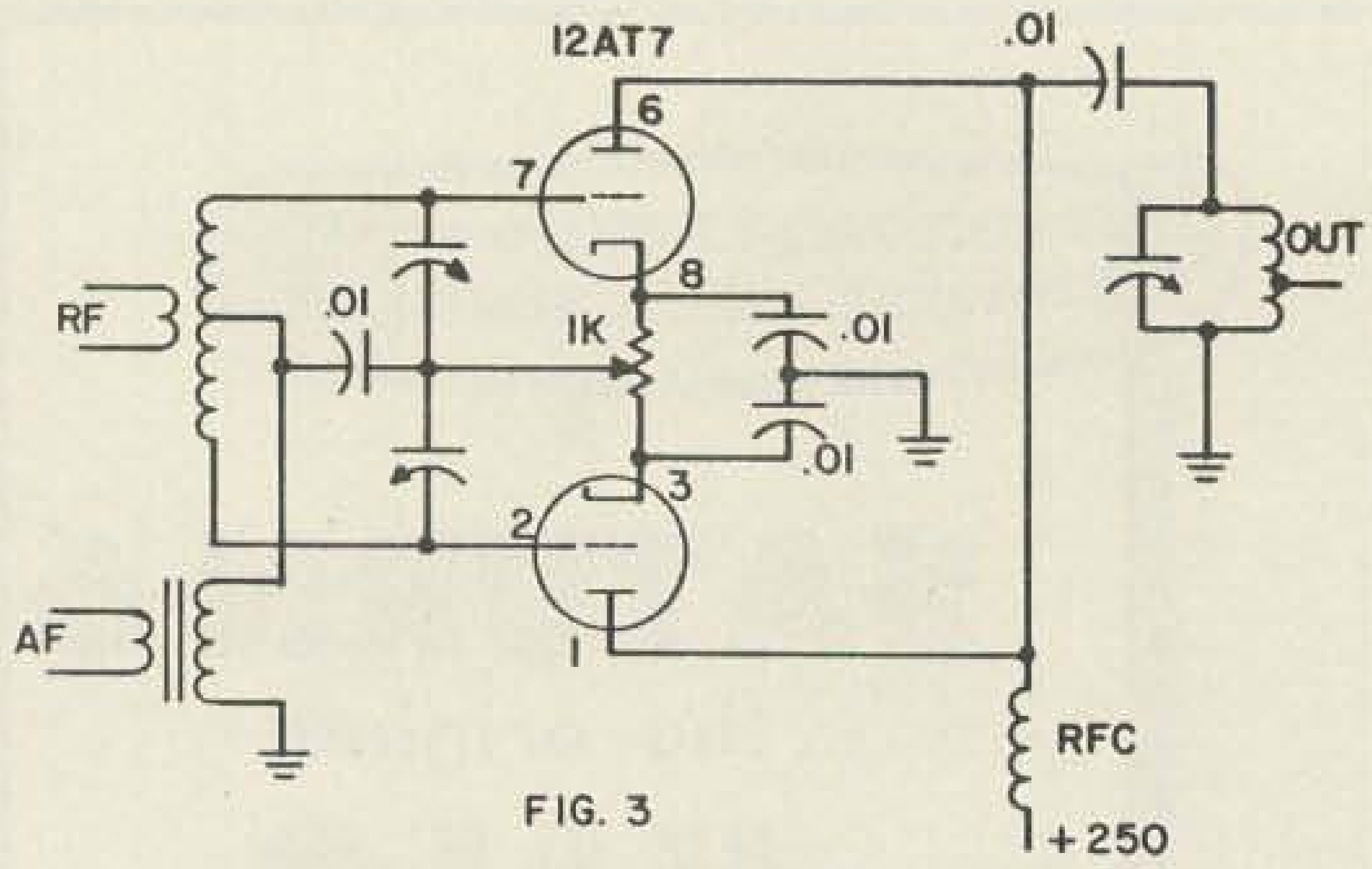
FIG. 2
Modified Push Pull Modulator

Under these conditions, the upper tube acts a little like a cathode follower for the audio coming into its grid. The audio appears across the cathode resistor, which is much larger than the plate resistors. The lower tube, then, functions as a grounded-grid amplifier. However, the upper tube in addition to being a cathode follower acts a little like a conventional amplifier too.

A conventional amplifier shifts the phase of incoming signals 180 degrees; cathode followers and g-g amplifiers do not shift phase at all. Thus the audio signals at the two plates must differ by 180 degrees—and this implies that the audio at the two grids also differs by the same amount, thus satisfying the requirement for push-pull input!

Both the circuits we've seen so far use push-pull input and push-pull output, with the modulating signal applied in parallel. Now let's look at one which uses single-ended output.

This is the push-push balanced modulator



Push Push Balanced Modulator

of Fig. 3. So far as the rf circuit is concerned, this circuit is identical to the push-push frequency doubler with one exception. The output circuit is tuned to the same frequency as the input.

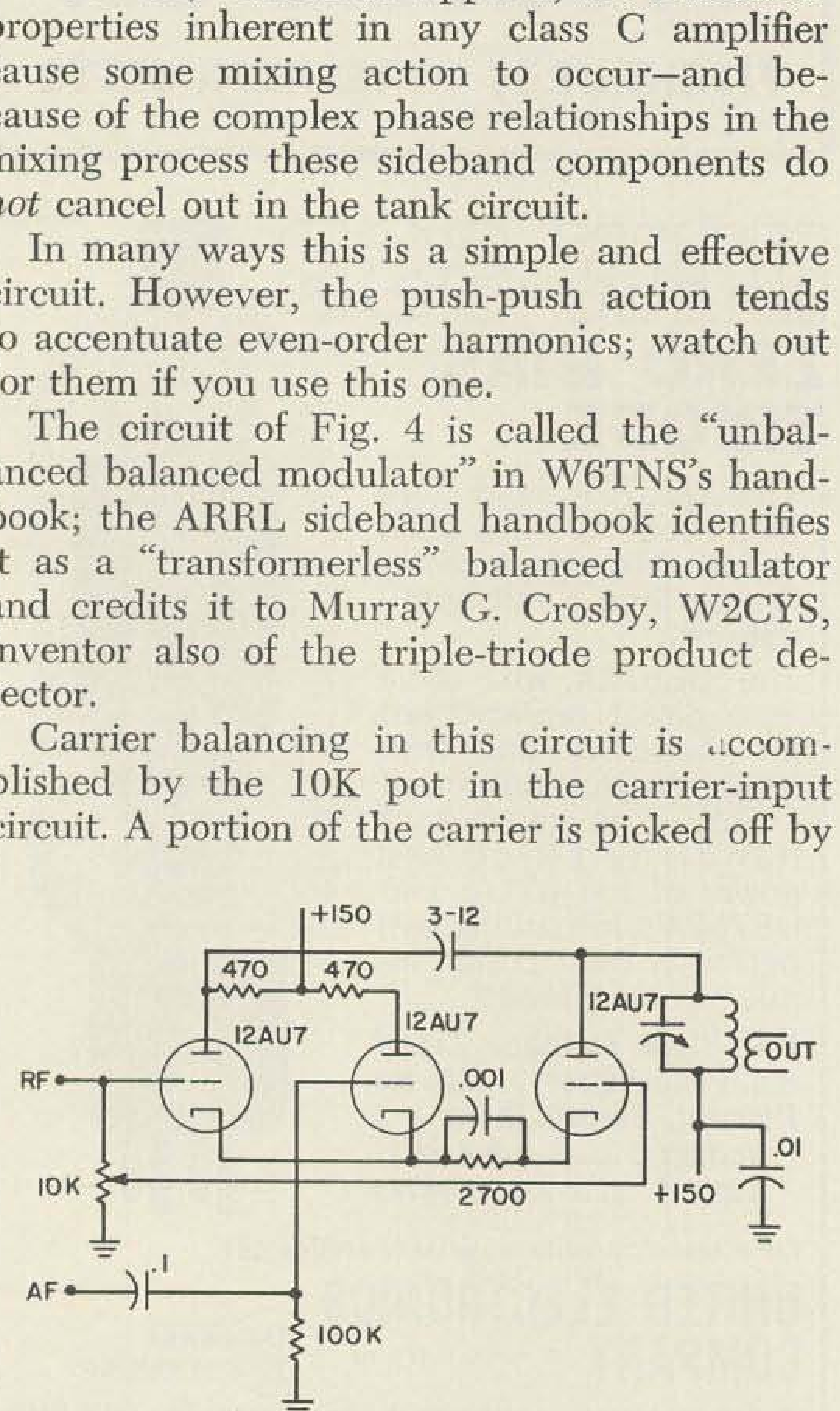
Carrier is balanced out because one of the two tubes is always conducting (in the absence of audio) and the plate-current pulses fill each other in. You might say they beat each other's brains out at the tank circuit.

