U.H.F. Tubes for Communication and Measuring Equipment

U.H.F. TUBES
FOR COMMUNICATION AND MEASURING EQUIPMENT

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PREFACE

The use of electronic apparatus operating at frequencies of 300 Mc/s and higher is steadily extending in an ever widening field of applications.

Radio and radar for communication and navigation are vital elements of modern sea- and air-traffic and have greatly increased its efficiency and safety. Public services, e.g. police, fire, and medical departments largely depend on mobile transmitting and receiving equipment for rapid and effective action in emergencies. Balloon sondes have very much helped to increase the accuracy of weather forecasting, and at present, seamen, airmen and farmers all over the world are relying upon these forecasts in making vital decisions.

In all these applications the use of radio waves in the decimeter and centimeter ranges is imperative for various reasons, such as the overcrowding of longer wave ranges and the small power supply available in mobile and portable equipment.

To further add to the possibilities offered by conventional tubes with their relatively simple and reliable design and their well-known circuit technique even at the wavelengths required for use in the decimetric wave range, various improvements were introduced in these tubes. The use of centimetric waves, however, made it necessary to develop tube types which differ fundamentally from conventional tubes both in design and construction.

In this book the tube range for U.H.F. and S.H.F. waves is described in detail. In addition, some applications of tubes for the measurement of the noise factor at these high frequencies are dealt with.

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INTRODUCTION

The wavelengths for transmitting signals are steadily becoming shorter, which is due to the following reasons:

(1) The longer wavebands, which are suitable for broadcasting and telecommunication, are becoming more and more crowded.

(2) Apart from this overcrowding, television and frequency-modulated transmitters would occupy such wide bands with their broad frequency spectrum that the available space in the medium and long wavebands would scarcely be sufficient for a single transmitter.

(3) In radar techniques the use of extremely short wavelengths is required with a view to their specific properties, such as the possibility of producing narrow beams, thereby being reflected against small surfaces.

The new problems which arose by the urge to apply ever decreasing wavelengths were solved most satisfactorily by electronic engineering, by means of improvements and new designs of electron tubes.

The highest frequency at which conventional tubes still operate is determined by the following factors:

(1) Transit time effects. These effects become noticeable at frequencies at which the duration of one cycle of the alternating voltage is no longer large compared with the time required by an electron to travel from the cathode to the anode. At these frequencies the mutual conductance of the tube decreases, the input circuit is heavily damped, and the signal-to-noise ratio deteriorates.

(2) Undesired couplings caused by the capacitances, selfinductances and mutual inductances of the electrodes and their connections.

(3) Losses that increase with the frequency, such as dielectric losses occurring in the glass envelope and dissipative losses produced in the electrodes, and their connections; at very short wavelengths the latter losses predominate.

The most obvious method of reducing the influence of transit time effects consists in decreasing the interelectrode spacings. The clearance between the cathode and grid is particularly important, because in this space the velocity of the electrons is fairly small, as a result of which the time required by the electrons to cover this distance is relatively long. By mounting the cathode and grid close to each other, the mutual conductance of the tube is increased. It is true that the capacitance between these electrodes is also increased in this way, but the total result is an improvement of the tube properties as far as short-wave operation is concerned.

A reduction of undesired couplings and losses can be obtained by shortening the connections between the electrodes and their terminals. In some of the types described in this book (the EC 80, EC 81 and K 81 A) the electrode system is mounted on a glass disc into which the contact pins have been fused, which offers the possibility of minimizing the distance between the electrodes and the external circuit. The subminiature type DC 70 is provided with connecting leads which are fused into the glass disc and can be soldered directly to the wiring.

At frequencies exceeding approximately 500 Mc/s these tubes become unsuitable, and recourse must be taken to disc-seal triodes. In these tubes (the EC 55, EC 56 and EC 57) the concentric electrode system has been replaced by flat, equidistant electrodes. In this way extremely small interelectrode distances can be obtained, such as are required for minimizing the transit times. The electrode connections are formed by metal discs which protrude through the glass envelope into which they are fused, thus ensuring very small selfinductances. These discs are so arranged that they can easily be included in coaxial or waveguide systems. The EC 55 can be used on decimetric waves; the EC 56 and EC 57 are suitable for wavelengths down to 7.5 cm (4000 Mc/s).

