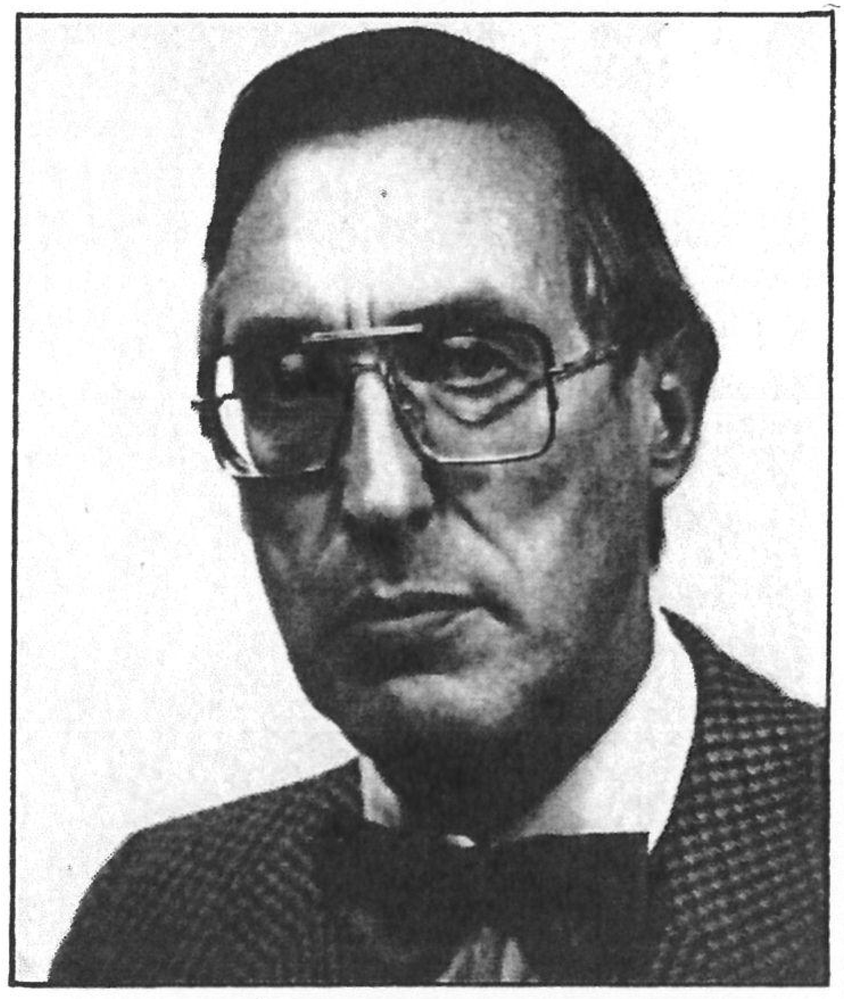
Optical communications — 1935 style

Very effective light-beam voice communication was in use by the German military in 1935.

by D.W. Rollema, PAoSR



Dirk Wietse Rollema was born at Hengelo, Netherlands, in 1929. In 1956 he obtained his degree in electrical engineering from the Technological University at Delft, and is now with Philips Telecommunication and Information Systems at The Hague, working as a project coordinator in the field of maritime traffic control systems.

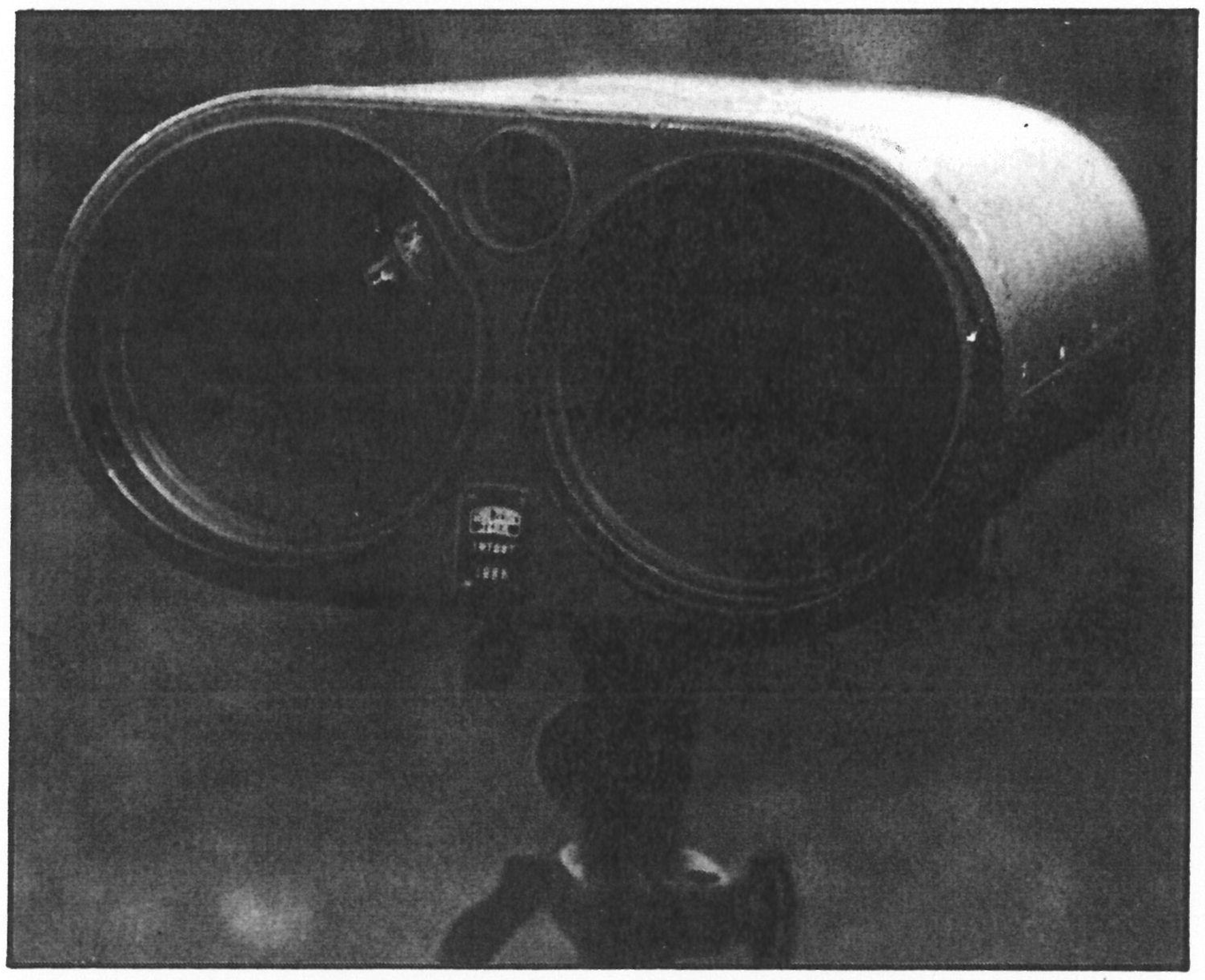
He has held amateur radio callsign PAoSE since 1951 and is active mainly on 40 and 80 metres, operating home-constructed equipment. PAoSE belongs to a European group of amateurs which uses the old Hellschreiber system of teleprinting over radio.