However, with audio applied, the non-linear properties inherent in any class C amplifier cause some mixing action to occur—and because of the complex phase relationships in the mixing process these sideband components do *not* cancel out in the tank circuit.

In many ways this is a simple and effective circuit. However, the push-push action tends to accentuate even-order harmonics; watch out for them if you use this one.

The circuit of Fig. 4 is called the "unbalanced balanced modulator" in W6TNS's handbook; the ARRL sideband handbook identifies it as a "transformerless" balanced modulator and credits it to Murray G. Crosby, W2CYS, inventor also of the triple-triode product detector.

Carrier balancing in this circuit is accomplished by the 10K pot in the carrier-input circuit. A portion of the carrier is picked off by



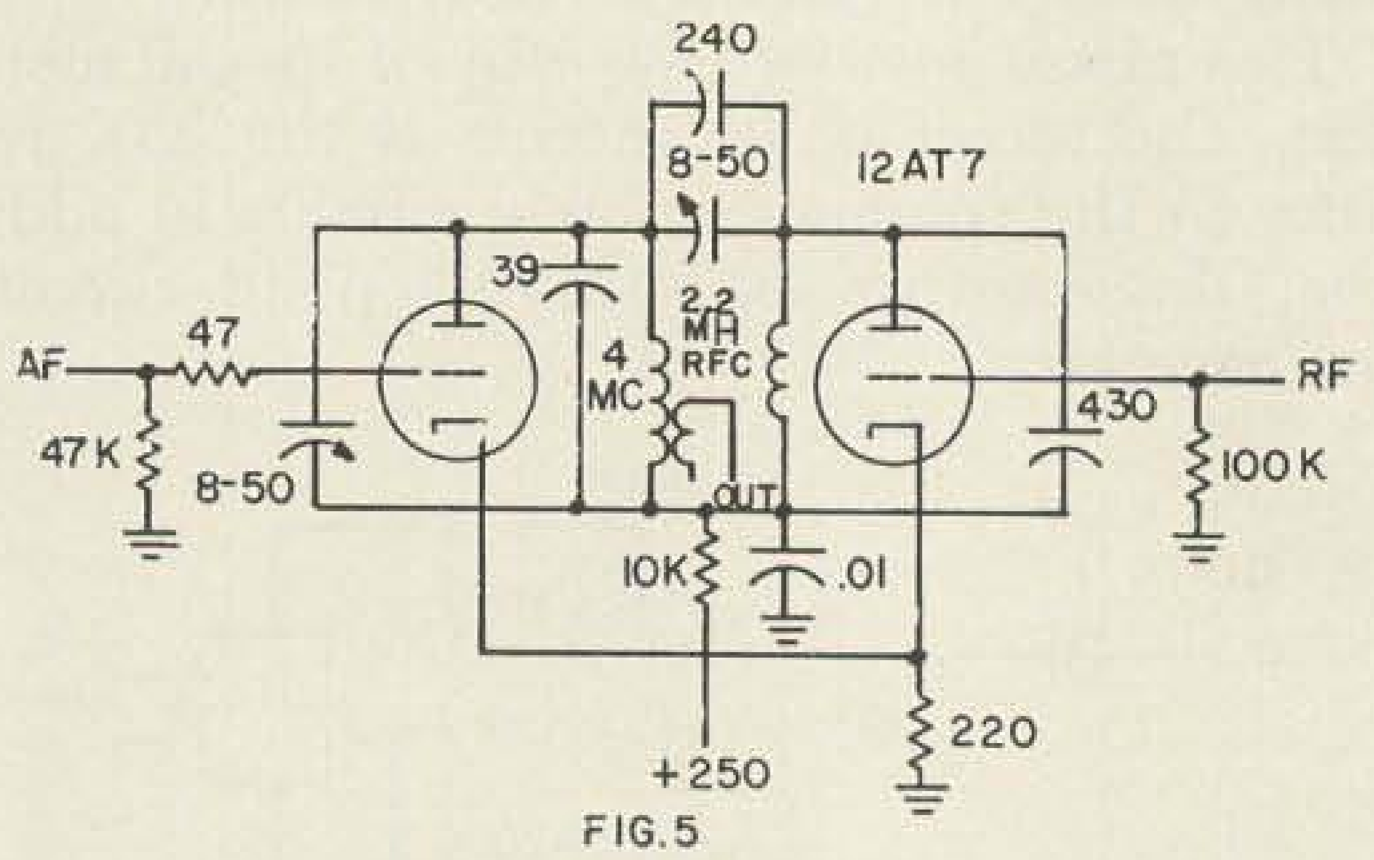
Crosby "Unbalanced" Balanced Modulator

this pot and fed, out-of-phase, to the output circuit. The adjustable capacitor is used to neutralize capacative feedthrough in the tubes.

The major advantage of this circuit, aside from novelty, appears to be the exceptionally low distortion created. Crosby reports distortion less than ½ of 1 percent, using this design.

Another active modulator which does not require push-pull circuitry is shown in Fig. 5. This one is used in the KWS-1 for frequency conversion, but can also be used for audio modulation.

In the absence of audio input, the circuit acts as a long-tailed phase splitter for rf, and the out-of-phase rf is then cancelled out in the plate circuit.



Collins Balanced Modulator

When audio is applied to its input jack, the balance conditions which produced the rf cancellation are upset, and the sidebands appear in the output. Suggested audio signal level is about one-tenth of a volt, while about 1½ volts of the rf are required.

All the active-modulator circuits looked at so far require plate-supply power. The circuit of Fig. 6, though, known as the "plate-modulated" balanced modulator when By Goodman, W1DX, first described it in the November, 1949, QST, requires no power except for the filaments.

