Notes on

CATHODE MODULATION

By FRANK C. JONES,* W6AJF

Optimum adjustment of a cathode modulated r.f. amplifier depends primarily upon the amount of audio power available from the modulator, assuming that there is a reserve of r.f. excitation. The r.f. excitation requirements are low under all conditions of adjustment; therefore ample r.f. excitation for all modes of operation will be assumed.

The ideal conditions for cathode modulation with a given r.f. amplifier and a.f. modulator are those under which the a.f. amplifier is called upon to deliver its maximum undistorted output at 100 per cent modulation. Under these conditions maximum efficiency and output can be obtained, and the voice quality as heard on the air will always be sufficiently good for amateur or communication work.

If the available a.f. power is approximately 5 per cent of the d.c. power input to the plate circuit of the modulated r.f. amplifier, the grid bias circuit should be by-passed back to ground (point C in figure 1). The full a.f. voltage should be applied to the grid circuit and the by-passed grid leak or fixed bias supply should connect to point C on the modulation transformer. The grid current should be low if complete modulation is desired, usually about 1 to 3 ma. per tube. The cathode impedance will be between 500 and 1000 ohms for orthodox amplifiers, either push-pull or single ended.

Measurements made with a number of different r.f. amplifiers ranging from a 6L6-G up to a 250TH gave approximately the same values of cathode impedance and little difference was noted when two tubes were operated in push-pull. Therefore a value of about 1000 ohms can be taken as average for the condition of adjustment in which the available a.f. power is approximately 5 per cent of the d.c. input.

If the available a.f. power is from 10 per cent to 20 per cent of the class C input, greater r.f. drive may be used and the efficiency and output will be greater. The grid bias return should be made to a tap on the output winding of the modulation transformer (point B). A center tap connection is suitable for a.f. powers of 10 per cent in the case of medium μ tubes. High μ tubes require less a.f. voltage in the grid circuit to produce the desired amount of grid bias modulation. With higher values of a.f. power, the grid leak should not be by-passed for audio frequencies, and it may be necessary to return it to a tap quite close to the filament end of the secondary of the modulation transformer (point A).

With greater r.f. drive there is less a.f. degeneration in the cathode circuit, and the cathode impedance will therefore be somewhat higher, usually between 1800 and 3000 ohms. A value of 2000 ohms can be taken as sufficiently close in all cases where the available a.f. power is 10 per cent of the d.c. input, or as 3000 ohms where the available a.f. power is 20 per cent of the a.f. input.

With the 10 per cent ratio, the d.c. grid current should be from 5 to 10 ma. per tube

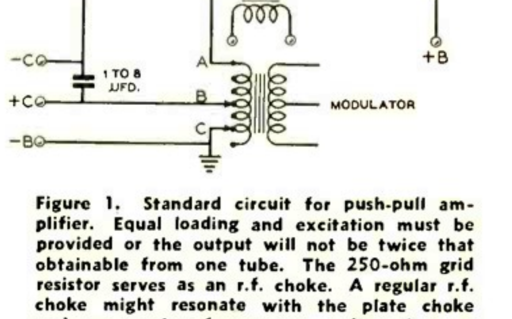

Figure 1. Standard circuit for push-pull amplifier. Equal loading and excitation must be provided or the output will not be twice that obtainable from one tube. The 250-ohm grid resistor serves as an r.f. choke. A regular r.f. choke might resonate with the plate choke and cause a low frequency parasitic. A parasitic choke may be required in one grid lead to one tube in order to prevent u.h.f. parasitics.

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and the d.c. bias should be from 3 to 7 times cutoff. Higher μ tubes should be run at a greater number of times cutoff. With a 20 per cent ratio (a.f. to d.c. input), the d.c. grid voltage should be at least twice cutoff for low μ tubes, 4 to 7 times cutoff for medium μ tubes (20 to 30) and 7 to 10 times cutoff for high μ tubes. The d.c. grid current should be from 10 to 20 ma. per tube. With the 20 per cent ratio, the carrier efficiency can be quite high due to the relatively high degree of r.f. excitation. In actual practice, efficiencies of from 65 to 70 per cent have been obtained with harmonic distortion of less than 6 per cent at 90 per cent modulation (20 per cent a.f. ratio).

Relative Operation Data

As an example of what to expect with a cathode modulated r.f. amplifier running at high plate voltage and limited to a plate dissipation of 100 watts, the following carrier powers can be obtained with modulation percentages and distortion tolerances suitable for amateur service:

5% ratio a.f./d.c. input	.....100 w. carrier
10% ratio	.....150 w. carrier
20% ratio	.....225 w. carrier

In case the cathode modulation transformer has no secondary taps, a 25,000-ohm 50-watt resistor with a slider tap can be connected across it, and the grid bias lead connected to the tap. With the tap in the center of the resistor, the two halves of the resistor act in parallel so far as the d.c. is concerned, and provide 6250 ohms of grid leak bias in addition to the regular bias.

