The 6DQ5 — the latest of a series of tubes of increasingly higher performance in wide-angle TV sweep circuits — takes a relatively tremendous plate current at zero grid bias, and with only 150 volts on the screen. This offers the possibility of obtaining high power output at comparatively low plate voltage, a possibility investigated by the authors and reported in this article. Conclusion: The 6DQ5 has a lot to offer as an s.s.b. linear amplifier.

Linearity and Power Output with a New TV Sweep Tube

The 6DQ5 as a Linear Amplifier

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In considering a tube type for use as the output linear amplifier of a mobile s.s.b. transmitter, tests were made on the 6DQ5, a new receiving type designed for horizontal amplifier service in color TV receivers.[1] Published curves show that a high peak plate current of 700 ma. flows at the time the instantaneous plate voltage swings down to 50 volts across the tube. This operation occurs without driving the grid positive and for a screen voltage of only 150 volts. Large plate voltage swings give high efficiency,[2] and large peak plate currents give high output power. The grid maintains good control of plate current down nearly to cutoff, which suggests that linearity can be obtained with a fairly small no-signal plate current, lowering the average d.c. power requirement. To verify these facts a graphical analysis was made to give operating values and computed linearity. These values were used for an experimental breadboard.

Linear Amplifier Requirements

Occasional speech peak powers are so much greater than average speech power that something akin to a radar pulse operation is desired. These peaks are not too important in "getting the message through" but cannot be easily clipped [3] without causing splattering in sideband. For this reason a TV deflection tube designed for pulse service without the grid driven positive performs well. If properly designed Class AB_2 operation is used peaks are not clipped as the grid is driven farther positive, but large drive power is required to drive the grids positive. Puckett has described this for grounded-grid operation.[4]

In general, Class AB_1 amplifiers are limited in power output to the amplitude achieved when the grid is driven up to zero bias, while Class AB_2 amplifiers are limited in power output by heat dissipated in the plate at large inputs or simply by running out of grid power from the driver.

If flat-topping is allowed to occur only a small percentage of the time the average speech power is small compared with the peaks [5] and, hence, on the average the tube dissipation is not too much larger than the no-signal dissipation. For this reason our amplifier is operated at rated plate dissipation under no-signal conditions, and the low average power of speech prevents exceeding the rated plate dissipation too much. If precautions during tune-up are observed and sustained whistling is avoided, good tube life can be expected, especially in mobile service.

Comparable peak power output from a tube such as a 6146 cannot be obtained by running it above its ratings on peaks unless a plate voltage several times maximum rated is used. Such mobile supplies are uncommon, and the 6146 would be continuously overloaded voltage-wise. The 6DQ5 is overloaded plate-current-wise, but during speech duty cycles only. Higher screen voltages are unsatisfactory because grid operation is then largely in the remote cutoff region, where there is diminishing control over plate current. This introduces large distortion in the cross-over region of the two-tone test, and appears as pronounced concavity in the trapezoidal linearity pattern.

Since similar considerations hold for audio-frequency amplifiers it appears that a 200-watt Class AB_1 modulator for a.m. (pardon the expression!) could be built using a pair of 6DQ5s

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[1] The manufacturer voiced no disapproval of this particular use of the tube, but the tube warranty does not include such experimental use.

[2] R. L. Norton, "Transmitting Tubes for Linear Amplifier Service," available from Penta Labs., Inc., Santa Barbara, California. This paper discusses tube requirements for efficient linear output. The 6DQ5 is an example of an efficient type.

[3] Phil J. Ferrell, "Constant Amplitude Speech," *I.R.E. National Convention Record 1958*, Part 8, p. 190.

[4] Puckett, "Notes on Grounded-Grid R.F. Amplifiers," *QST*, December, 1954.

[5] H. Magnuski and W. Firestone, "Comparison of SSB and FM for VHF Mobile Service," *Proc. IRE*, December, 1956, p. 1834. This paper shows that for 2 per cent flat-topping speech, the r.m.s. power is 1/8 of p.e.p.