By ingeniously taking advantage of the transit time effect, it has been found possible to construct electron tubes which are suitable for use on centrimetric and even on millimetric waves, namely tubes with velocity modulation. To this category belong, amongst others, the klystrons; the so-called reflex-klystrons are designed for use as oscillators. In this book two types are described, namely the reflex-klystrons 2 K 25 and the 723 A/B, which are suitable for use in the 3 cm band.

The noise figure of a receiver gives very important information regarding its quality and can be measured even at metric waves by means of the vacuum diode K 81 A, used as a standard noise source. For noise measurements on centrimetric waves it is, however, necessary to use gas-discharge tubes, such as the K 50 A and the K 15 A, which have been designed for use on the 3 cm and on the 10 cm bands respectively.

SUBMINIATURE U.H.F. TRIODE DC 70

The DC 70 is a directly heated triode intended for purposes of transmitting and receiving at ultra high frequencies. It can for instance be used as an oscillator, amplifier, super-regenerative detector or mixer in walkie-talky equipment, balloon sondes, Citizens Radio or professional equipment, etc. When the tube is used as an oscillator, the output obtainable at 500 Mc/s ($\lambda = 60$ cm) is about 450 mW.

The filament voltage of the DC 70 is 1.25 V at a current of 0.2 A. Being a directly heated tube, its mutual conductance is high (3.4 mA/V at an anode current of 12 mA); the amplification factor amounts to 14.

The DC 70 is provided with leads which pass through the base and are to be soldered directly to the wiring of the circuit. For this reason no tube socket is used.

The small dimensions and battery operation make the DC 70 specially suitable for use in portable equipment. The tube can be mounted in all positions.

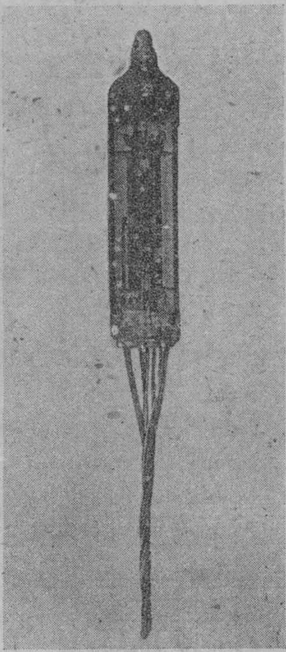

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Fig. 1. Photograph of the DC 70 (actual size).

TECHNICAL DATE

FILAMENT DATA

Heating: direct by battery

Filament voltage	V_f	=	1.25 V
Filament current	I_f	=	0.20 A

CAPACITANCES (measured with external shield and with leads marked n.c. left unconnected)

Anode to grid	C_{ag}	=	1.4 pF
Grid to filament	C_g	=	1.3 pF
Anode to filament	C_a	=	1.9 pF

MOUNTING POSITION: any

Note: Direct soldered connections to the leads of the tube must be at least 5 mm from the seal, and any bending of the tube leads must be at least 1.5 mm from the seal.

ELECTRODE ARRANGEMENT

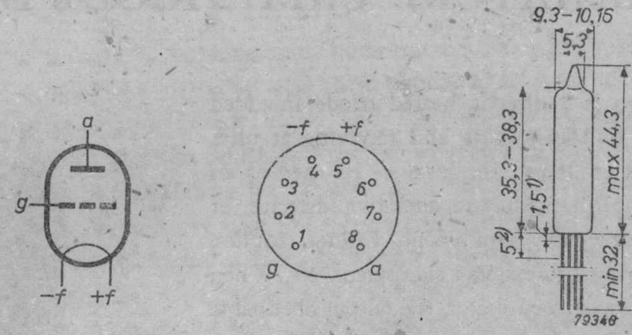

Fig. 2. Electrode arrangement, electrode connections and maximum dimensions in mm.