The author has a lively interest in the history of telecommunication and radar. Meeting several radio amateurs, who are also collectors, gave him the opportunity to analyse and describe World War II equipment, mainly of German origin.

Dirk Rollema is married and has two daughters.

During World War II the German forces availed themselves of pretty advanced telecommunication facilities. The radio equipment, for example, was very effective and of exceptional electrical and mechanical quality.

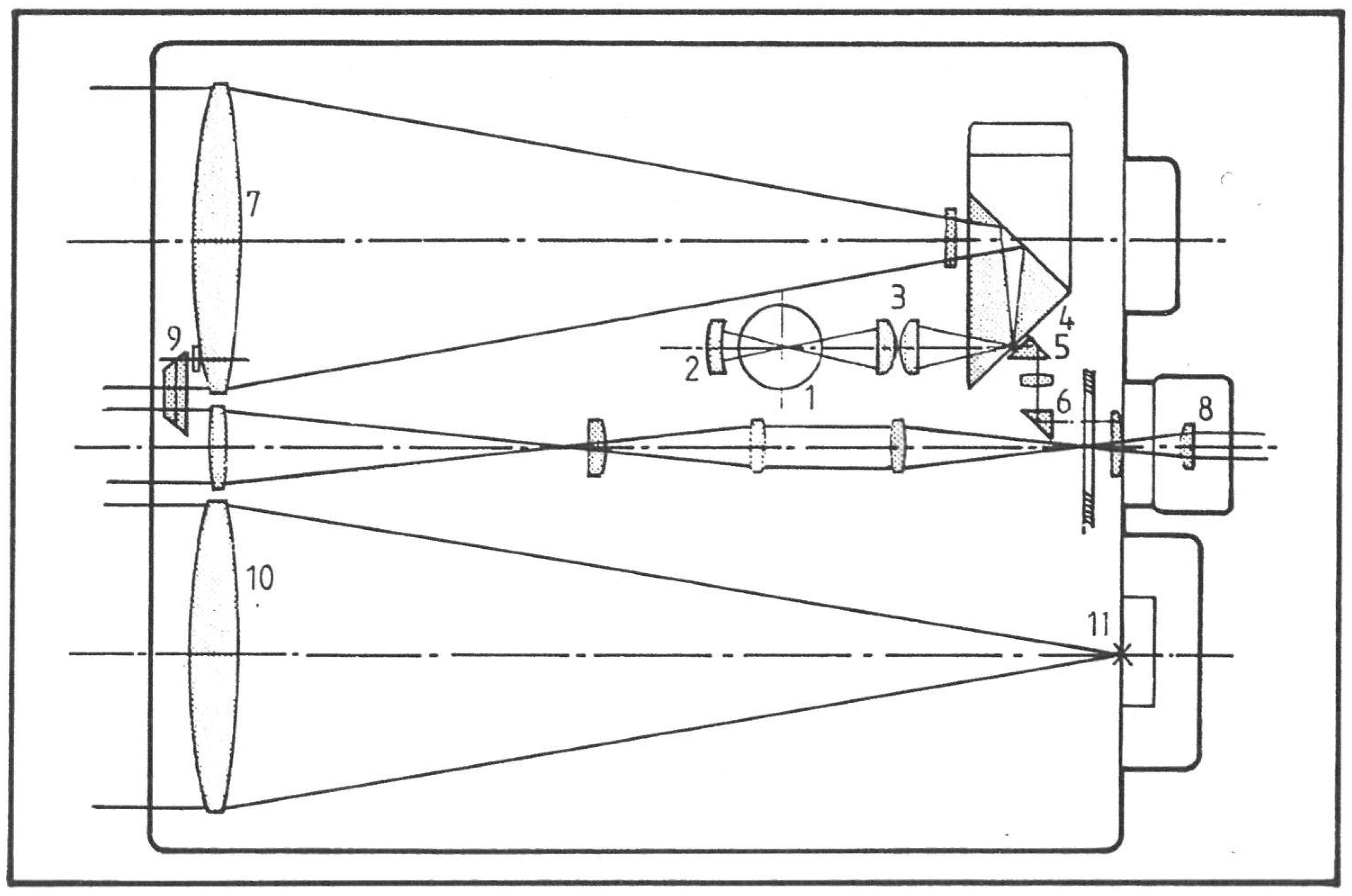
The optical communication equipment that was in use by the German army since 1935 was a closely guarded secret, but related documents were found during the first German Libyan campaign. It was not until the Battle of El Alamein in October, 1942, that the complete apparatus was found by the British. It was investigated and tested in the laboratories of the Royal Corps of Signals in the Middle East, in November of that year.



