A Deluxe Screen Modulator for Beginners

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ALTHOUGH a.m. is slowly becoming obsolete in amateur communication, there is no denying the fact that for the sheer pleasure of short-range high-fidelity voice communication, there is nothing to beat good-old a.m. It is the writer's earnest hope that a.m. would not be wiped off completely from the face of amateur radio!

When the writer started building his present c.w./a.m. transmitter, he had a difficult decision to make as far as the type of modulation was concerned. Economy of construction was certainly aimed at, but not at the expense of signal-quality. After some reassuring words from his friend Wickram, 8Q6WA who has built high-power screen-modulated commercial transmitters, the writer decided to go in for screen modulation. Although the writer started the project with not a small measure of diffidence, the result has been a pleasant surprise—Indian and DX hams have made very good comments on the signal quality and at least one DX ham has refused to believe that the writer is on screen modulation! The writer can now declare with some confidence that a properly designed screen-modulated transmitter can give the same punch and quality as a plate-modulated transmitter, at least as far as listening tests go.

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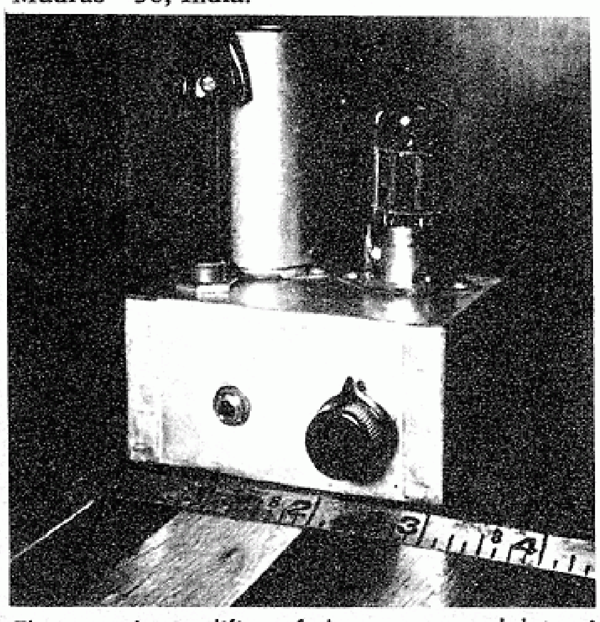


The speech amplifier of the screen modulator is housed in a small sub-chassis. The auxiliary gain control is on the top side of the chassis.

Operating Conditions

It is worthwhile to remember here that the basic principle underlying screen modulation is the fact that the efficiency of a radio-frequency power amplifier (PA) is, within limits, proportional to the screen voltage. In order to obtain good linearity with screen modulation, the tube current as well as the tube efficiency should *both* vary in direct proportion to the instantaneous screen voltage, so that, the PEP output at modulation peaks will be *four* times the carrier output without modulation. It follows that the d.c. screen voltage should be nearly half of that used for c.w. operation, maintaining a low tube efficiency of about 35%.

The issue now arises as to why many screen modulated transmitters put out a mediocre signal. For proper screen modulation, the following requirements should be met.

(1) The plate voltage of the PA should be quite high, preferably equal to the maximum recommended c.w. rating. This is 750 volts for 807/1625 tubes. Unless the plate voltage is high enough, the screen voltage loses its control on the tube conductance at the positive peak of its modulation swing, due to saturation effects.

(2) The proper d.c. screen voltage should be chosen so as to maintain half of the peak efficiency that can be attained at modulation peaks. With 807/1625 tubes, this is around 125 volts, but it can be raised somewhat by carrier control, provided the plate voltage is high enough. In general, the *higher* the plate voltage, the *higher* can be the screen voltage, subject to the limitations of plate dissipation and curvature of the screen characteristic.

(3) Since the screen impedance of the PA varies with the instantaneous screen voltage,

the d.c. screen voltage should be obtained from a regulated supply or carrier control should be used. During modulation, the d.c. screen current, which is simply the time average of the instantaneous screen current over a cycle of modulation, shows a marked increase. Consequently, if a screen-dropping resistor is used without carrier control, the d.c. screen voltage *drops* with deep modulation, causing non-linearity and splatter at the downward peaks of the modulation swing. In the writer's opinion, this accounts for the mediocre performance of many a screen-modulated transmitter.