TYPICAL CHARACTERISTICS

Anode voltage	V_a	=	150 V
Grid voltage	V_g	=	−4.5 V
Anode current	I_a	=	12 mA
Mutual conductance	S	=	3.4 mA/V
Amplification factor	μ	=	14

OPERATING CHARACTERISTICS AS AN OSCILLATOR AT 500 Mc/s

Anode voltage	V_a	=	150 V
Cathode current	I_k	=	20 mA
Output power	W_o	=	0.45 W

LIMITING VALUES

Anode voltage	V_a	=	max.	150 V
Anode dissipation	W_a	=	max.	2.4 W
Cathode current	I_k	=	max.	20 mA
Grid current	I_g	=	max.	5 mA
Filament voltage	V_f	=	max.	1.35 V (absolute maximum)

U.H.F. TRIODE EC 80 FOR GROUNDED-GRID CIRCUITS

The EC 80 is an indirectly heated triode designed for use at ultra high frequencies. As an amplifier the tube can be used up to 500 Mc/s. The amplification factor and the mutual conductance are high ($\mu = 80$ and $S = 12$ mA/V), while the noise of the tube is very small (noise figure about 8 dB at 300 Mc/s with a bandwidth of 4.5 Mc/s).

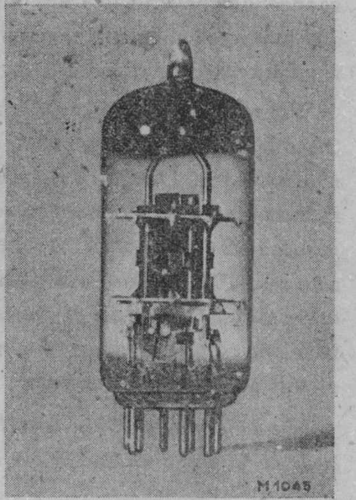

Fig. 3. Photograph of the EC 80 (actual size).

These properties make the EC 80 suitable for a number of applications on decimetric waves, for example in Citizens Radio and professional equipment, radio links, measuring equipment, etc. etc. Due to its high mutual conductance and low noise the EC 80 will also be of great use in a number of applications at lower frequencies. We mention, for instance, broad-band amplifiers, I.F. stages following a crystal mixing stage, etc. The EC 80 is specially intended for use as an amplifier and mixer in grounded-grid circuits. In these circuits the grid, instead of the cathode, is the common electrode of the input and output circuits. In fig. 4 the basic diagram of a grounded-grid amplifier is shown; in such a circuit an appropriately constructed grid will act as a screen between anode and cathode, making a separate screen grid superfluous. In spite of the ultra high frequencies, it will therefore be possible to use triodes instead of pentodes in these circuits with good results.

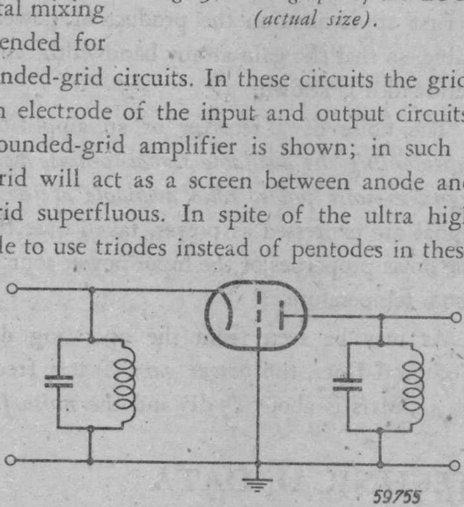

Fig. 4. Triode in grounded-grid circuit. The d.c. sources have been omitted.

Owing to the absence of the so-called partition noise inherent in a pentode, the total noise of a triode is much smaller than that of a pentode. This explains the favourable behaviour with respect to noise of the triode EC 80 in grounded-grid circuits.

In order to reduce the effects of troublesome capacitances, self-inductances and resistances, the measures described in the Introduction have been taken. In this connection special attention must be drawn to the self-inductance of the grid lead. This lead being common to both the input and the output circuits, self-inductance will tend to cause instability. In the case of the EC 80 this has been avoided by connecting the grid to four pins in parallel. If the corresponding socket contacts are connected to earth, the self-inductance of the grid lead and the tendency to instability will be reduced to a minimum.

