EF 8 Low-noise variable-MU R.F. amplifier pentode

The EF 8 is a variable-mu R.F. amplifier the chief feature of which is its very low noise factor. As the noise produced in screen-grid and pentode valves is caused mainly by the distribution of the current between the screen and the anode — from which point of view a low screen current is advantageous — efforts have been made in the design of this valve to keep this current as low as possible. In principle, the construction of the EF 8 is similar to the conventional pentode, embodying control, screen and suppressor grids, but between the control grid and screen of this valve an additional grid has been introduced, wound with exactly the same pitch as the screen and normally connected to the cathode. The turns of this extra grid are situated exactly opposite those of the screen grid and this auxiliary electrode repels and bunches the electrons on their way towards the anode, the bunches thus passing just between the turns of the screen grid. In this way, the number of electrons actually arriving on the screen is very much smaller than when the auxiliary grid is not used. Fig. 3 illustrates the paths of the electrons through the different grids.

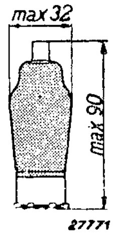


Fig. 1
Dimensions in mm

Fig. 2
Arrangement of electrodes and base connections.

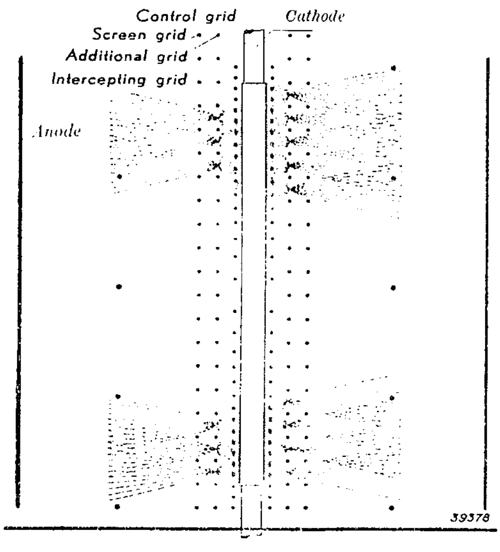


Fig. 3

Paths of the electrons from the cathode to the space between screen grid and anode. The second grid together with the third form a focusing device the actual focus of which lies roughly in front of grid 2. In this way the electrons are passed through the meshes of the third grid, resulting in a very low current to this grid.

The purpose of grid 3 is to draw from the cathode a sufficient number of electrons through the two grids (grids 1 and 2) with their low potential and this can take place only if the conductance of g_3 through g_2 is high enough, which means a wide pitch for grids 2 and 3. For the same reason it is necessary to increase the screen voltage, which in the EF 8 is 250 V instead of the usual 100 V. One drawback of this arrangement is that the dimensions of the various grids must be such as to permit the anode to exert sufficient attraction through the grids g_4, g_3 and g_2.
In consequence, the anode-to-grid capacitance is higher than usual in

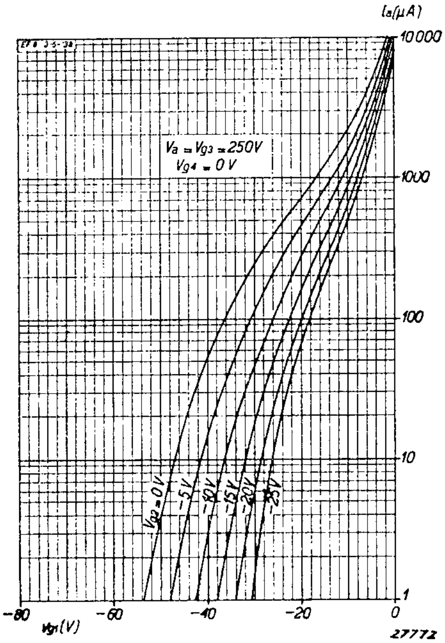


Fig. 4
Anode current as a function of the grid voltage, for different values of the bias on grid 2.

a pentode such as the EF 5 or EF 9, being max. 0.007 $\mu\mu$F, as against 0.003 $\mu\mu$F in the case of the EF 5. The impedance is therefore also lower, viz. 0.45 megohm. However, as the EF 8 finds practical application only as an R.F. amplifier, that is, as the input valve in a receiver, the higher C_{ag1} and lower impedance do not in themselves form an objection. In the short-wave range the circuit impedances are in any case on the low side, whilst in the normal broadcast bands the opportunities for amplification by means of this valve would, usually, not be fully utilized, since the signal input to the frequency-changer would then be too great.