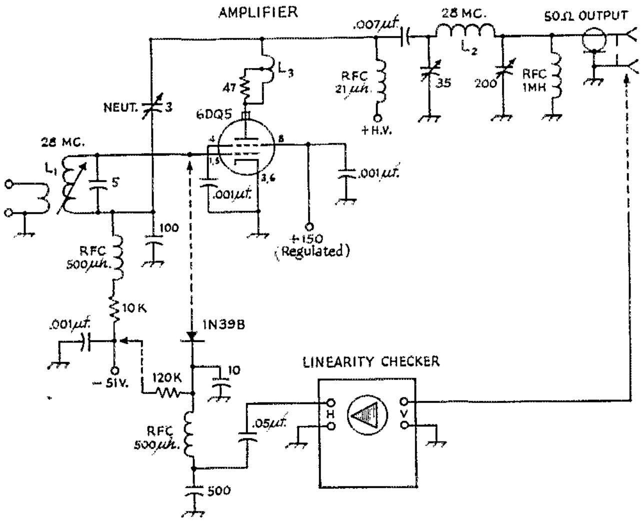

Fig. 1—Circuit diagram of the experimental linear amplifier and set-up for checking linearity. Capacitances are in µµf. unless otherwise specified.
L_1—1 µh. with 2-turn link.
L_2—1 µh. (6 turns No. 16 spaced wire diam. on 1½-inch form).
L_3—5 turns No. 20, tapped at center, wound on 47-ohm 1-watt resistor.

and would require only a small voltage-amplifier tube as a driver, with no driver transformer.

Linear Amplifier Construction

An amplifier was built using the circuit shown in Fig. 1 to operate at 29 Mc. Bruene capacitance-bridge neutralization and a pi-network output circuit were used. A regulated screen voltage must be furnished but since the maximum screen current required is about 8 ma. a VR tube is ideal. A variable bias supply was used, but series-connected dry batteries can be substituted since no current is drawn from them. The heater requires 6.3 volts at 2.5 amperes.

In resonating the grid and plate coils the unusually large tube input capacitance of 23 µµf. and output capacitance of 11 µµf. should be taken into consideration. A plate tank Q of 12 was obtained by using the plate tuning capacitance per meter of wavelength shown in Table I, multiplying it by the wavelength in meters of the band on which operation is planned and subtracting 11 µµf. for tube capacitance. The coil that resonates with this value of capacitance gives the correct L/C ratio for a Q of 12.

The parasitic suppressor data also are given in Fig. 1. With this design the plate parasitic suppressed in our circuit was at 130 Mc., so TVI should not be much of a problem.[6] This relatively high frequency attests to the low-inductance leads of the tube when the double pin connections to screen, cathode, and grid are used.

Since we measured 80 watts output with less than 0.4 watt driving power it is fairly obvious that good shielding between the grid and plate circuits is necessary. We did this by keeping all

[6] Grammer, "V.H.F. Parasitics in Beam Tetrodes," *QST*, August, 1952.

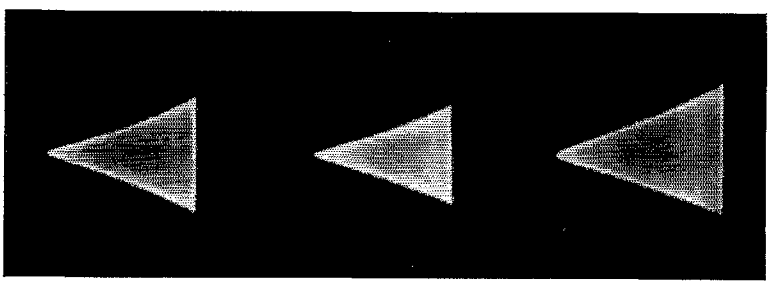

Fig. 2—Oscilloscope patterns showing linearity. Conditions for A, left, and B, center, as follows:

	A	B
Plate voltage	700	500 volts
Screen voltage	150	150 volts (regulated)
Grid voltage	−51	−46 volts
Zero-signal plate current	35	48 ma.