The principles of operation here are very similar to the circuit of Fig. 1, except that the audio is fed to the cathodes rather than to the grids. Plate power is supplied by the audio input only, however. In the absence of audio, no

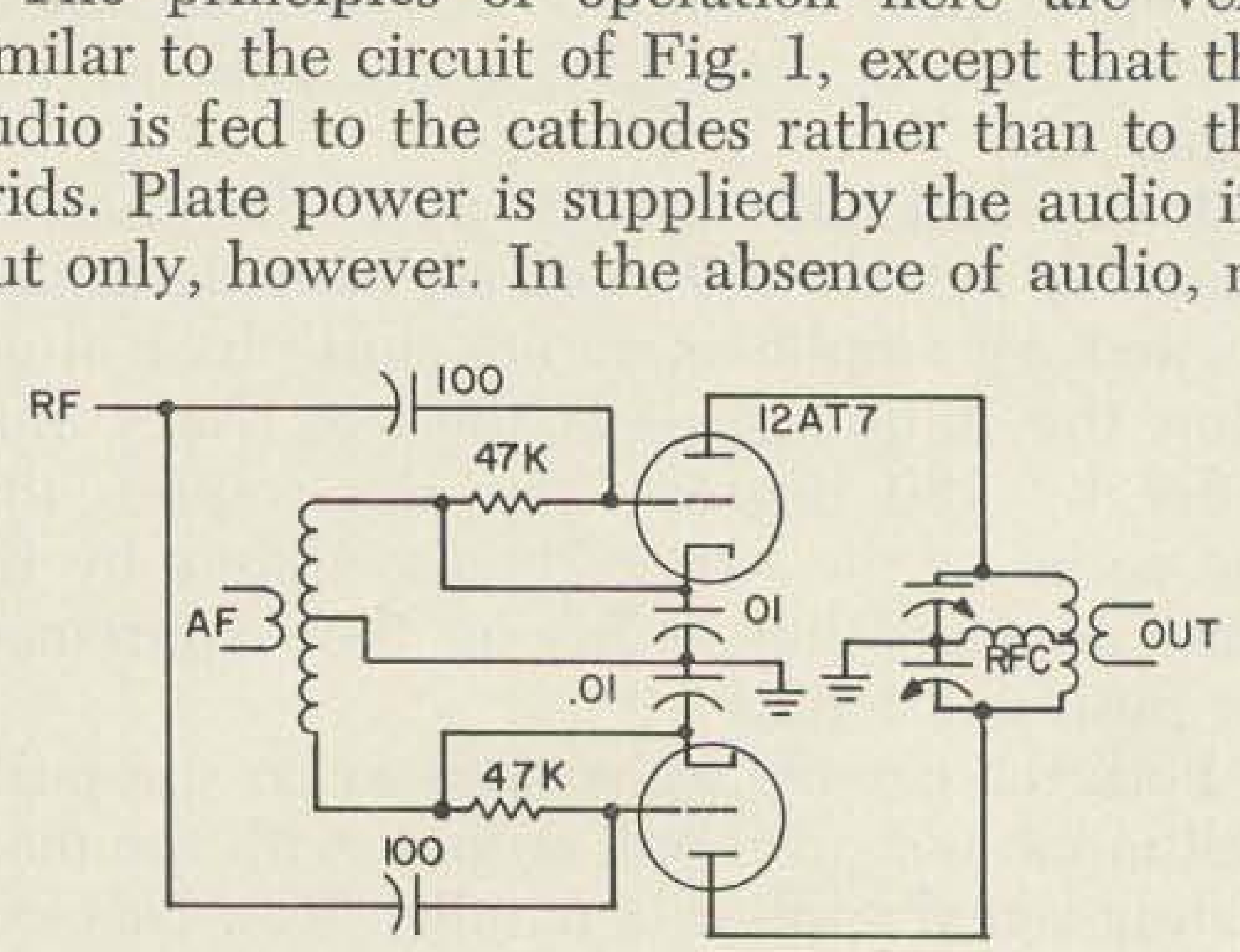


Plate-modulated Balanced Modulator

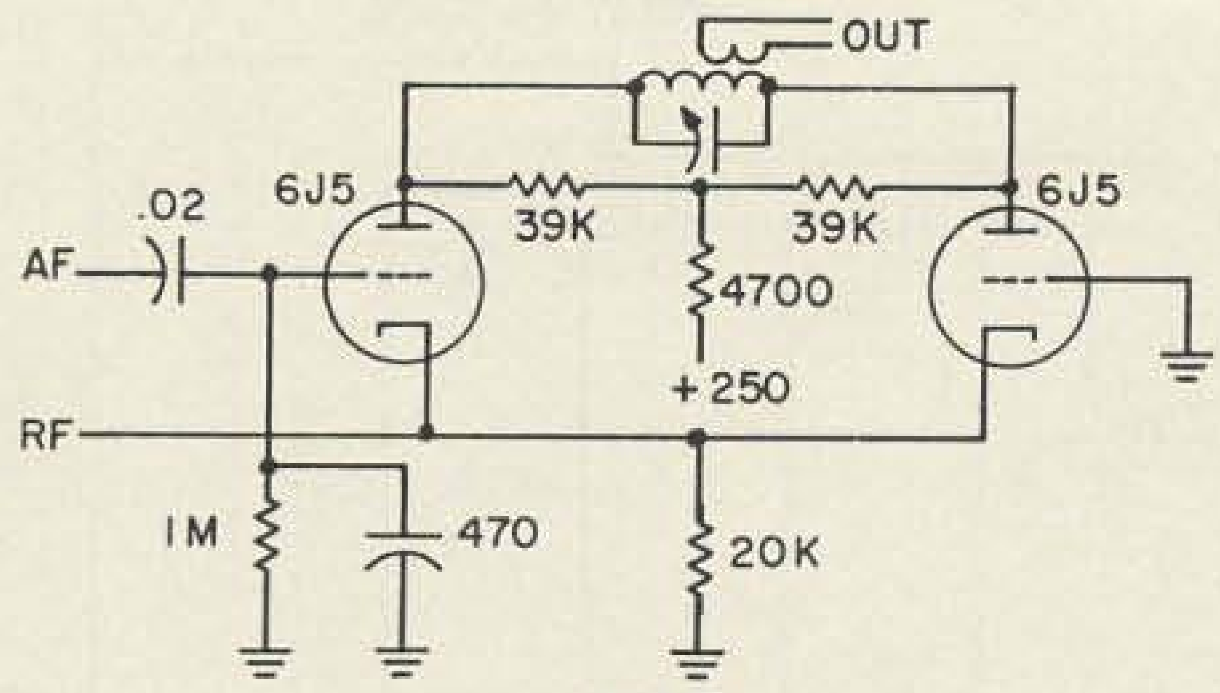


FIG 7

W7BMF/Motorola Balanced Modulator

power is applied to the stage and nothing naturally, gets through. When audio is applied, one cathode goes positive while the other goes negative. The tube whose cathode is positive does nothing—but the one whose cathode goes negative can then amplify so long as the audio half-cycle lasts, and routes carrier and sidebands through to the output. The carrier balances out in the push-pull tank, leaving the sidebands.

The circuit shown in Fig. 7 is credited to W7BF in its first published appearance, with the note that it is "swiped from Motorola." Its major feature is that it does not require push-pull input for either the audio or rf signal; rf input is to a 20K cathode resistor common to both tubes, while the audio signal is phase-split by the pair acting as a long-tailed splitter.