Amplification is greatest behind the input valve of the receiver, but it is much less in the following stages and the latter therefore contribute in a very much smaller degree towards the general background noise. Usually the input valve is a frequency-changer and, as is generally known, this type of valve is fairly noisy, for which reason, in high-performance receivers where many different precautions are taken to suppress interference, including background noises, an R.F. pre-amplifier is employed.

The use of the EF 8 as R.F. amplifier ensures excellent characteristics from the point of view of the suppression of cross-modulation. The valve is generally provided with automatic gain control and its high performance should therefore be maintained especially on very strong signals, that is, with the full control applied to the valve. A very satisfactory cross-modulation curve is obtained on an anode current of 8 mA in the uncontrolled condition and the special design of the valve ensures that background noise, for which this high anode current would otherwise be an adverse factor, is kept at an extremely low level.

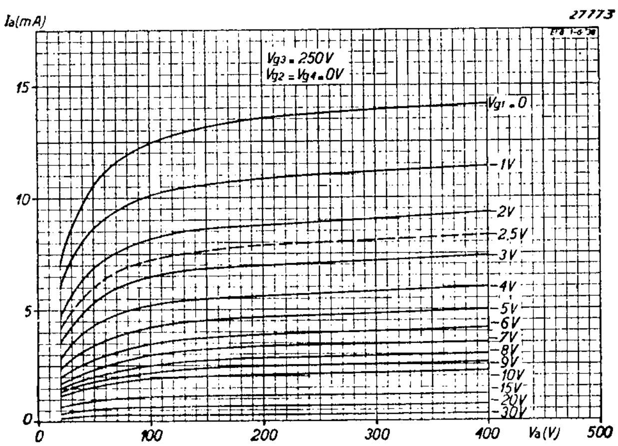


Fig. 5
Anode current as a function of the anode voltage, for various values of the bias on grid 1; grid 2 is connected to the cathode.

In connection with these features, the screen current has been effectively reduced to 0.2 mA,

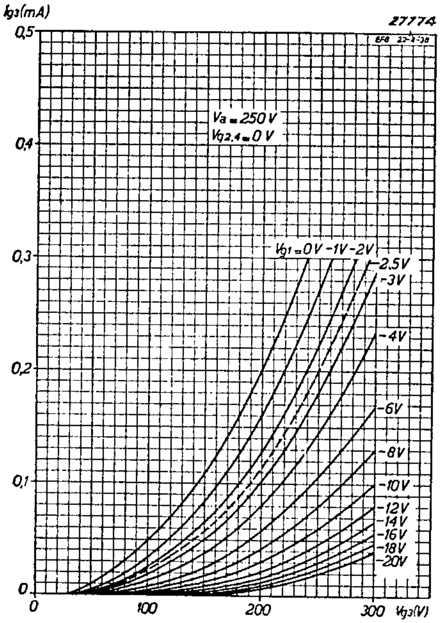


Fig. 6
Screen-grid current as a function of the screen voltage, for different values of grid bias; grid 2 connected to cathode.

in contrast with which that of the EF 5 is 2.6 mA and, due to this low current, the equivalent noise resistance does not exceed 3,200 ohms.

The corresponding value in the EF 5 is 15,000 ohms, which means that the EF 8 is five times better from the aspect of freedom from background noise.

At the same time, the valve, as such, is not the only source of noise; the circuits and resistors connected to the grid are also contributory factors and ultimate improvement in the signal-to-noise ratio is obtained more especially in certain particular cases. For example, if the impedance of the tuned circuit connected to the grid is, say, 10,000 ohms at 15 m, the arrangement may be regarded thus, that the noise in the first stage is produced by a resistance of 10,000 + 3,000 = 13,000 ohms; with the EF 5, the total noise resistance would be 10,000 + 15,000 = 25,000 ohms. Now the noise voltage of a resistance is proportional to the root of the resistance value, and this shows an improvement, in the case of EF 8, of $\sqrt{\frac{25,000}{13,000}} \cong 1.4$ times.

At the low-frequency end of the short-wave range, say at 50 m, the impedance of the circuit is usually much lower, being of the order of 3,000 ohms, and here the advantages of the EF 8 come more to the fore, since the total noise resistance, using that valve, becomes 6,000 ohms, as against 18,000 ohms in the case of the EF 5. This yields an improvement factor, with respect to freedom from noise, of $\sqrt{\frac{18,000}{6,000}} = 1.73$

On the other hand, in the medium- and long-wave ranges circuit impedances are much higher, being in the region of 100,000 ohms, and the preponderance of the noise, both with the EF 8 and the EF 5, is due to the circuit and not to the valve; the EF 8 then generally gives the better results. If, for any reason, the circuit impedances in these ranges are also comparatively low, the EF 8 will still ensure greater success.