A 1938 model seen from the front.

The official German designation was *Das Lichtsprechgerät (80 mm):* the 80 mm relates to the size of the lenses. A larger model also existed and we come back to that briefly at the end of the article. Lichtsprechgerät 80 was developed and produced by the well known firm Carl Zeiss of Jena. The photographs convey a general impression of the equipment, as restored by two Dutch collectors, Messrs Arthur Bauer, PAoAOB and Cas Caspers, PAoCSC. An important feature of the instrument is that it may be operated on white, red or infra red light, merely by selecting the required filter with a knob. The ranges obtainable are given in the operating manual[1] and seem to be conservative, as usual for German wartime equipment. For speech they are quoted as 3 km for white and red light and 2 km for "invisible" (infra red) light. Gifford Hull[2] states the range as five miles (8.25 km) as an average, effective range obviously depends largely on atmospheric conditions: rain and fog will considerably reduce the range. A great advantage over radio is that security is pretty well guaranteed; even at five miles distance the light eliminates the possibility of interception and secures secret communication in the dark, whilst the range is not appreciably reduced[2]. There are, of course, operational restrictions, apart from the limited range. The apparatus functions only over an unobstructed optical path, but it could also be used as an intermediate link in a telephone line connection, and so could be used to bridge a river or a valley.

Fig. 1. **Ray paths in the 80 mm light telephone.**



Transmitter

The author had access to a reproduction of the operating and technical manual for Lichtsprechgerät 80 from 8 September 1938: Figure 1 is taken from that book[1]. The transmitter forms the upper part of this diagram. Light from an incandescent lamp 1 is focused on the modulator prisms 4 and 5 by means of mirror 2 and condenser lens 3: the lamp (4.8V, 4W) is run from a rechargeable battery, good for approximately five operating hours. After passing the modulator, the light is focused to a parallel beam by means of the 80 mm lens 7. The beam is six yards wide at a mile and thirty yards at five miles, as already mentioned. The functioning of the modulator remains a bit obscure after reading the manual but luckily Gifford Hull gives a much better description of it and we will follow his words: Fig. 2 is taken from his article. The light from the lamp-house strikes the hypotenuse side of a right-angle prism. The other angles of the prism are not quite 45 degrees, so that at the point of first reflection the mean angle of incidence is approximately the critical angle for glass and air media, and partial reflection and partial refraction take place. The area at which this first reflection takes place is a small rectangle measuring 3 × 1½ mm, the surrounding glass being blackened. The armature consists of a flat metal strip, pivoted at its centre, its ends being located closely between the pole pieces of the armature coils, which are so phased that one pushes and the other pulls.

A small, right-angle prism is carried on the armature, near its centre, and it is so positioned that one of its sides rests in contact with the small rectangle of the main prism. As the armature moves in accordance with the voice currents, so the pressure of the small moving prism against the larger prism changes in accordance with the voice currents. It will be appreciated that since the small prism is mounted close to the axis of rotation of the armature, its travel is small, but its pressure is great. It is necessary, then, when considering the analysis of the action of the device, to bear in mind that it is the pressure of the small prism on the large one that alters — not so much the air gap between the two.

If these two glass surfaces were truly optically flat and in perfect contact, there would be no change of medium at this point and no internal reflection would take place. Hence, no light would pass through the main prism. But as soon as the contact between the prisms becomes imperfect, a change of light media will occur, and internal reflection will result. In practice, the contact is never perfect, for all pressures of the prism, and most of the light is reflected. But the varying pressure brings about a varying degree of contact, which, in its turn, varies the amount of light reflected through the main prism. This, coupled with the fact that the angle of incidence is nearly the critical angle, makes the modulator a relatively efficient device.

A device is incorporated to control the quiescent, no-signal, pressure of contact. The operator is supposed to adjust this to give maximum sensitivity and minimum distortion. Gifford Hull also provided Fig.3 in his article which shows the response curve of the modulator.

The photographs show a built-in telescope that is used for setting-up the optical link, Fig.1. showing the optical rays within the telescope, which is also used for monitoring the modulator action. Part of the light that is not totally reflected in prism 4 is passed on to the eyepiece of the telescope via prisms 5 and 16 and lens 8. Looking into the telescope a green lighted rectangle is seen — the intensity of which changes with the modulation.

