(Please notice my, non italic, additional comments, AOB)

Transcript of T.R.E. (TRE) report No. 6/R/25

FINAL TECHNICAL REPORT ON THE GERMAN RDF EQUIPMENT CAPTURED AT BRUNEVAL ON 28TH FEBRUARY 1942

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(1) Introduction

This report follows the "Interim Report on the Technical Results of the Raid on Bruneval..."dated 24th March 1942, T.R.E. ref D.1841... and is purely technical description of the station in detail. Information about methods of jamming this and other stations together with observations of a more operational nature will be contained in a separate report entitled "Report on the investigation of Enemy Short Range RDF Stations:, T.R.E. ref 6/R/13. Certain information in this present report was extracted from a Prisoner's Report.

(2) General layout of the Station
All the equipment was mounted on a mobile trailer. On this trailer was a single paraboloid 2.8 metres diameter, to the back of which was fixed all the apparatus with the exception of the presentation equipment. The latter was inside the operating cabin which was mounted to the rear and slightly to one side of the paraboloid... .

The paraboloid was movable both in azimuth and in elevation, the first being done done either manually by a hand-wheel in the operating cabin, or electrically by an operator-controlled push-botton. Elevation was done manually only. D/F was obtained by working on the maximum lobe.

Power for the apparatus is designed to work off A.C., probably at 175 volts the power supplies were not captured but the modulator unit contains a transformer which requires this primary voltage.

On this particular site, the trailer was parked about 50 yards from the edge of a 300 ft cliff, thus enabling very low angle radiation to be obtained in a seaward direction.

The transmitter, receiver, modulator, and some supplies were mounted in boxes on to back of the paraboloid on shockproof mountings. All the boxes were with te exception of the power supply, and comprise:-

(i) The T/R Box
(ii) The Modulator Box
(iii) The Receiver I.F. Amplifier Box

The T/R box is made of cast aluminium and is 241/2" x 101/2" x 61/4". It contains the three separate withdrawable units; the transmitter, the receiver mixer; and the receiver local *oscillator,.... At the back of the box is the common T and R feeder system and the connection to the main feeder...*

The modulator box measures 13"x 123/4"x 61/4"and contains the transmitter modulator only....

The receiver I.F. box measures 61/2"x 7"x 121/2" and contains about half the total I.F. amplifier. The other half was probably contained in the presentation equipment (which was not captured) inside the cabin.

Also on the back of the paraboloid was a small switchboard consisting of 10 push-bottons for switching the apparatus on and off.

(Circuit description has been omitted, AOB)

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(c) Valves and Cathode Ray Tube

The valves in the modulator are all of the same type, namely Telefunken LS50's. Those are dealt with in detail an the Valve and CRT section of this report. This valve is a pentode and characteristics as measured at T.R.E. are appended. The valve is of exceedingly robust construction like all valves in this equipment. All the leads are brought through the base.

The CRT is similar to our VCR91 and has a green screen.

(d) Method of Construction of the Unit

The unit is is of extremely robust construction and makes full use of aluminium alloy castings and pressings, bakelite mouldings and ceramic terminal blocks. Details of the construction can be seen from the appended photographs of the unit. Points of interest are the method of holding the valves in position which is virtually foolproof, the method of holding the CRT and the fact that ceramic valve holders are used throughout, although there are no ultra high frequencies present. Also the small size of some of the fixed condensers with respect to their voltage rating is particular note-worthy, e.g. C33 is a 1 microfarad 25)450 volt condenser measuring 1"x1"x 1". The excellent manufacture of the output connections is also of interest.

(4) Details of Transmitter

The transmitter proper is a single valve oscillator modulated on its grid and using a simple Colpitts circuit. The circuit diagram is appended... The anode circuit consists of a tuned line which is very short owing to the valve inter-electric capacity. A variable ceramic condenser which can be tuned externally forms the only tuning control on the equipment. The H.T. is fed through a ceramic condenser bushing of interesting design, ... and the grid is fed in through a smaller bushing of low capacity to ground.

The power is taken off by the aerial feeder which is tapped on to a lumped resonant circuit, coupled inductively on to the main tank circuit. The aerial feeder is attached to the oscillator unit by means of a large concentric plug.

The filament circuit is an unbalanced shielded line of flat brass strip which can be seen clearly in...

A low pressure air-cooling system is used for blowing air on to the valve.