In order to avoid an excessive signal

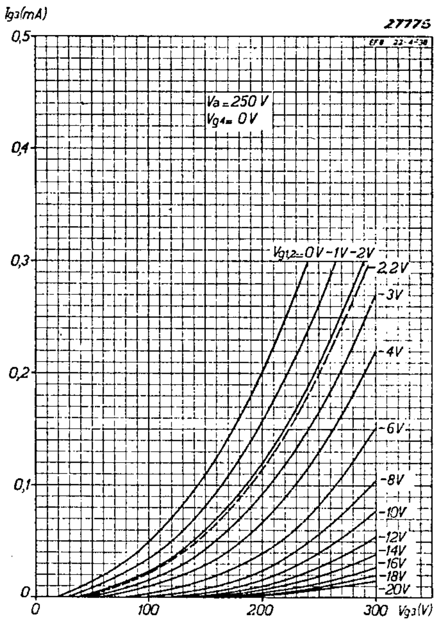


Fig. 7
Screen-grid current as a function of the screen voltage, for different values of grid bias; grid 2 connected to the bias of grid 1.

voltage being applied to the frequency-changer of a receiver employing R.F. amplification, the latter should not be too high, a factor of about 10 being quite sufficient. When "noisy" valves are used successive amplification should be suppressed somewhat to limit the noise, and this can be effected by taking a tapping from the second R.F. circuit. Conversely, if the valve is not noisy the amplification preceding the valve may be reduced so that also the R.F. valve will have weaker signals to handle, this being better from the point of view of reducing cross-modulation and modulation distortion. The signal on the R.F. valve is reduced by connecting the grid to a tapping in the circuit and this has the effect of considerably lessening the background noise.

The noise resistance of the EF 8 increases

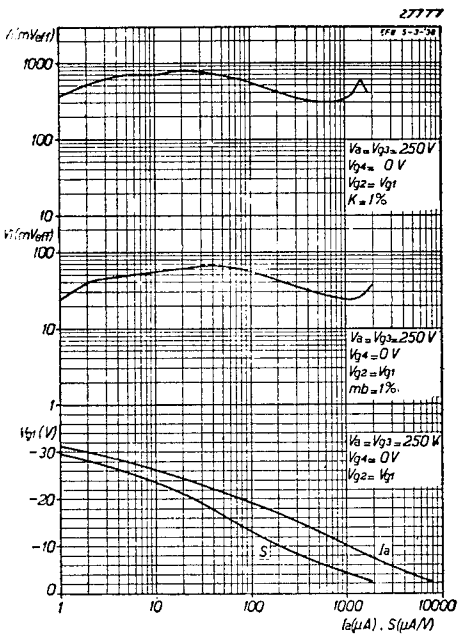


Fig. 9

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross-modulation; grid 2 connected to control voltage on grid 1.
Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance *S* and anode current *Ia* as a function of the grid bias.

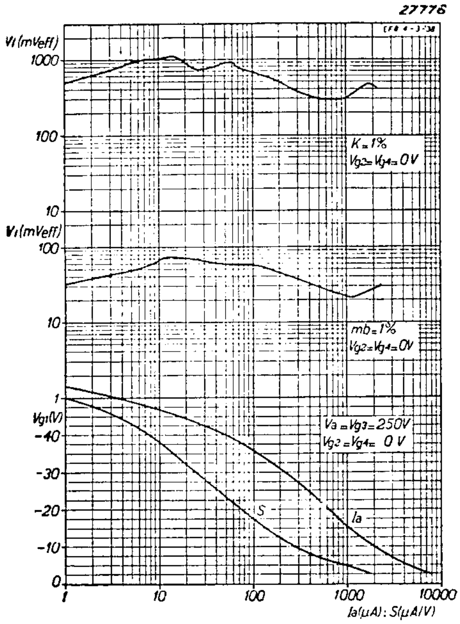


Fig. 8

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross-modulation. Grid 2 connected to cathode.
Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance *S* and anode current *Ia* as a function of the grid bias.

according as the grid becomes more negative, but as a higher control voltage from the A.G.C. corresponds to a stronger signal the ratio of signal to noise is nevertheless improved.

On short waves the impedance values of the EF 8 are very good and ensure satisfactory amplification in this range: as the H.F. resistance between anode and grid, to earth, as compared with that of the ordinary practical circuit is quite high, amplification values can be obtained from the EF 8 in the short-wave range equal to the product of anode impedance and mutual conductance.