Part of the light emitted by lens 7 is reflected into the telescope by means of the tetrahedral prism 9. The filament of the lamp is thus seen above the just mentioned green rectangle, and is used for pointing the transmitter at the opposite station. To attenuate the image of the filament, two red filters[15] of different transmission can be selected at will, one for day

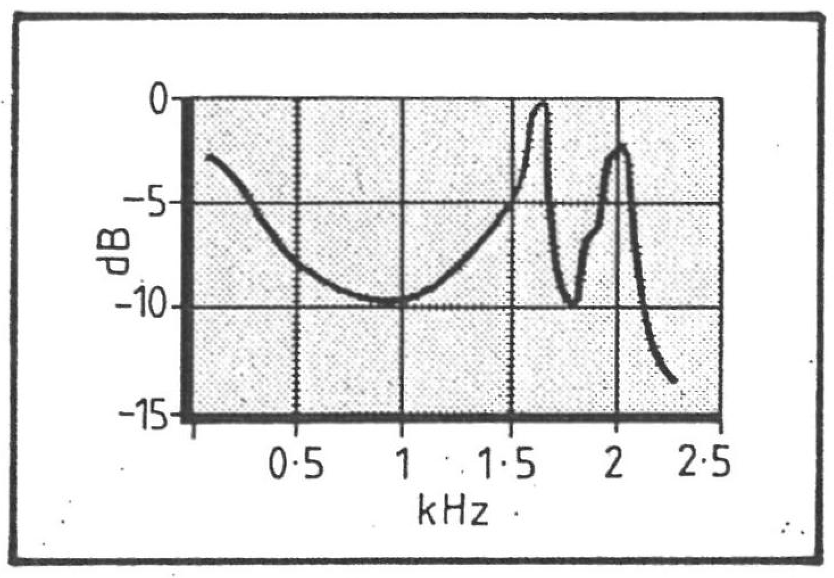