An economical method of operation of a cathode modulated amplifier when the a.f. power is limited to between 5 and 10 per cent of the d.c. plate input is to drive the grid somewhat harder and not attempt to modulate quite as high a percentage. The grid current should be about 10 or 20 ma. per tube for this type of operation, and the bias between 6 and 10 times cutoff. The modulation transformer tap should be adjusted for 2000 ohms impedance, and a combination of fixed and grid leak bias used. A 10,000-ohm grid leak (*not* by-passed for a.f.) is typical for two tubes. About 100 volts of fixed bias (by-passed if not battery bias) should be supplied, or else an unbypassed cathode resistor of about 300-500 ohms used in the modulated stage. For a single-ended amplifier the same values hold except that the grid leak should be about twice as high in value.

Either neutralized triodes or any variety of screen grid tubes can be used for this type of operation. Screen grid tubes and very high μ triodes should be run at the highest possible plate voltage for good efficiency and ease of antenna coupling adjustment. Under these conditions, the antenna coupling is not critical and excellent voice quality can be obtained.

A typical amplifier operating at present in the 160-meter band under these conditions has 1500 volts on a pair of 812's, 300 ma. plate current, a 500-ohm cathode resistor, a variable grid leak, 40 ma. grid current, and a measured carrier output of 275 watts. The modulator consists of a pair of class AB_1 6L6's fed directly from a phase inverter. The 812's are being "pushed" a bit, but these values are given as typical of amateur operation. Oscilloscope patterns indicated a limit of about 60 per cent undistorted modulation, but all stations worked report excellent voice quality with the carrier heavily modulated. A check revealed less sideband splatter than when lower input and a greater modulation percentage was used, and the 100 per cent increase in carrier seems to more than offset the slight decrease in modulation percentage, the modulation percentage still being sufficient to elicit reports of "heavy modulation." Similar results were obtained with the transmitter operating on the higher frequency bands.

Parasitics

The importance of making sure the modulated amplifier is perfectly neutralized and free from parasitics applies to a cathode modulated amplifier the same as to any other type of modulated amplifier. Any parasitic oscillation due to lack of neutralization, electromagnetic feedback between grid and plate coils, r.f. choke low frequency parasitics, or (most important of all) u.h.f. parasitics, will usually produce poor voice quality and possibly splatter.

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Because cathode modulation can be used satisfactorily over a wide range of operating conditions, depending upon the relative amounts of plate modulation and grid modulation utilized, considerable confusion has arisen regarding optimum adjustments. In this article Mr. Jones gives some hints on design and adjustments which are of signal importance to every amateur interested in cathode modulation.

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To test the amplifier for susceptibility to parasitics, proceed as follows: Remove the excitation, reduce the bias to zero, and apply reduced plate voltage of such value that the plate dissipation is less than the safe maximum. There should be no grid current reading, and the plate current should remain absolutely constant when first the grid and then the plate tuning condensers are rotated from minimum to maximum capacity. There should be no indication when a neon bulb is touched to various parts of the plate circuit. An Ohmite parasitic suppressor in *one* grid lead will in almost every case cure u.h.f. parasitics in an amplifier. Methods for checking for the presence of all kinds of parasitics and means of eliminating them will be found in the RADIO HANDBOOK. It is *extremely important* that all traces of parasitics be removed from the modulated amplifier before it is put on the air.

Amateurs appear to worry more about getting an "exact impedance match" between the modulator and the cathode circuit of the modulated stage, while actually it is of greater importance to make sure the amplifier is free of all types of parasitics and r.f. feedback. The cathode impedance is not critical, and an impedance mismatch of 2 to 1 or even 3 to 1 can be tolerated without noticeably affecting the voice quality. This applies especially to modulators using push-pull 6L6's, as the plate-to-plate load on 6L6's can be varied over wide limits without seriously affecting their modulating ability.

Antenna for 112 Mc.

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than on 56 Mc. The array is bidirectional, and for complete coverage should either be arranged for rotation through 135 or more degrees, or else two arrays used at right angles to each other.

Other Arrays

The close-spaced unidirectional arrays widely used on the lower frequency bands can be used with great success on 112 Mc. The elements may be oriented either vertically or horizontally, depending upon which type of polarization is desired. Close-spaced driven arrays of the W8JK type also can be used to give excellent gain and directivity. The important precaution to observe is to avoid, if possible, all insulation at voltage loops on arrays having low radiation resistance by making the elements self-supporting and anchoring them at points near the voltage node. When insulators are absolutely necessary, they should be of the very best quality when used at points of high voltage.