Grid 2 may be either connected direct to the cathode or it may be included with grid 1 in the automatic gain control circuit. In the latter case the control is more pronounced, but the cross-modulation curve is then not so good as when grid 1 is connected to the cathode: it is

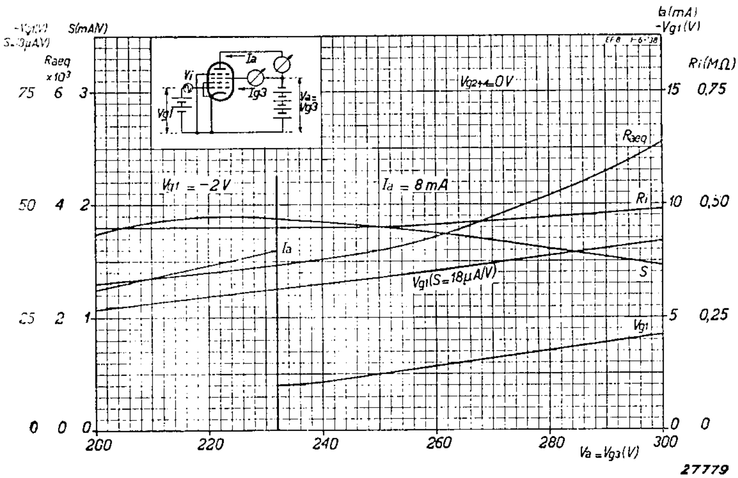


Fig. 10
Characteristics relating to various data as a function of the anode and screen-grid voltages; grid 2 connected to cathode. Left-hand side of the vertical line: at $Vg_1 = -2$ V; right-hand side: at $Ia = 8$ mA.

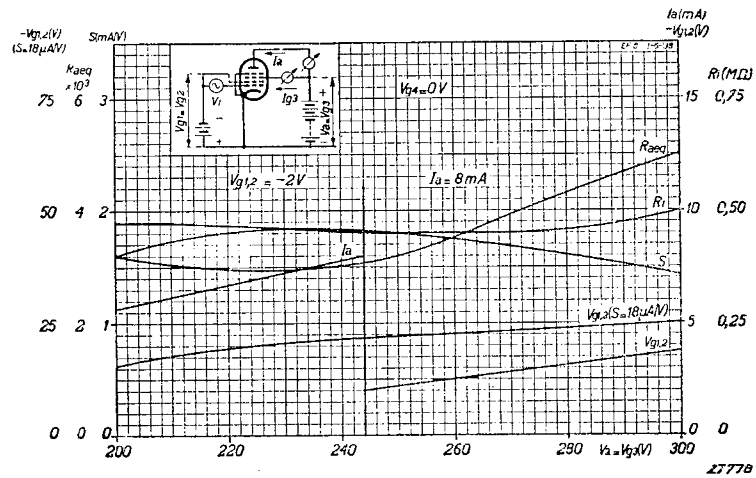
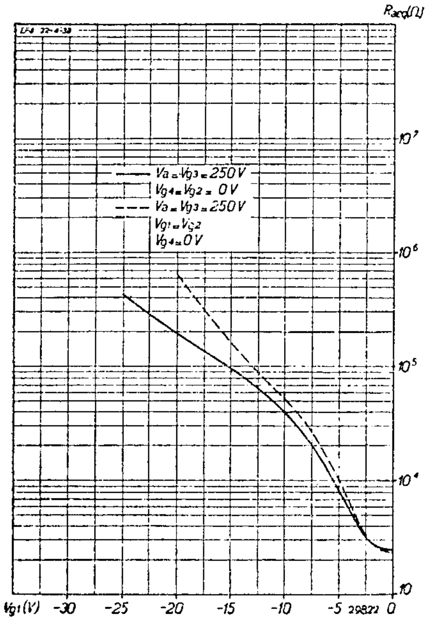


Fig 11.
Characteristics relating to various data as a function of the anode nda screen voltages. Grid 2 connected to control voltage on grid 1. Left-hand side of vertical line: $Vg_1 = Vg_2 = -2$ V. Right-hand side: $Ia = 8$mA



thus possible by means of the EF 8 to design A.G.C. circuits giving more, or less, control as required.

HEATER RATINGS

Heating: indirect, A.C. or D.C.; series or parallel supply.

Heater voltage . . . . V_f = 6.3 V

Heater current . . . . I_a = 0.200 A

CAPACITANCES

$C_{ag1} < 0.007\ \mu\mu F$

$C_{g1} = 4.6\ \mu\mu F$

$C_a = 7.8\ \mu\mu F$

Fig. 12
Equivalent noise resistance as a function of the grid bias. The broken line refers to the case where grid 2 is connected to the control voltage on grid 1; the full line is for the grid connected to cathode.