Fig.3. **Response curve of the modulator.**

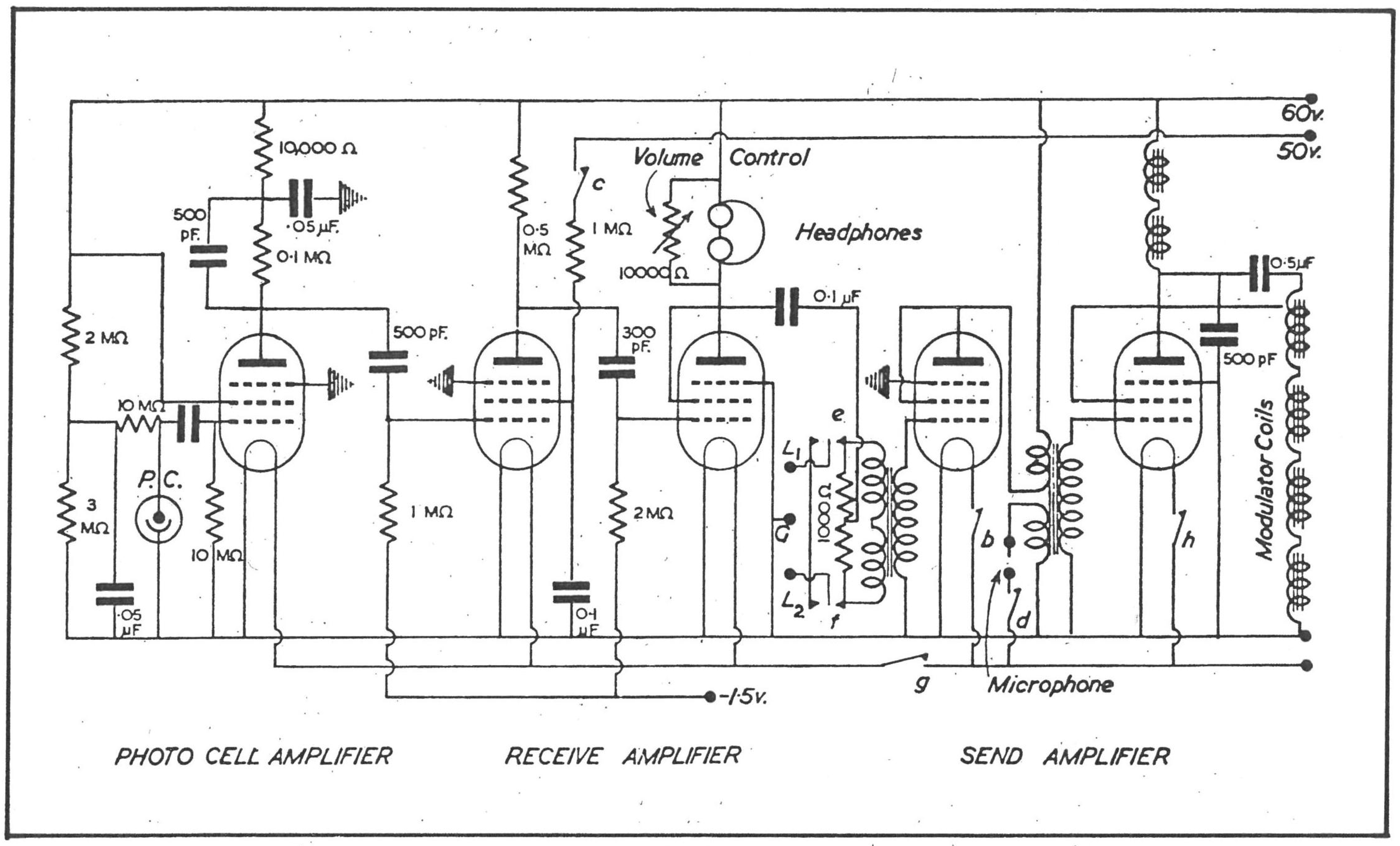


Fig.4. **Circuit diagram of the amplifiers.**

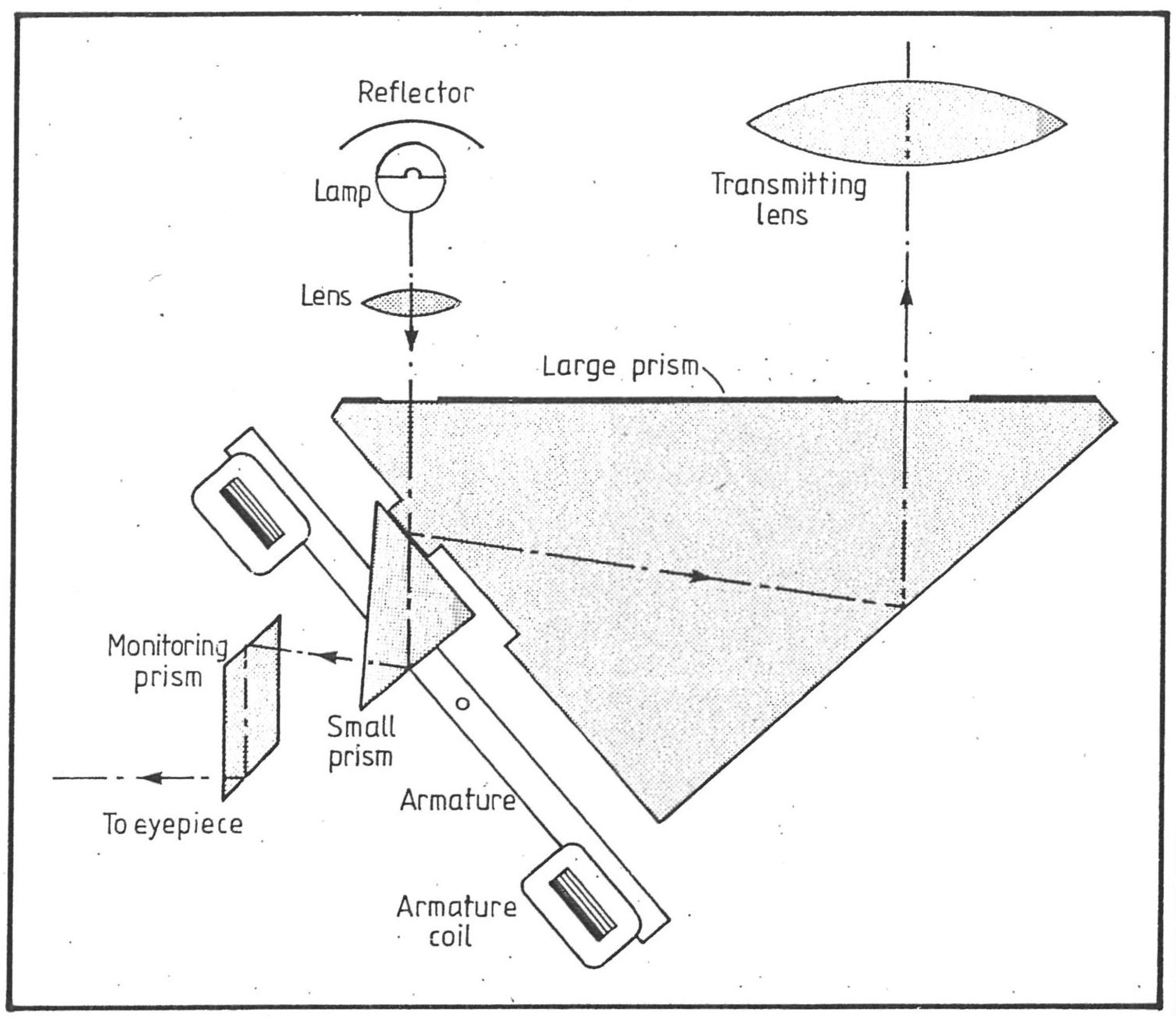


Fig.2. **Diagram showing method of modulating the light beam.**

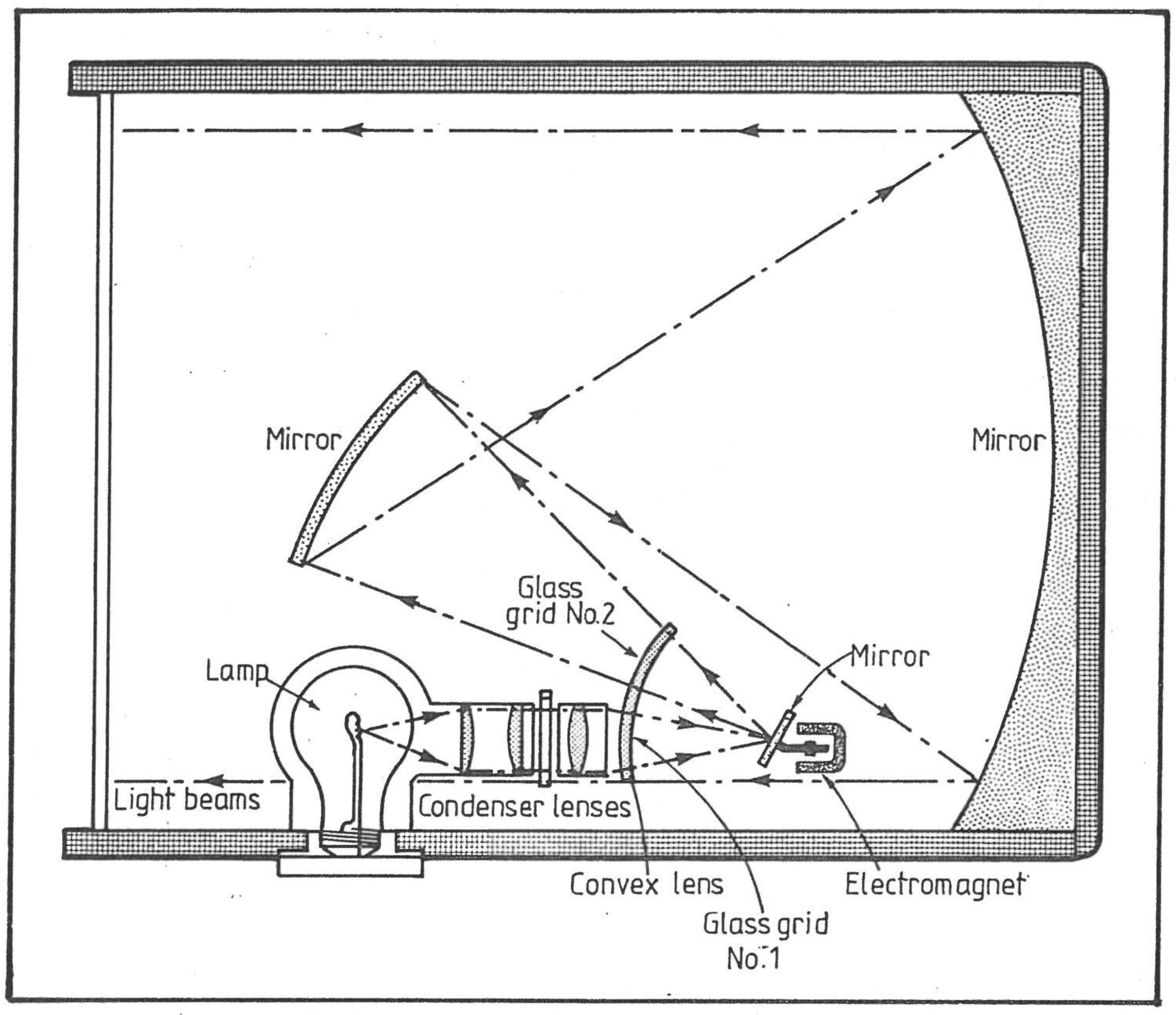
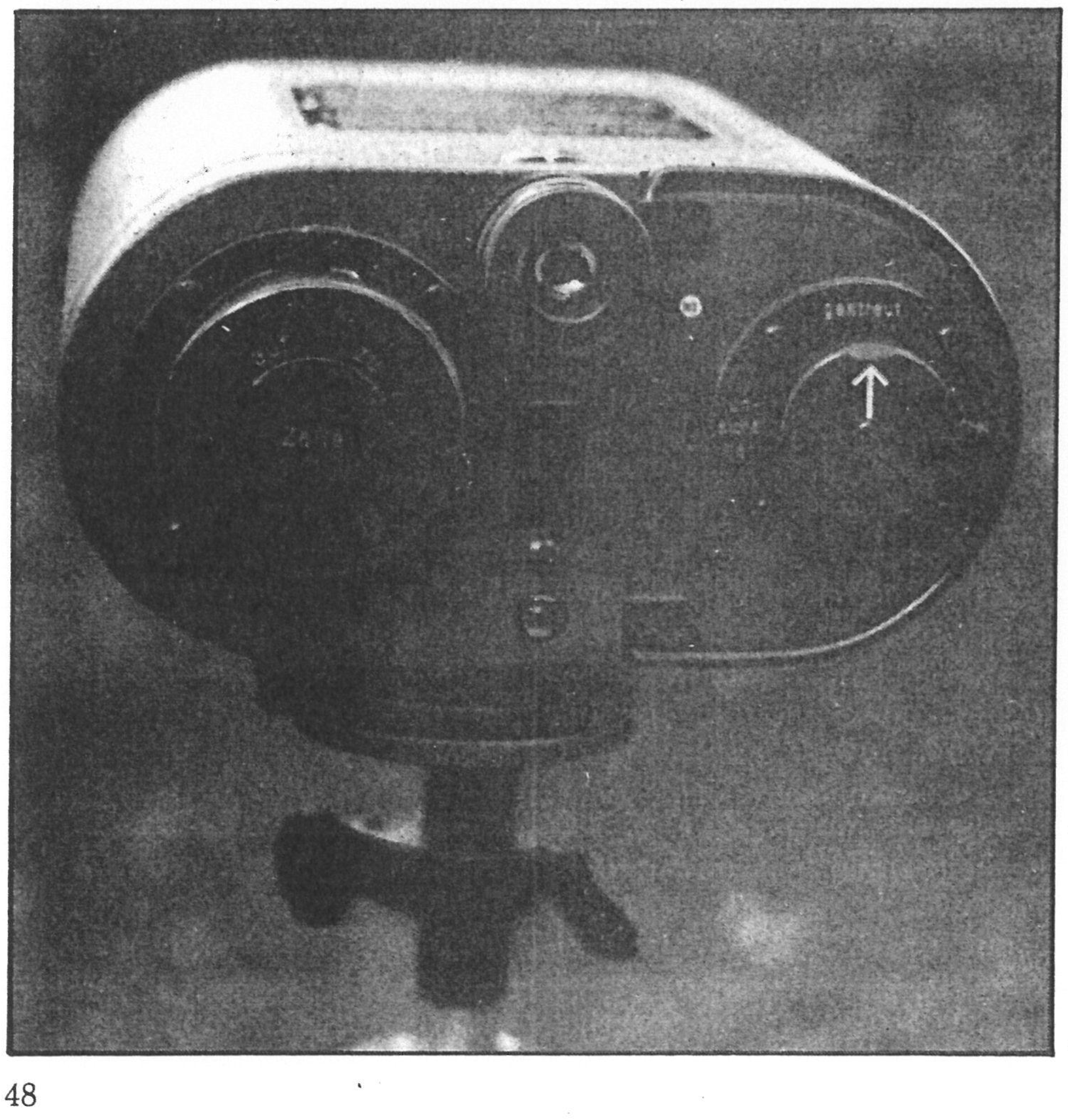


Fig.5. **Ray paths in the transmitter of the 250/130 mm light telephone.**



At the left the detachable cover for the photo-conductive cell. At the right the selector for the optical filters in the transmitter beam. *Unsichtbar* means infra-red filter; *Gestreut* is a possibility not mentioned in the text, which spreads the light over a wider angle to ease sighting; *Frei* produces white light without a filter; the fourth position *Rot* cannot be seen in the picture: it selects red light.

and the other for night operation.