Whereas the gain of a tube at lower frequencies is only slightly influenced by the input and output impedances of the tube, this is no longer the case on decimetric waves. Due to the influence of transit-time effects, resistance and self-inductance of the connecting leads, etc., these input and output impedances are reduced in such a way that their influence on the gain becomes very great, and as a result, the control of amplifying tubes will require power. Therefore, instead of speaking in terms of voltage amplification, as normally is done at lower frequencies, we will have to take into consideration the power gain. The definition of this quantity is as follows:

The power gain of an amplifier is the optimum ratio between the output power and the power available at the input.

As the power gain is dependent upon the width of the frequency band to be amplified, it is always necessary to mention the bandwidth of the amplifier. As a first approximation the product of power gain and bandwidth has a constant value, so that the gain at any bandwidth can be calculated if the gain at a certain bandwidth is known.

The noise of a receiver or an amplifier is defined by *the noise figure F, representing the available signal-to-noise power ratio at the input, divided by the signal-to-noise power ratio available at the output.* Here both the noise and the signal are expressed as power, taken over the bandwidth of the amplifier, whilst the noise properties of the input power source are expressed in terms of a resistor at room temperature.

As may be seen from the operating data of the EC 80 mentioned under Technical Data, the *power gain G* at a frequency of 300 Mc/s and a bandwidth of 4.5 Mc/s is about 15 dB and the *noise figure F* about 8 dB (see also fig. 8).

TECHNICAL DATA

HEATER DATA

Heating: indirect with a.c. or d.c.; parallel supply
Heater voltage . . . . V_f = 6.3 V
Heater current . . . . V_f = 0.48 A

ELECTRODE ARRANGEMENT

To ensure stability of functioning in grounded-grid circuits, the four grid contacts must be connected to earth.

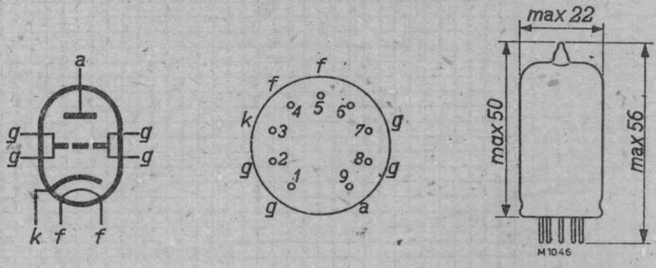

Fig. 5. Electrode arrangement, electrode connections and maximum dimensions in mm (noval base).

CAPACITANCES (measured with the tube cold and with grounded grid)

Input capacitance	$C_{(g+6)(k+f)}$	=	5.1 pF [1]
Input capacitance	$C_{(g+f+6)k}$	=	9.3 pF [1]
Capacitance between anode and cathode	C_{ak}	<	0.075 pF
Capacitance between anode and cathode plus heater	$C_{a(k+f)}$	<	0.08 pF
Output capacitance	$C_{a(g+6)}$	=	3.4 pF [1]
Output capacitance	$C_{a(g+f+6)}$	=	3.4 pF [1]
Capacitance between cathode and heater	C_{kf}	<	8 pF

TYPICAL CHARACTERISTICS

Anode voltage	V_a	=	250 V
Cathode bias resistor	R_k	=	100 Ω
Anode current	I_a	=	15 mA
Mutual conductance	S	=	12 mA/V
Amplification factor	μ	=	80

OPERATING CHARACTERISTICS (grounded grid)

Power gain at 300 Mc/s (bandwidth 4.5 Mc/s)	G	= appr.	15 dB
Noise figure at 300 Mc/s (bandwidth 4.5 Mc/s)	F	= appr.	8 dB

LIMITING VALUES

Anode voltage in cold condition	V_{ao}	= max.	550 V
Anode voltage	V_a	= max.	300 V
Anode dissipation	W_a	= max.	4 W
Cathode current	I_k	= max.	15 mA
Grid current start ($I_g = +0.3\ \mu A$)	V_g	= max.	−1.3 V
External resistance between heater and cathode	R_{fk}	= max.	20 kΩ
Voltage between heater and cathode	V_{fk}	= max.	100 V

[1]) 6 denotes pin No. 6.