In many ways, this circuit is similar to the one shown in Fig. 2. The major differences are the high-impedance untuned rf feed to the cathodes, and the RF filter included in the audio input circuit.

All of the active modulator circuits discussed so far give only DSB output; the circuit in Fig. 8, first described several years ago in QST by VE6CN, allows a choice of DSB or phase-modulated output.

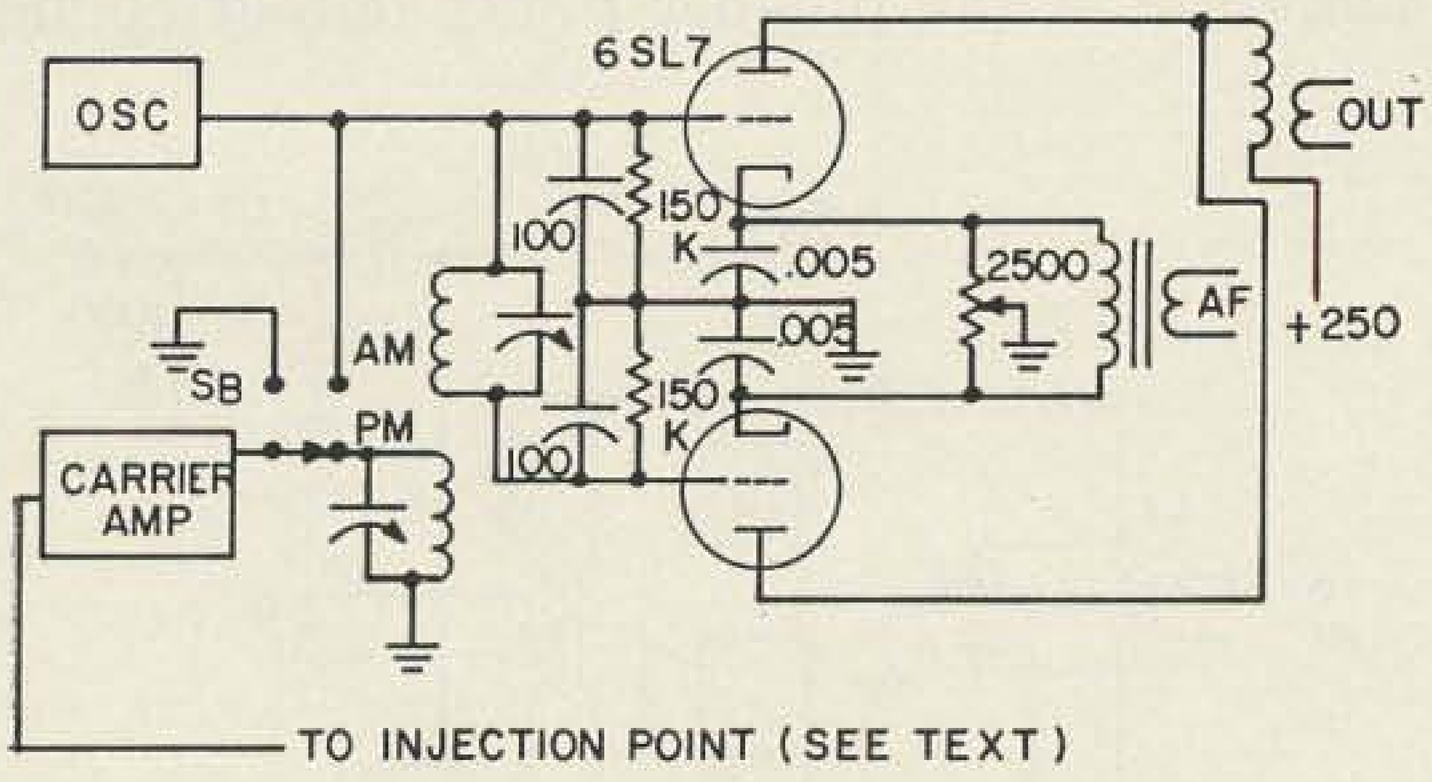


FIG. 8

VE6CN Phase-or-sideband Modulator

This circuit is very similar to the push-push modulator of Fig. 3, with the changes all being in the circuitry between the oscillator and the rf input to the modulator.

With the switch in the sideband position, rf input to the two grids of the modulator tubes