	A	B
Max.-signal plate current (single tone)	190	185 ma.
Max.-signal screen current	5	8 ma.
Power output	80	53 watts p.e.p.
Frequency	29	29 Mc.

The pattern at C, right, taken by applying the same signal to both input terminals of the test circuit, shows the linearity of the test circuit alone, for comparison with the amplifier patterns at A and B. An ideal amplifier would give exactly the same pattern as C.

Table I

	Calculated Values [1]		Measured Values [2]		
Plate Voltage	700	500	700	500	volts
Screen Voltage	150	150	150	150	volts
Plate Current (zero sig.)	35	48	35	48	ma.
Bias Voltage	−54	−49	−51	−46	volts
Plate Current (single tone) ma.	194	218	190	185	ma.
Screen Current (single tone) ma.	—	—	5	8	ma.
Input D.C. Watts (single tone)	136	109	133	93	watts
Output Power Watts (single tone)	101	71	80	53	watts
Tube Load Resistance	2080	1430	2000	1430	ohms
Plate Tuning Capacitance μμf./Meter of Wavelength [3]	3.3	4.6	3.3	4.6	
Efficiency	74	65	60	57	per cent

[1] These are calculated values. The calculated outputs must be decreased by 10 per cent or so, depending on circuit losses, to get realizable output.
[2] These are measured experimental values at 29 Mc.
[3] For a Q of 12, make plate tuning capacitance in circuit equal to this value times wavelength in meters of band operated, minus 11 μμf. of tube output capacitance. For example, on 20 meters, with plate voltage of 500, plate capacitance is $20 \times 4.6 - 11 = 81$ μμf.

the plate circuit, including the neutralizing capacitor, above the chassis and the grid circuit below.

Amplifier Operation

The tube was neutralized by putting a signal into the plate output terminals and adjusting for a null at the grid input side. Then the voltages were applied and the bias was adjusted to give 35 ma. static plate current with 700 volts on the plate. The required bias varied by a volt or two on different tubes tried. At this point the bias was decreased for an instant to cause 200 ma. plate current and the circuit checked for any parasitic output. Expected troubles associated with higher-capacitance tubes were nonexistent, and the ease of obtaining stable operation was a pleasant surprise. In fact, the parasitic suppresser was removed and only a very weak parasitic oscillation was present. This, however, was a single-band amplifier and more troubles would be expected in a band-switching design.

Drive was applied and loading increased until maximum output was obtained with drive just short of grid current. If loading is not sufficiently heavy the screen current will be higher than optimum. The output was quickly measured under these single-tone conditions by an r.f. voltmeter across the 50-ohm load and an output of 80 watts was indicated. The input was 190 ma. at 700 volts or 133 watts. This is 53 watts plate dissipation in a tube rated at 24 watts, so the precautions necessary at tune-up can be appreciated. The over-all efficiency was 60 per cent. Higher efficiency is difficult to attain at 29 Mc. without more specialized components. Circuit losses generally go up with frequency, so an output closer to the calculated 101 watts should be obtained on the lower frequency bands.

In consideration of the commonly available mobile plate supplies the circuit was then operated at a plate voltage of 500. An output of 53 watts was measured under the conditions shown in Table I. The grid drive was measured and appeared to be less than 0.4 watt.

A 6146 was placed in the circuit, and the screen voltage raised to 200 volts. The 6DQ5 produced a power output about double that of the 6146.

Linearity Measurements

A modulated drive was next substituted for the single-tone drive and the 1N39B diode envelope detector was connected to the 6DQ5 grid as shown in Fig. 1. The photograph of Fig. 2A shows the linearity with 700 volts on the plate and 80 watts p.e.p. output, while Fig. 2B shows the linearity for 500 volts on the plate and 53 watts p.e.p. output. The photo of Fig. 2C was made without the amplifier, thus giving a check on the linearity of the measuring circuit.