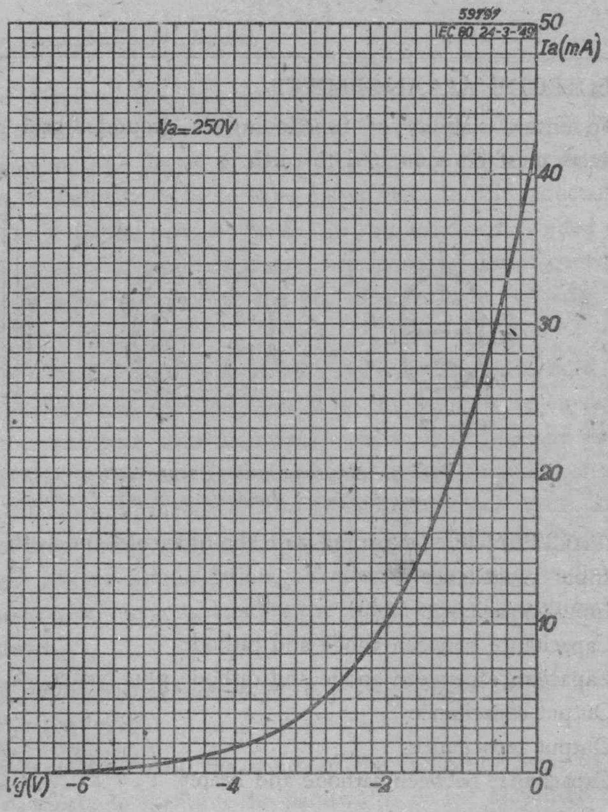

Fig. 6. I_a/V_g characteristic of the EC 80 at an anode voltage of 250 V

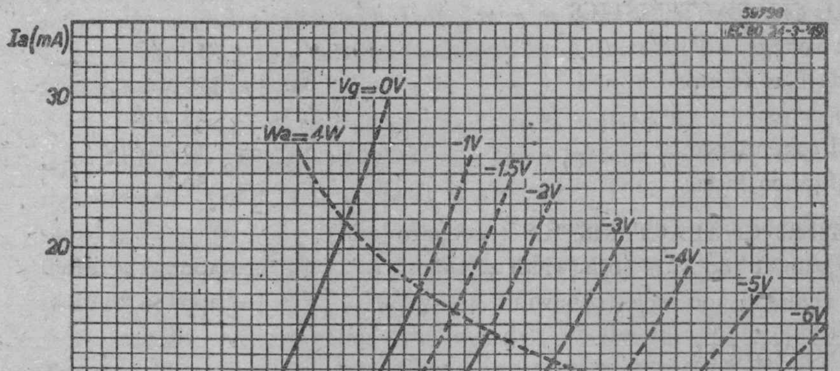

Fig. 7. I_a/V_a characteristic of the EC 80. The maximum admissible anode dissipation is indicated by the dashed line $W_a = 4\,W$.

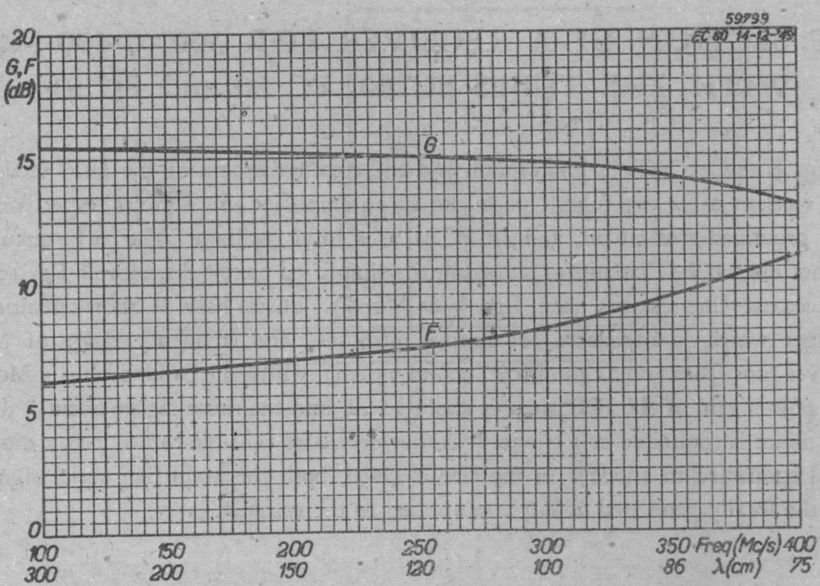

Fig. 8. Power gain G and noise figure F of the EC 80 as a function of the frequency f and wavelength λ.