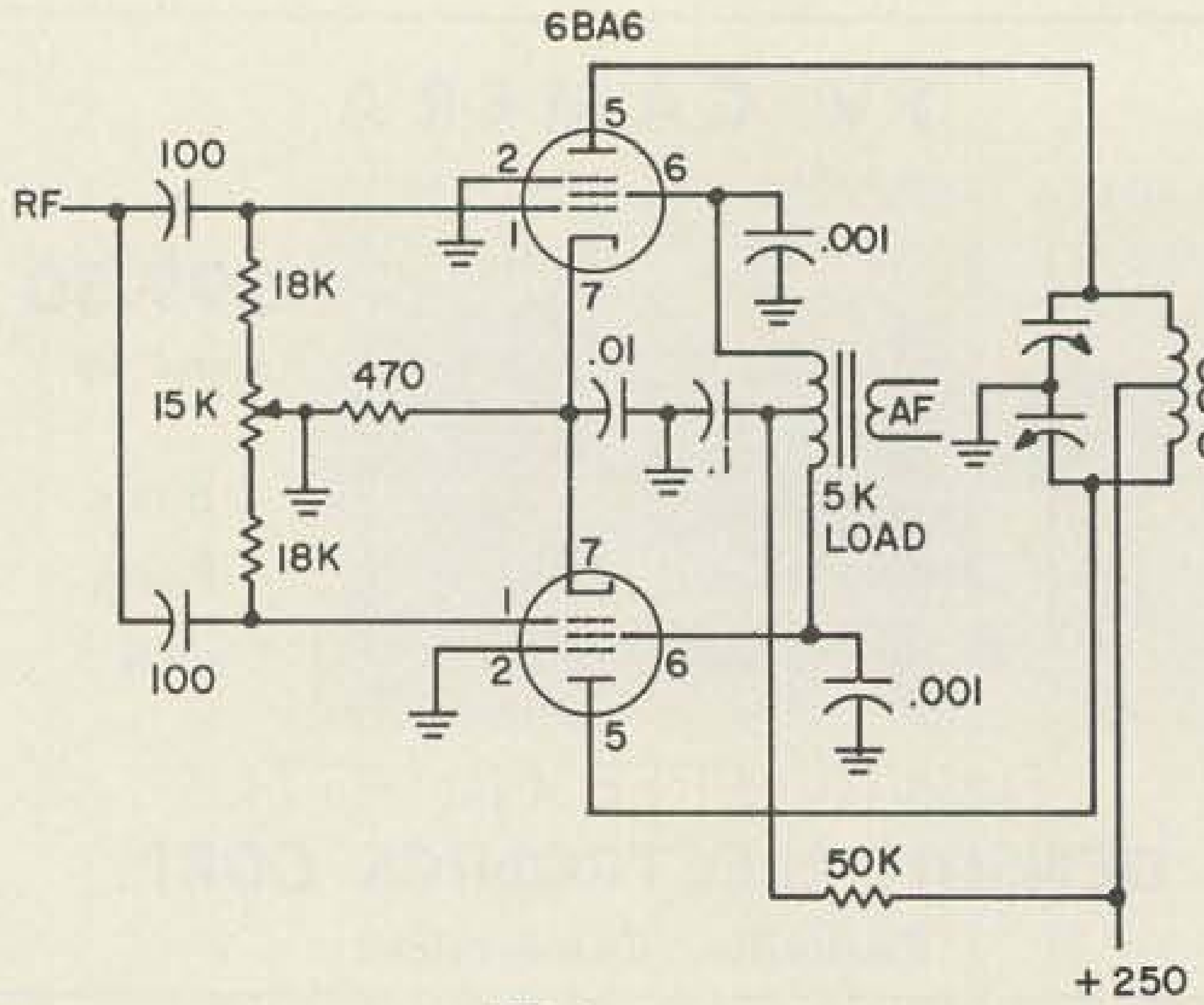


FIG. 9
Pentode Balanced Modulator

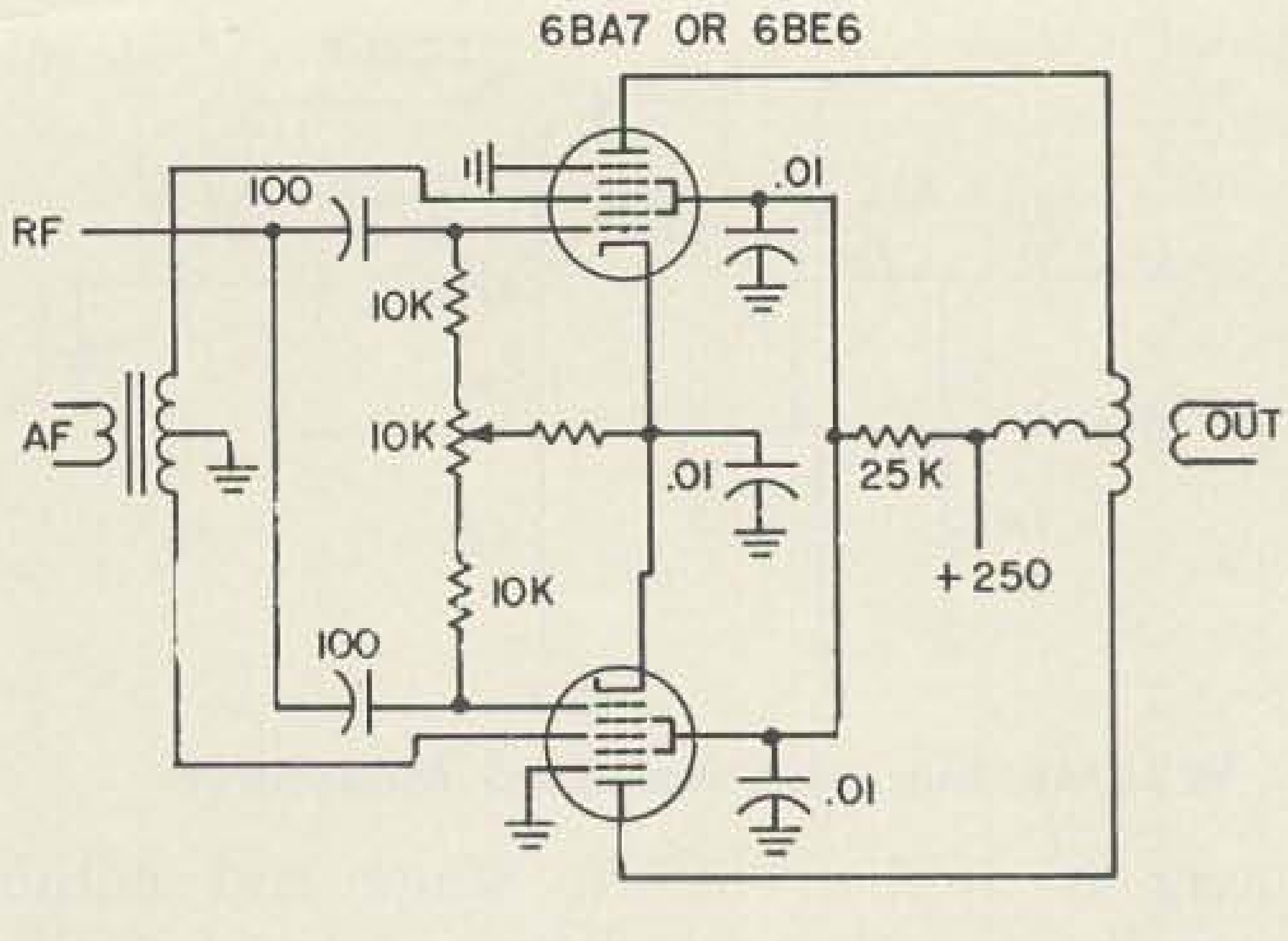


FIG. 10
Pentagrid Balanced Modulator

is applied in push-pull. Filtered sideband output goes on through the transmitter. In the AM position, the same action takes place except that a portion of the rf input is also applied to the "carrier amplifier" and is re-inserted in a stage following the filter. And in the PM position, carrier voltage 90 degrees out of phase with that applied to the modulator is applied to the carrier amplifier.

The 90-degree phase shift between re-inserted carrier and the sidebands produced by the modulator result in phase modulation. This circuit allows good deviation to be obtained without multipliers.

Up until now, we've been looking only at those circuits which use triode tubes. However, pentode and beam-power tubes can also be employed, as can transistors and one type of tube specially made for balanced-modulator service. We'll look at these circuits now.

Fig. 9 shows a balanced modulator using type 6BA6 pentodes. Rf input is applied to the grids in parallel while the output is taken from the plates in push-pull fashion. Audio is applied to the screens push-pull, and in the absence of audio input all the rf carrier balances out. The pot in the grid circuit allows complete balancing of the circuit.

When audio is applied, the tube whose screen goes positive at any instant draws more current than the other, unbalancing the circuit and allowing the sidebands to appear in the output tank.

As shown, this circuit uses positive voltage on the screens. With a bit of juggling, the screens can be returned to ground and then current drain in the absence of audio will be almost nothing at all.

The pentagrid balanced modulator of Fig. 10 derives from a circuit originally described by Villard, W6QYT, in the April, 1948, issue of QST. This was less than 6 months after W6QYT triggered off the current boom in sideband by putting W6YX on the air SSB. It is seldom used any more because of cost of components, but still retains all its advantages of low distortion and easy adjustment!

This circuit operates in the same manner as the pentode circuit of Fig. 9, except that the audio signal is applied to grid-3 instead of to the screen in each tube. Interaction between audio and rf signals is minimized by the screening action of grids 2 and 4.

Though most balanced modulators operate at low signal levels, they need not necessarily do so. The circuit of Fig. 11 is widely used to produce a double-sideband output signal directly in the final stage, and depending on the tube type chosen can produce power ranging from watts to kilowatts!

This circuit operates in exactly the same manner as that shown in Fig. 9 except that the tubes are heftier. Grid input at carrier frequency is fed push-pull fashion simply to allow use of the popular pi-net output circuit.