OPERATING DATA: EF 8 employed as R.F. amplifier

(g_2 and g_4 connected to cathode).

Anode voltage	V_a	= 250 V		
Voltage on grid 2	V_{g2}	= 0 V		
Screen-grid voltage	V_{g3}	= 250 V		
Voltage on grid 4	V_{g4}	= 0 V		
Cathode resistor	R_k	= 305 ohms		
Grid bias	V_{g1}	= —2.5 V [1])	—34 V [2])	—50 V [3])
Anode current	I_a	= 8 mA	—	—
Screen-grid current	I_{g3}	= 0.2 mA	—	—
Mutual conductance	S	= 1,800 μA/V	18 μA/V	1 μA/V
Internal resistance	R_i	= 0.45	> 10	> 10 M ohms
Equivalent noise resistance	R_{eq}	= 3,200 ohms	—	—

OPERATING DATA: EF 8 employed as R.F. amplifier

(g_2 connected to control voltage on grid 1; g_4 connected to cathode).

Anode voltage	V_a	= 250 V		
Screen-grid voltage	V_{g3}	= 250 V		
Voltage on grid 4	V_{g4}	= 0 V		
Cathode resistor	R_k	= 265 ohms		
Grid bias (grids 1 and 2)	$V_{g1} = V_{g2}$	= —2.2 V [1])	—22 V [2])	—28 V [3])
Anode current	I_a	= 8 mA	—	—
Screen-grid current	I_{g3}	= 0.2 mA	—	—
Mutual conductance	S	= 1,800 μA/V	18 μA/V	2.5 μA/V
Internal resistance	R_i	= 0.45	> 10	> 10 M ohms
Equivalent noise resistance	R_{eq}	= 3,200 ohms	—	—

[1]) Without control
[2]) Mutual conductance reduced to one - hundredth of uncontrolled value
[3]) Extreme limit of control.

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V
Anode dissipation	W_a	= max. 2.5 W
Screen voltage in cold condition	V_{g2o}	= max. 550 V
Screen voltage	V_{g2}	= max. 300 V
Screen dissipation	W_{g2}	= max. 0.08 W
Cathode current	I_k	= max. 12 mA
Grid voltage at grid current start (I_{g1} = + 0.3 μA)	V_{g1}	= max. —1.3 V
Grid voltage at grid current start (I_{g2} = + 0.3 μA)	V_{g2}	= max. —1.3 V
Resistance between grid 1 and cathode	R_{g1k}	= max. 3 M ohms
Resistance between grid 2 and cathode	R_{g2k}	= max. 3 M ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	= max. 100 V

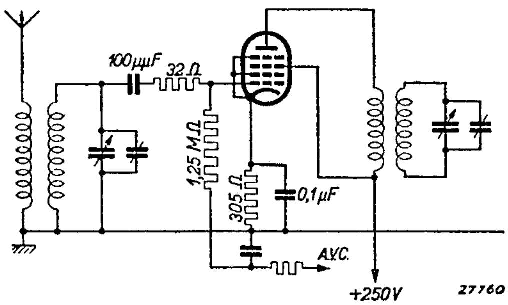


Fig. 13
Circuit diagram of the EF 8 used as R.F. amplifier in a superhet receiver with A.G.C. on grid 1 only.

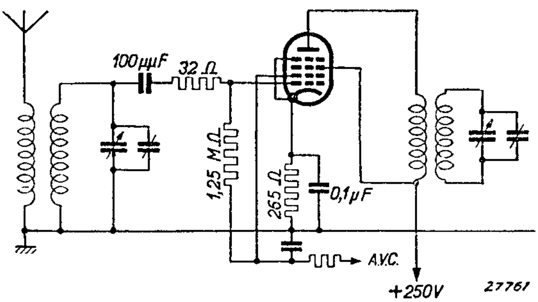


Fig. 14
As Fig. 13 but with A.G.C. on grids 1 and 2.

APPLICATIONS

The application of this valve is restricted to the first R.F. stage of a receiver. With respect to background noise it has outstanding properties in the short-wave range, as well as on medium and long waves. The very good cross-modulation characteristic, inter alia, is of considerable importance. Grid 3 may be connected direct or, better still, via a resistor of low value with decoupling capacitor, to the H.T. line. At voltages higher than 250 V it is necessary to increase the grid bias in order to avoid overstepping the scheduled maximum anode dissipation; this has the effect of reducing slightly the mutual conductance. Figs 10 and 11 give some useful data for this valve, at different values of anode and screen grid voltages.