(4) The operating bias, either fixed bias or self-bias, and the grid current should lie *in between the values recommended for c.w. and plate modulation*. For 807/1625 tubes, the bias voltage should be −65 to −75 volts and the grid current 3 to 4 ma.

(5) The PA should be loaded much more heavily than for c.w. In the absence of an oscilloscope, the proper loading can be arrived at only by listening tests. With a self-biased final, the plate-current dip should be barely discernible as the final tank is tuned through resonance. If an r.f. voltmeter or ammeter is connected to the antenna line, the meter should never show a downward flicker with modulation. Without carrier control, there should be a slight upward flicker at modulation peaks.

(6) The audio output of the screen modulator should be heavily swamped by a load resistor placed across the secondary of the modulation transformer. This minimizes audio distortion due to the varying screen impedance of the PA during modulation.

With a final employing 807/1625 tubes in parallel at plate, screen and bias voltages of 750, 125 and —70 volts respectively, the plate input will run around 45 watts per tube. At 35% efficiency, the plate dissipation is as high as 30 watts and the tube will run quite hot. If, however, the plate shows any color, the screen voltage should be lowered to the extent necessary.

Carrier Control

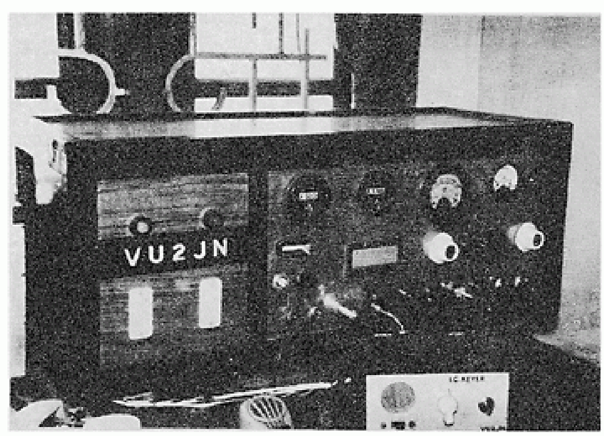
The main factor limiting the output from a screen-modulated PA is the low tube efficiency and hence high plate dissipation. Because of the complex wave-form of the speech signal modulating the screen, a somewhat higher average output can be realized by keeping the d.c. screen voltage and hence the plate input low, and raising it momentarily in accordance with the amplitude of the modulating audio signal. In the writer's transmitter, the screen voltage under no-modulation conditions is 125 volts, and with full modulation it is raised to 175 volts. This is only a moderate amount of carrier control and does not give rise to the somewhat unpleasant "boominess" noticeable in some commercial transmitters employing deep carrier control. In order to have fast response and low distortion, the time-constant of the carrier control circuit should be about 0.1 second.

Design

Let us consider the design of a screen-modulated PA, utilizing three 807/1625 tubes in parallel and running an input of about 150 watts.

The screen impedance of the PA varies with the instantaneous screen voltage but, as an approximation, it can be taken to be the d.c. screen impedance under c.w. conditions, *i.e.* about 45,000 ohms. For three tubes in parallel, the modulating impedance is 15,000 ohms. Adopting a swamping resistor of 10,000 ohms 10 watts, the net load on the secondary of the modulation transformer is 6,000 ohms. Using a receiver output tube as the modulator, its output impedance will be about 5,000 ohms. Hence the turns ratio of the modulation transformer should be $(5000 : 6000)^{0.5}$ or 1: 1.1.

Adopting carrier control, let the maximum d.c. screen voltage with full modulation be 175 volts. For complete cut-off of the carrier at the downward peak of the modulation swing, the peak a.c. voltage should be 10% greater than the d.c. voltage, *i.e.*, about 195 volts. This corresponds to 140 volts rms. The power delivered by the



VU2JN's 150 watt c.w./a.m. transmitter incorporating the Deluxe Screen Modulator.

secondary of the modulation transformer will then be $140^2/6000 = 3.3$ watts. Assuming a transformer efficiency of 75%, the primary power required is less than 5 watts.