BASE AND SOCKET

The EC 80 is provided with the standard noval base, and can therefore be mounted in a socket of normal construction. However, at the very high frequencies at which the tube is used, the material of the socket must answer high requirements. The socket type 5908/46 is recommended.

Its small dimensions and normal operating voltage make the EC 80 specially suitable for use in fixed, as well as in mobile equipment. The tube can be mounted in all positions; if, however, shocks are to be expected, or if the tube is not mounted in an upright position, it is recommended that the tube be supported.

In order to ensure stable functioning of the EC 80, it is recommended to use a cathode resistor for obtaining the negative grid bias (see e.g. fig. 10*a* with resistors R_2 and R_7 of 100 Ω).

H.F. SECTION OF A RECEIVER FOR 300 to 400 Mc/s WITH THE TUBES EC 80, EC 80 and EC 81

Figs 9 and 10 show a photograph and the circuit diagram of the H.F. section of a receiver using two tubes type EC 80, as an amplifier and a mixer respectively, in a grounded-grid circuit, and an EC 81 as a local oscillator. The H.F. circuits are not normal L.C. circuits as shown in the simplified circuit diagram of fig. 10a, but coaxial line circuits (see figs 9 and 10*b*). These have a short-circuiting plunger which is adjustable for tuning purposes. The frequency range of the receiver runs from 300 to 400 Mc/s (100 to 75 cm), whilst the bandwidth is 5 Mc/s. The power gain of the H.F. stage is about 12 dB and the noise figure about 8 dB. The mixer is connected as a triode. It is, however, also possible to use it as a diode (grid connected to anode). In the circuit given, both the amplified aerial signal and the locally generated voltage are applied to the cathode.

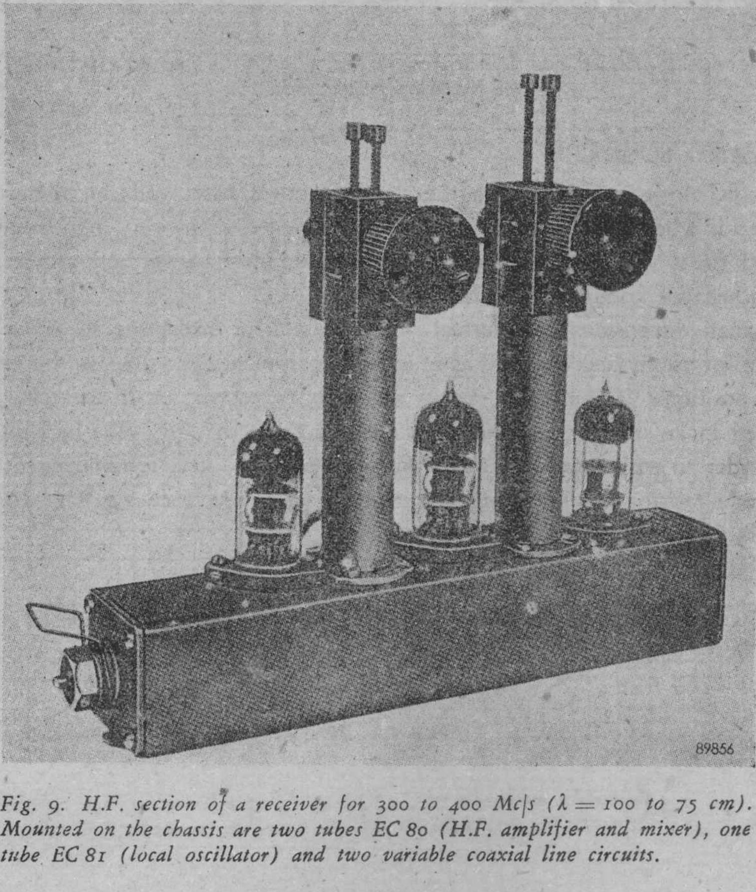

Fig. 9. H.F. section of a receiver for 300 to 400 Mc/s ($\lambda = 100$ to 75 cm). Mounted on the chassis are two tubes EC 80 (H.F. amplifier and mixer), one tube EC 81 (local oscillator) and two variable coaxial line circuits.