Since the sighting telescope and transmitter have been set in the factory with their axes parallel, it follows that the transmitter beam will fall on the distant object whose image is covered by the lamp filament image. Provided that a view of the distant station can be had, it is an easy matter with this device to set up the equipment.

Receiver

The modulated light signal from the distant station enters the instrument via the 80 mm lens 10 and it is focused on the photo cell 11. Only a very small area, about 1 mm, of this thallium sulphide cell is exposed to the light. This is done because the image of the distant transmitter formed on it by the lens 10 is also very small, and increasing the cell area beyond what is needed to receive the whole image results in loss of sensitivity. This follows since the fractional change in cell resistance on illumination is diminished by the effect of the unilluminated parts of the cell[3]. The "Thalofide" type cell is inferior to a caesium cell, which has a better high-frequency response; however, its sensitivity to red and infra-red light is better than that of caesium cell. The cell can easily be changed by removing the cover shown in the photograph at the left.

Electronics of Lichtsprecher 80.

The circuit diagram of Fig.4., given by Gifford Hull, is better than the one in the German manual. The three amplifiers are housed in a separate box, shown in the photograph. Valves are of the standard type used by the German army during WW II — high-gain, directly heated pentodes, type RV2P800, mounted upside down in a tubular holder, being supported at both ends. The photo-cell amplifier is conventional; the cell receives a positive voltage by means of a high-resistance potentiometer from the h.t. line. The anode circuit has a resistance/capacity network that attenuates at about 4000 Hz, the purpose being presumably to minimize photo-cell hiss. This amplifier uses two valves in cascade, resistance-capacity coupled, and the last valve is triode connected to secure a low impedance for the phones. The output is also taken to the telephone bridge input circuit, the operation of which will be discussed later.

The sending amplifier normally uses but one valve, triode connected, fed by the microphone, and the anode is parallel fed by an l.f. choke, the anode load being the armature coils of the modulator. The send-receive switch normally switches on the appropriate amplifier; duplex operating is therefore not possible. But for the purpose of working into a telephone line, the switch is turned to "Telephone" and this places the bridge circuit in the sender amplifier input — and the receiver amplifier output. The bridge is balanced, to prevent singing of the circuit.

Provision is also made for keying the lamp filament by means of a push button at the end of a cord, connected to the terminals *Blinktaster* in the photograph. This provides facility for Morse transmission, but reception has to be visual. Under these conditions, greater distances are possible. The valve filaments are supplied from a separate rechargeable battery, sufficient for 20 operating hours: the −1.5V, +50V and +60V come from an anode battery, good for 100 hours operation.

Mechanical construction

With a device of this sort, mechanical rigidity is of prime importance. The tripod is strongly constructed and whilst the head is fixed to it by a single universal fixture, it is very rigid. The head itself is made of aluminium and optical technique has been employed by Carl Zeiss throughout the apparatus. The lamp-house, whilst being detachable, is firmly held in position and the modulator is mounted on a slotted platform, so that initially it may be located correctly with respect to the lamp and the transmitting lens. The modulator prism is housed in a heavy machined brass holder, located within the permanent magnet of the armature system. The photo-cell clips into its holder very simply, but perfect positioning is ensured by the holder, since it is necessary that the incoming light is focused dead on the centre of the cell by the 80 mm receiving lens. The whole apparatus has a mass of 54 pounds.

Restoration of Lichtsprecher 80

Several specimens of Lichtsprechgerät80, or simply Lichtsprecher 80, as the apparatus was also called, found their way to collectors of wartime communication equipment and were lovingly restored to original shape, some by Arthur Bauer of Diemen (near Amsterdam) and Cas Caspers of Veldhoven (near Eindhoven). After some preliminary experiments, the equipment was given a field test on a cold winter day in December 1983. Cas Caspers had selected a path of two kilometers between two little-used bridges over the Beatrix Canal near Eindhoven. Although alignment is critical due to the narrow beam width, communication was quickly established. Mr Caspers' son Remco operated a third unit. From the behaviour of the link it became clear that spanning a larger distance should pose no problems.

To find such a longer, unobstructed path is a different matter. The author was lucky to be invited for the experiment. He noticed that the audio was rather limited in frequency range and both linear and non-linear distortion were evident. Nevertheless, speech was easily readable. The non-linear distortion was also manifest from the fact that the light from the distant transmitter was fluctuating visibly under modulation. If the modulation were linear (symmetrical) this should not be possible.