Calculations and Measurements Compared

Table 1 shows the calculated operating conditions for 700- and 500-volt plate supplies. The calculated power outputs of 101 and 71 watts do not include circuit losses. The last two columns show measured operating values and measured power outputs including circuit losses at 29 Mc. On lower frequencies, measured power outputs closer to the calculated values should be obtained since circuit losses are smaller.

Tube handbook curves for a screen voltage of 150 were replotted as constant current curves, and are shown in Fig. 3. Operating conditions and power outputs for plate voltages of 700 and 500 were computed using the Eimac Computer aid.[7] Also, a linearity curve, shown in Fig. 4, was computed by taking various grid drive voltages

[7] Eitel-McCullough, Inc., San Carlos, California, "Tube Performance Computer," Applications Bulletin No. 5.

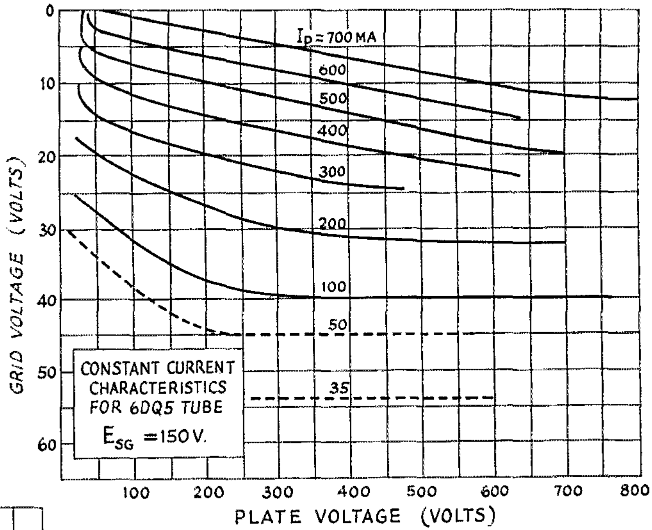

Fig. 3—Constant-current curves for the 6DQ5. This set of curves was constructed from the published plate family of curves for the tube.

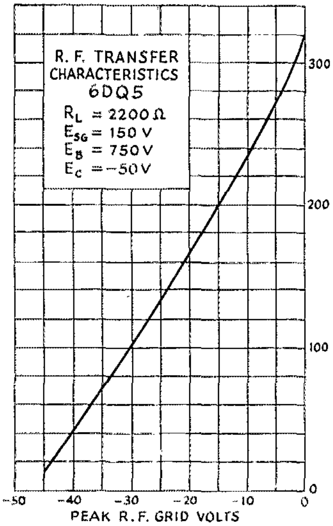

Fig. 4—Transfer characteristic of the 6DQ5 as a linear r.f. amplifier, based on data obtained from the experimental 29-Mc. set-up.

and computing r.f. output amplitudes for each drive level.

Summary

As a Class AB_1 linear amplifier, the 6DQ5 produces about twice as much power output as a 6146 at similar linearity and with similar plate voltage. Sizeable p.e.p. output of 53 to 80 watts can be obtained with one tube and a 500- to 700-volt mobile plate supply. The grid-drive requirement on 29 Mc. was less than 0.4 watt. The tube dissipation is exceeded during talk periods, but the compactness, large output, and low drive power are attractive for mobile use. *Exceeding dissipation, as proposed, is not only* believed justifiable because of the low duty cycle of speech but is even more tolerable in mobile use because of shorter periods of operation. *Measured linearity is fairly good; rough calculations* give 25 db. suppression of spurious products in the unwanted sideband, and the large peak-power capability tends to minimize flat-topping *and the splatter it causes.* As a final advantage, the 6DQ5 costs less than the 6146. QST

Strays

Here is the October schedule for the Western MARS Technical Net.

AF-MARS Western

(Sundays 1400 local time, 7832.5 3295, 143,460 kc.)

Oct. 4 — Bowdoin Arctic Exploration.

Oct. 11 — Net Session and Conversion Information.

Oct. 18 — A PNPN Switch.

Oct. 25 — A Review of Parametric Amplifiers.