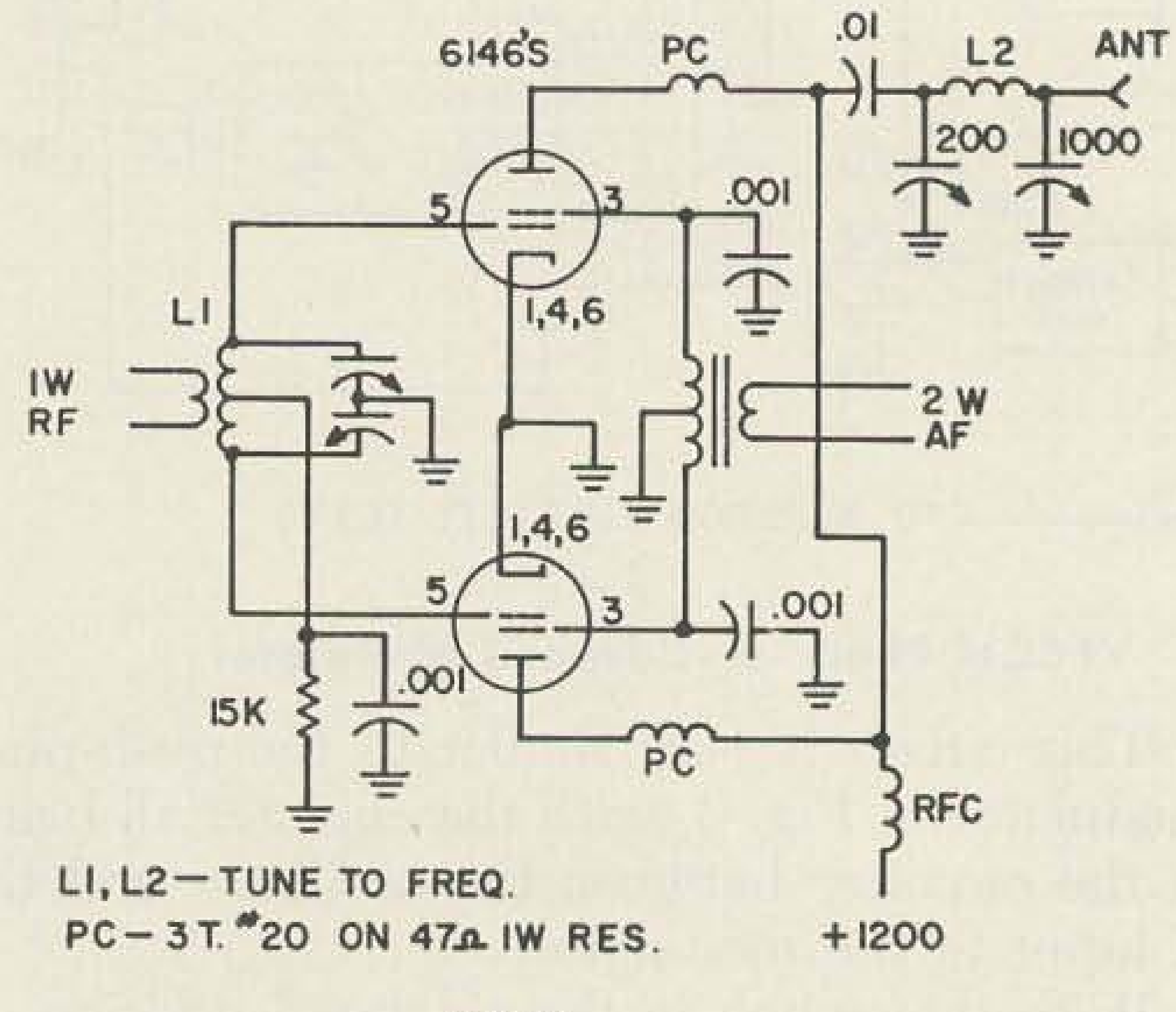


FIG. 11
400-watt PEP DSB Modulator

Modulation is applied to the screens in push-pull.

With the 6146 tubes shown, plate voltage can be as high as 1200 volts. This is twice normal rating, but is no higher than the voltage applied during modulation peaks in AM service! To estimate allowable ratings for other tubes, double the voltage rating for AM service and use anything up to that figure. Current on peaks, though, should not exceed that rated for AM use.

Output power of this circuit, as shown, will be in the neighborhood of 400 watts peak. Maximum indicated input power will be only about 240 watts, however. No-signal plate current should not exceed 25 mils.

And while balanced modulators may operate at either high or low signal levels, they need not always use tubes or diodes. The circuit of Fig. 12 employs a pair of rf transistors.

This circuit operates identically to the triode push-pull modulator of Fig. 1; the differences are entirely due to the differences between tubes and transistors.

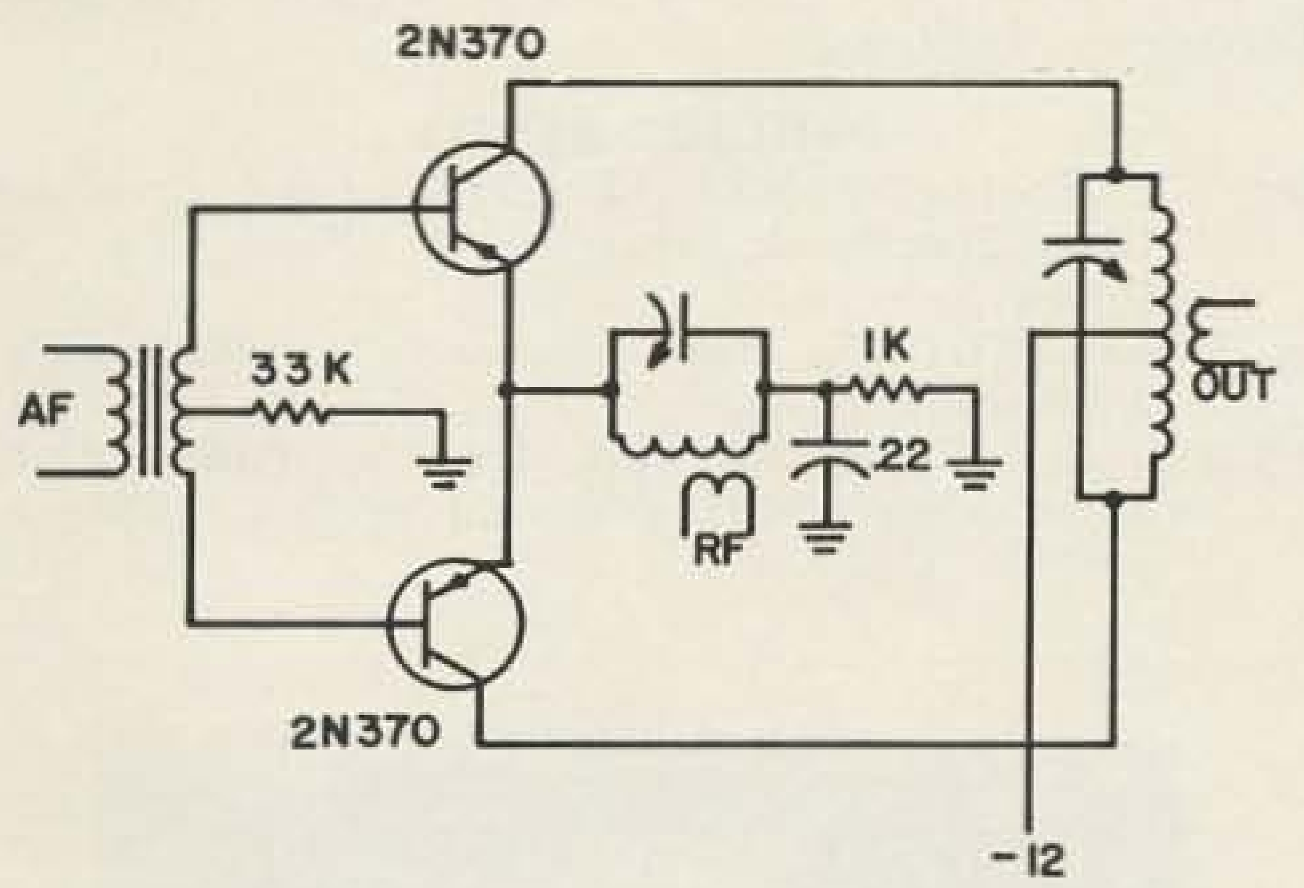


FIG. 12

Transistorized Balance Modulator

RF input is applied to the emitters in parallel, while the radio signal is applied to the bases in push-pull. Note that no base bias is present. Thus, in the absence of audio input the transistors and cutoff and cannot conduct; therefore, balance is not particularly critical.