(a) Details of the valve

The valve is a Telefunken LS180. The grid and anode are brought out through the top of the valve through double seals (to reduce the lead out inductance) and the filament is brought out through the base of the valve... The filament is a double spiral. The grid is parallel wire cylinder (squirrel cage) and the anode is heavily finned for cooling.

The filament is thoriated tungsten and takes 121/2 amperes at 6.2 volts A.C. (the actually voltage was given for each valve individually, AOB)

The maximum anode voltage is not known exactly but is definitely above 11 kV.

The frequency limit is not known but probably lies in the region of 750 Mc/s. (this estimation was too optimistic, its practical maximum application was < 600 MHz, this captured Würzburg set operated at 560 MHz, AOB)

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(c) Methods of Construction

As can be seen from the photograph the oscillator is a separate unit which can be plugged into the T and R box. It is made entirely of aluminium castings and is completely enclosed so that there is no power lost by radiation. The valve is uncapped and is held in position by springs.

The design of the circuit shows no great novelty of technique but it is considered that they are both efficient and simple in construction. It is difficult to see how the valve could have been made give appreciably more power by any other form of construction.

(5) Details of Receiver

The stages in the three receiver units are as as shown in block form in...

The initial frequency changer is a double diode, Telefunken LG2, with a $\lambda/4$ balanced line circuit between anodes, the signal being fed on to the circuit from a screened twin feeder.

The local oscillator employs two LD2 valves operating in a tuned-plate tuned-grid circuit on about 146 Mc/s. This oscillator drives a Telefunken LD5 valve used a quadrupler which feeds, *through a length of cable, a high Q resonant circuit made of lumped concentric L and C elements, mounted on the rear of the frequency-changer box. The oscillator feed to the mixer is by means of of a small probe, roughly a 1/4 λ long, projecting from the concentric circuit to between the ends of the diode line.*

The output of the mixer is at 25 Mc/s. and the first four stages are followed by a second frequency changer reducing the IF to 6.5 Mc/s. Following this mixer are three stages of amplification at 6.5 Mc/s., the output being fed low impedance into a concentric cable. The bandwidth of the IF amplifier is 0.5 Mc at 6 db. down.

On test the receiver gave a noise factor of 20 db. corresponding to a noise voltage of 4.1 microvolts in series with 80 ohms.

(a) The frequency changer is a double diode Telefunken LG2 valve used in a λ/4 parallel line circuit housed in a cast box. The assembly is shown in...

The signal from the aerial is fed through a concentric line into a transformer, balanced output of which feeds through a short screened twin line to the leads marked A in Plate IV and so the diode line. The parallel resonant line, B, consists of two ceramic tubes plated with some metal, presumably silver. This line is grounded at one end and tuned with a small balanced preset variable condenser, E, at the other end, the coarse adjustment being provided by shorting strap, S.

Connections are run from the anodes down to the centres of these lines probably by a metal coating on the inside. After passing through the screen these inner loads are connected to the terminals F from which points the feeds are taken to the primary of the balanced to unbalanced IF transformer. The secondary of this transformer is connected to the output plug at D in...The coupling in the transformer has an adjustment which appears from the sealing paint on the locking screws to the preset before going into service.

The local oscillator voltage is injected into the circuit by a probe C in... which couples loosely to the diode ends of the line. The other end of the probe is fed by the high Q concentric circuit with selects the required fourth harmonic component from the output of the local oscillator which is fed between the units through the short length of flexible cable H...

During the transmitter pulse the diodes are cut off by a large negative pulse of about 800 V (which actually was - 2.4 kV, AOB) *which is applied to the centre of the primary of the IF transformer and through the inner of the lines to the anodes of the valve, this being possible as there is no D.C. connection in the mixer circuit between the inner lines and earth.*

The suppression pulse is supplied from across a 5000 ohm resistance in the Impulse Generator Unit. (known as type number IG62, AOB) *As the cathode of the LG2 is grounded this 5000 ohm resistance is the only resistance in the mixer circuit and acts as bias resistance for diode. The current flowing in this circuit during working conditions is about 200 microamps.*

(b) Local Oscillator

The Beat Frequency oscillator consists of two parts, an oscillator and a frequency multiplier which quadruples the oscillator frequency.

The oscillator itself is a push-pull tuned-plate tuned-grid circuit using two Telefunken LD2 valves, working on about 146 Mc/s. The circuit is mounted in a ceramic frame plated on the inner side with copper, the whole assembly being housed in a cast iron box.