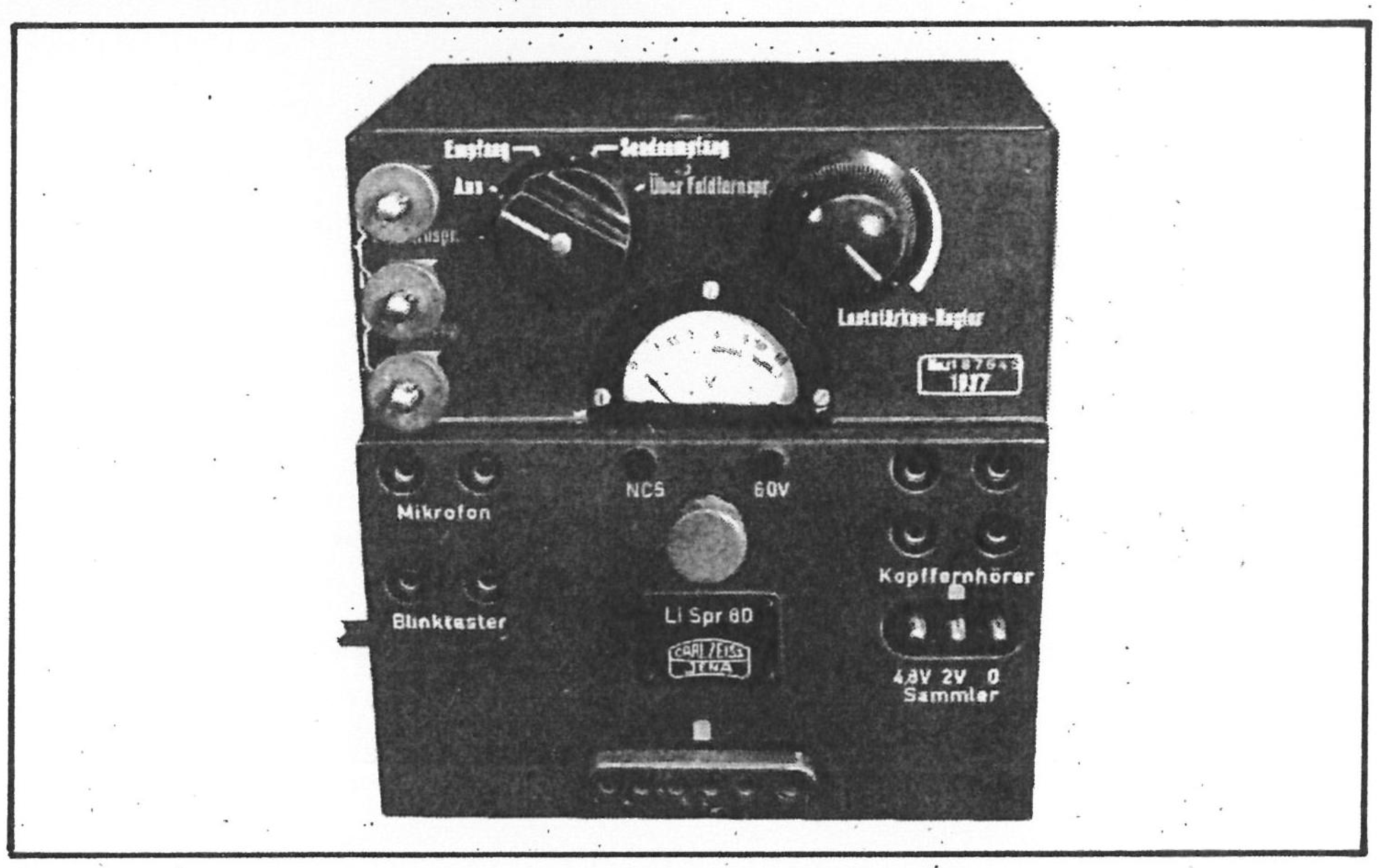
Mr Caspers was standing with his unit on an old Bailey bridge, one of the few "temporary" leftovers from WW II. Occasionally a motorcar passed the bridge and shook it so heavily that the Lichtsprecher had to be set up anew.

During the summer of 1983 Caspers had already tried his instruments over a shorter distance. From time to time he noticed a strange musical note in his headphones, which he finally traced to insects in the light beam, their wings obviously causing intensity variations in the light striking the receiver. It needs no comment that the author found it a fascinating experience to see and hear these almost fifty-year-old devices in action again.

Bridge to bridge. Caspers communicating over 2 kilometers.

Lichtsprecher 250/130

As mentioned in the introduction the Germans developed during WW II an improved version of Lichtsprechgerät 80, which was designated Lichtsprecher 250/130. It has a receiver of 130 mm diameter and a transmitter aperture of 250 mm. The light modulator was of entirely different construction from that described above for Lichtsprecher 80. The principle follows from Fig.5[4]. The light from the lamp traverses a grid and after reflection from a speech-controlled mirror falls on a second grid, an image of the first grid being formed on the second one. It will be seen that the amount of radiation passing the second grid depends on the position of the mirror, so that, by controlling the mirror movement by the microphone current, the radiation beam is modulated[3]. A novel feature of Lichtsprecher 250/130 was a sunlight attachment for utilizing the rays of the sun as a light source instead of the electric lamp. Unfortunately no particulars on this intriguing feature were given in the literature available to the author. The photo-cell was of the lead sulphide type instead of thallium sulphide, providing a better frequency response. This improved photo-condictive cell was also used in some of the later Lichtsprecher 80 models. The operational features of the 250/130 mm model were about the same as those of the 80 mm equipment, but the range was greater, as to be expected from the larger optics. Tests indicated that the equipment was capable of transmission up to 20 miles, subject to weather conditions. But adjustment becomes more critical as the distance is increased and, because the sighting controls do not have vernier settings, the equipment may not have been used over the maximum distances for which it is theoretically capable[4].



Box containing the electronic part. Opening the lid reveals the four amplifier valves.

Acknowledgement

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References

1. Manual for "Das Lichtsprechgerät (80 mm)", number D 877/2, issued on 8 September 1938 at Berlin.
2. D. Gifford Hull, Capt.: "The German Army "Speech-on-Light" Signalling Apparatus". *Electronic Engineering,* October, 1943.
3. Bernard Lovell: Electronics. The Pilot Press Ltd., London, 1947.
4. "Improved German Photophone". The origin of this article could not be traced.