When audio is applied, only that transistor whose base goes negative can conduct. Carrier balances out in the push-pull tank circuit, leaving only the sidebands to be amplified.

RCA type 2N370 transistors were specified in the original description of this circuit; the newer Amperex 2N2084 "universal" rf transistors should work equally well if not better, due to higher frequency ratings and greater power-handling capability. With 2N370's, power should be kept in the 10-20 *milli*watt region for reliable results.

The final active-modulator circuits we'll ex-

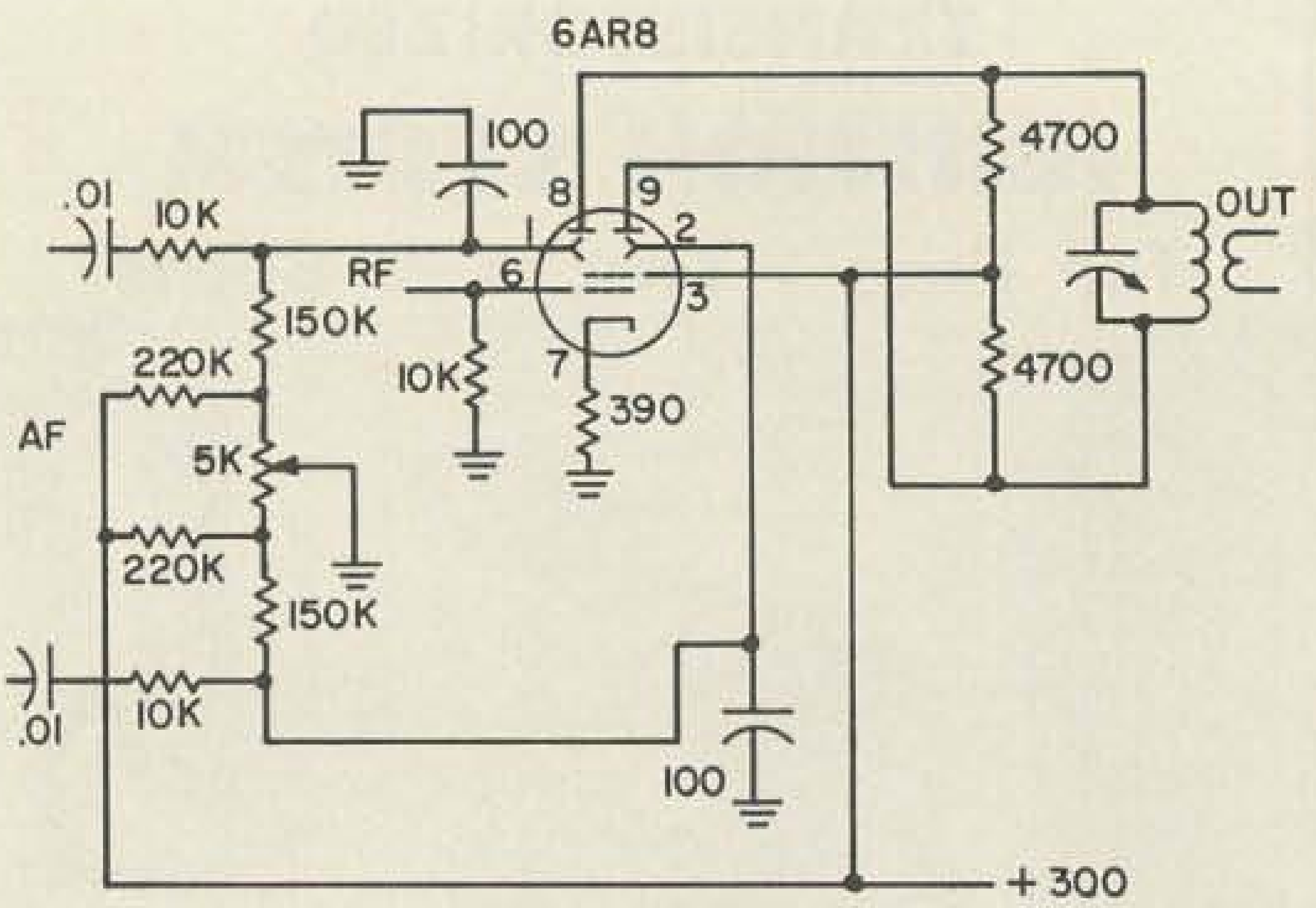


FIG. 13
Orr-Stoner 6AR8 Balanced Modulator

amine are those built around the sheet-beam tube.

This tube was originally developed for color television, and the first one to reach the market in any quantity was the type 6AR8. Bill Orr W6SAI, described a modulator built around this tube in the July, 1956, issue of CQ. The circuit of Fig. 13 is an adaptation of the Orr design.

Unfortunately, the 6AR8 is almost extinct now. However, RCA came out with a special tube designated the 7360 which performs the same function, and which in addition was especially designed for balanced-modulator use. With this tube, 50 db of carrier suppression is easily achieved and even greater suppression can be obtained with a little care.

The circuit shown in Fig. 14 is one recommended for use with the 7360. Note that it is quite a bit more complex than that of Fig. 13. Either should perform well with either tube.

Unlike all the other balanced-modulator circuits, the circuits of Figs. 13 and 14 operate by actual deflection of the electron beam within the tube.

The special tube contains a cathode and control grid, just like ordinary tubes, but then