The Modulator Circuit

Figure 1 shows the circuit-diagram of the modulator. The audio signal from the microphone is first amplified by a low-noise 6AU6 stage, and passes through separate gain controls to the two sections of an ECC83. One section is used in the speech amplifier line, while the output of the other section is rectified by a silicon signal-diode to provide a negative control voltage with a time-constant of about 0.1 second for carrier control. The control voltage also operates a modulation indicator using an EM84 magic-eye tube. Another silicon diode rectifies the audio to provide a fast-attack slow-decay a.g.c. voltage with an attack time-constant of about 0.05 second and a decay time-constant of 1.5 seconds for the purpose of volume compression. This voltage is applied to the suppressor grid of the 6AU6, so as to maintain a reasonably uniform output with widely varying microphone inputs. The entire speech amplifier is built inside a completely closed aluminum box, and tube shields are used for the 6AU6 and ECC83.

The modulator tube is a 7408 which is a high-fidelity version of the 6V6. With a 300-volt power supply, this tube provides more than 5 watts output at 7% total harmonic distortion. An EL84 may also be used but the THD will be about 10%. The modulation transformer uses a good audio-type core and has primary and secondary impedances of 5,000 and 6,000 ohms. The audio output, swamped by a 10K 10w. wire-wound resistor, is passed through 68-ohm 1-watt decoupling resistors to the PA screens. Each screen is bypassed to the cathode by a 0.001 mf 1000 v. disc ceramic right at the tube base. Some manuals suggest using screen stopper resistors, but the writer found that the stoppers actually increase the tendency for v.h.f. oscillation.

The carrier control circuitry is also shown in fig. #1. The EL84 control tube functions

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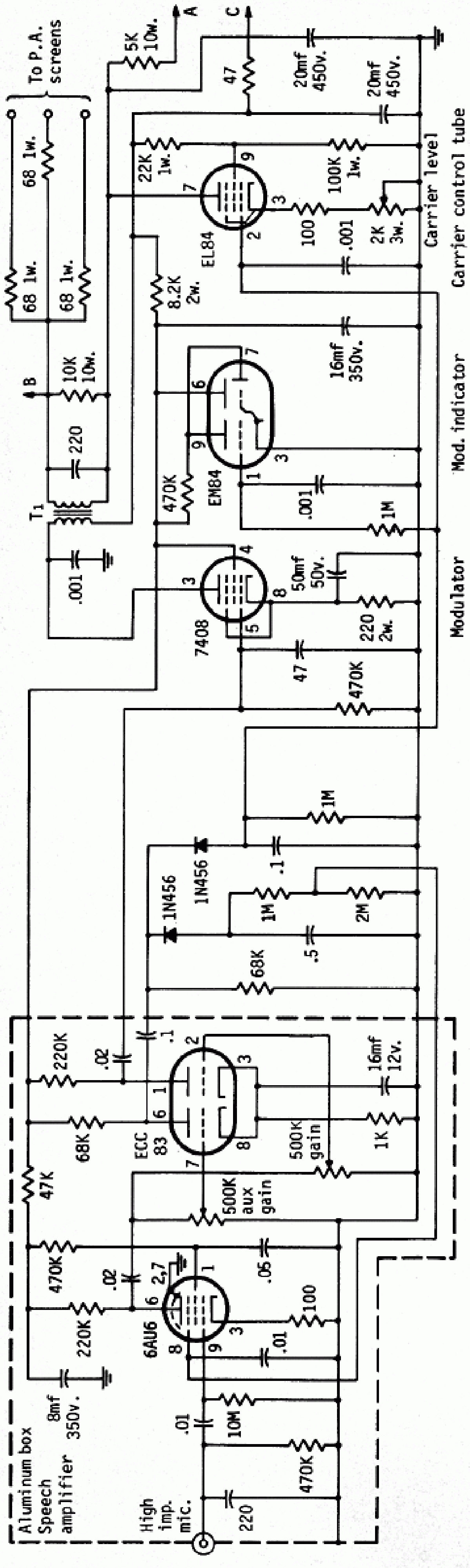

Fig. 1—Schematic of the Deluxe Screen Modulator. Transformer T_1 is a 5 watt modulation transformer, 5000 ohm pri., 6000 ohm sec.

Screen Modulator [*from page 39*]

as a controlled screen bleeder responding to the negative control voltage derived from the audio. A 2K 3w wire-wound potentiometer on the cathode of the EL84 sets the no-signal screen voltage to 125 volts, while the auxiliary gain control sets the screen voltage with full audio to 175 volts. ■