The tuned circuits are made of U-shaped ceramic plates coated with a white metal, apparently silver. The assembly is shown... While the oscillator and quadrupler assembly id mounted in the T and R box there is no means of adjusting the oscillator frequency or of changing the valves. If the unit is removed from the T and R box there is no hole through which the grid tuning condenser can be reached. This condenser, just under the coupling loop, J, cannot be reached except by removing the whole unit from its iron box.

The oscillator is preset in frequency by changing the capacities of C11, C12, C13 and C14...the condensers being actually formed between part of the plate and grid inductance snf the coated ceramic plates, Z, mounted on the silver coated ceramic shaft. By rotating the ceramic shaft the capacity of these condensers can be varied. Once the proper values are found the shaft is clamped and sweated to the copper plating lining the ceramic box. This can be seen fairly well in the photograph...of the oscillator...

The oscillator valves require an anode voltage of the order of 300 V. and when running in this circuit they draw about 50 mA. Provisions is made for possible metering of the cathode current of each valve and also the grid current and the plate current of both osc. valves, and grid current of the quadrupler.

Drive on the quadrupler is obtained by a small tuned hairpin loop, J, coupling to the anode circuit of the oscillator. The grid of the quadrupler has a certain amount of fixed bias and some self-bias. Conditions are arranged so that the total bias is such as to give maximum fourth harmonic component. The output is fed to a socket into which is plugged a cable.. This cable is roughly $\lambda/2$ *long in actual linear dimensions and is coupled at the other end by a small loop into the concentric circuit mounted on the back of the mixer box.*

This concentric selector circuit is of rectangular cross section, the inner wall consisting of two concentric tubes with a small clearance forming a lumped capacity which is tuned at about 585 Mc/s. (585/4 ≈ 146 MHz, which is the fundamental oscillator frequency, AOB) *with the inductance in the axial rod. The resonant frequency may be slightly changed by a small plate trimming condenser P. This circuit is shown...*

In view of the extremely specialised form of construction of this unit the frequency stability is probably very high, (this will be measured later), in fact much higher than is required in this equipment. It is therefore considered very probable that the was designed originally for communication purposes, especially as it is known the enemy (in casu the Germans, AOB) *have a communication system on frequencies of the order of 600 Mc.*

(c) IF Amplifier

The IF amplifier is made of nine units letters A-J, all Telefunken RV12P2000 low consumption pentodes. The general is shown.....

The output of the mixer is fed from the plug D through a concentric cable to the plug L on the IF unit. This connects directly to the grid of the first amplifier valve. Units A, B, C, and D are 25 Mc/s. amplifier stages employing single tuned circuit, apparently stagger tuned (see response curve). Unit E is an oscillator working at 18.5 Mc/s. Init F is a pentode convertor with cathode injection reducing the IF to 6.5 Mc/s. which is amplified by units G, H and J. The output "J" is fed through a step-down core transformer, tuned on the primary, to the output socket M. The best results are obtained by terminating this in 200 ohms. The overall gain of the amplifier is 70 db. with a bandwidth of 0.5 Mc/s. for 6 db. down. ....

The IF amplifier is made of pressed metal parts of some light weight alloy, Each stage is made as a unit and it is only necessary to take out 4 screws and unsolder 4 or 5 connections and the unit is free. Unit E, the second oscillator, is arranged to plug in. The reason for this was not at first seen until an occasion arose to remove Unit F. In order to remove Unit F, Unit E must be removed first to be able to unsolder the connection. In all the other units connections to be unsoldered in event of removal are readily accessible.

From the lightness and general method of construction of this unit it is thought very probable that it was originally designed for aircraft using another equipment, possibly for communications. Evidence in support of this is the output socket which is not congruous with the rest of the amplifier, and appears to have been added and the fact that the IF amplification of the RDF receiver carried out in two separate units. It seems likely that this particularly unit as originally constructed had two extra stages, probably an amplifier. There is room for these on the chassis when the output socket is removed as can be seen from ... and with this alteration the amplifier would have sufficient gain by itself to work headphones.

(6) AERIAL AND FEEDER SYSTEM

The aerial is a centre-fed half-wave dipole. Its reflector and the supporting structure containing the balance to unbalance transformer in the form of Pawsey stub is shown in...

The main feeder is an air spaced concentric of 70 ohms characteristic impedance with an outer diameter of about 1 inch. This branches into the Pawsey stub which is made in the form of a U with square section outer sheathing. There is a shortening bar across the limbs of this, forming and matching device by putting variable inductance across the dipole. In the best position of the shorting bar (which was as found) the standing wave on the main feeder was 2:1, and in the worst 4:1.