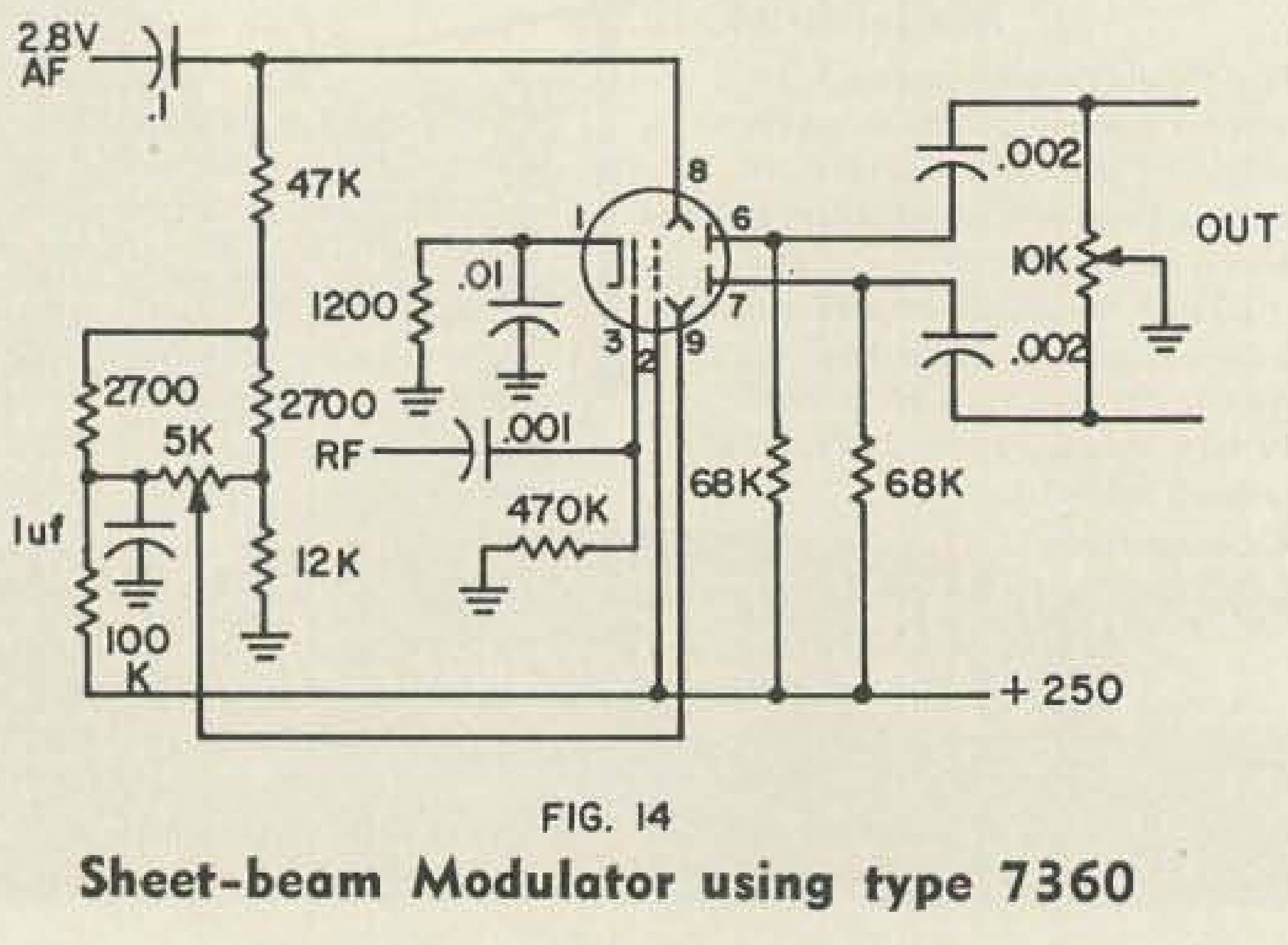


FIG. 14
Sheet-beam Modulator using type 7360

comes a pair of deflection plates (like in a scope tube) and two plates rather than one.

If carrier is applied to the control grid and push-pull audio is applied to the deflection plates, then the carrier signal will determine the amount of current flowing in each plate circuit while the audio signal will determine which plate circuit the current flows into.

The mechanics are actually very similar to those of the pentode modulator, in which the rf current available for each plate was the same but the audio signals applied to the screens determined which plate got the current at any given instant.

If the plates of the sheet-beam tube are connected in push-pull, then the in-phase rf from the control grid will cancel out in the absence of audio. Application of audio to the beam plates will unbalance the circuit, letting the sidebands show up in the output.

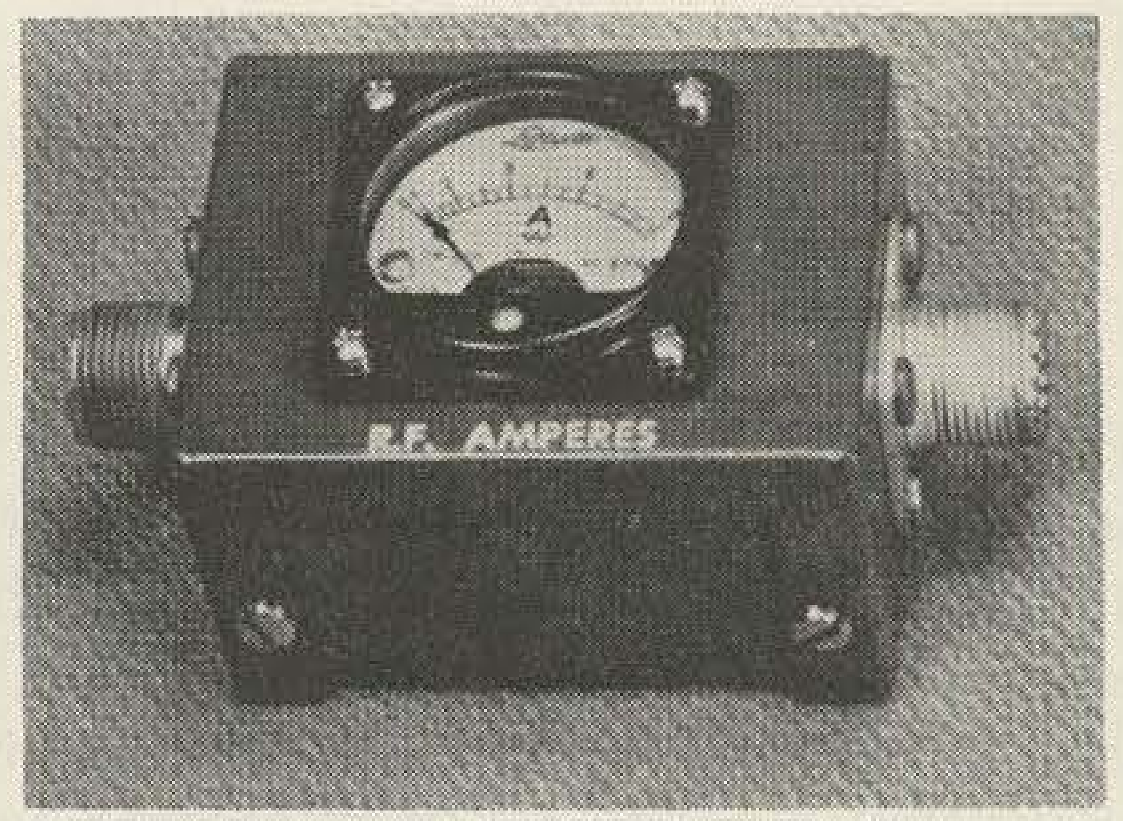
Undoubtedly, the circuits described here do *not* include all the possible active-modulator circuits. They do include most of them, though, and all those in wide use are discussed. For additional data on any one circuit, check the references below.

BIBLIOGRAPHY

Harry D. Hooton W6YTH, **Single-Sideband Communications Handbook**, Howard W. Sams, Inc., Publisher.

Don Stoner W6TNS, **New Sideband Handbook**, Cowan Publishing Corp.

ARRL Staff, **Single Sideband for the Radio Amateur** (first edition, 1954; second edition, 1958; third edition, 1962).



New Look in RF Ammeters

The amateur today can pick and choose from a wide variety of commercially available SWR bridges, impedance bridges, relative power indicators, absolute power indicators and other rf transmission system instruments. Although most of the factory assembled instruments are moderately priced, further savings may be realized by constructing one of the excellent kits