The common T and R system is formed by the branch of the main feeder to the T and R through twa adjustable phasing loops. The line to the R passes through a small balance to unbalance transformer of interesting design and then feeds the first tuned circuit which is connected to the double diode. It is arranged that the length of the feeder between the junction and the receiver first tuned circuit is N λ, and a large suppression pulse (-750 volts)(The actual voltage is not known, but from the modulator unit IG62 a -2400 volt was made available, AOB) *is applied to the diode anodes simultaneously with the transmitted pulse. Thus the open circuit is transferred to the junction point of the nλ/2 line during transformation.*

The transmitter phasing loop is adjusted so that during reception a very large impedance is present at the junction point.

As a system this is very efficient because no power is lost during either transmission or reception, but it is limited by the inverse voltage that the receiver diode will stand. This ability to withstand inverse voltage can only be obtained as the expense of increased time loss due to anode-to-cathode clearance being necessarily larger than usual, and for power outputs of the order of 100 kW. it is doubtful whether the system would be practicable. For small power it is excellent.

The dipole itself is made adjustable in length from 17.5 cm to 24.5 cm. by sliding 0.42 in dia brass tube over 0.31 in dia. tube.

The reflector is of curious design, being of sheet metal 95 cm long by 15 cm wide. It is mounted 8.75 cm (0.165) in front of the dipole and its function is to redirect energy back to the paraboloid.

The phasing loops are each adjustable over +/- 8 cm.

As regards construction, the shortness of feeder line and the use of ait spaced line throughout with few spacers is noticeable, as losses are very small and it is unnecessary for the aerial matching to be very exact. Standing waves need only to be small enough to prevent spark over.

The whole aerial system is very strong and well finished. Castings are used wherever possible with consequent reduction of matching time and waste material.

(7) FREQUENCY COVERAGE OF THE APPARATUS

This is extremely important from the point of view of jamming by us.

It is clear that the operator of one of these stations cannot make any rapid change of frequency at all because there is no external control of receiver local oscillator frequency.

By removing the units and adjusting them however, a considerable variation of frequency range of this is 531 Mc/sec. to 566 Mc/sec. To change the frequency by this amount would requie adjustments to at least the local oscillator and quadrupler (4 tuned circuits) the aerial phasing lops, and the aerial balance to unbalance transformer. This would require the services of a skilled technician and would some time to carry out.

If the transmitter were replaced also the frequency range would be much larger; probably 500 Mc/sec. to 700 Mc/sec approx. (Actually, the Germans went down to about 480 MHz and up to 580 MHz, as this proved to be the practical limit of the LS180 transmitter stage, AOB)

Thus the variation of frequency due to terminal drift of the local oscillator becomes of major importance when considering spot-frequency jamming useless a jamming system is used which automatically or manually tunes the jamming transmitter to the RDF frequency more or less continuously. This terminal drift will be measured later.

(8) NOTES ON VALVES AND CATHODE RAY TUBES

All the valves and all equipment were made by Telefunken, and the monitor CRT by Loewe Radio (this CRT was housed in the Modulator Unit IG62, as to monitor the shape of the transmitter pulse or that of the receiver blocking-pulse). *Without exceptions the valves are extremely robustly made and reach a very high standard in every respect. With the exception of the transmitting and the small pentode used in the IF amplifier they are all mechanically similar externally, using ring seals in the base for all the leads-out and a diecast aluminium alloy cap which is accurately lined up with the pins so that a strong and foolproof valve holder can be used. See... Details of interest are the tungsten for all the pins and the fact that the pins a tapered for easy insertion into the holder.*

Taking the valve in turn:_

(i) The transmitting Valve

This is called LS 180 and some more figures have already been given in Section (4) for ease of reference but are tabulated hereunder.

Max. anode voltage	- *above 12 kV. D.C. under oscillating conditions*
Anode dissipation	- *150 - 200 watts*
Filaments volts	- *6.2* (what they could not know is, that each valve was marked with its optimal value, AOB)
" *current*	- 12.5 amps
" *emission*	- *10 amps*
Amplification factor	- *30 - 50*
Frequency limit	- *probably about 750 Mc/s.* (actually, 600 MHz, AOB)

Grid and anode are brought out trough the top of the valve, each by a double seal to reduce inductance. The filament, which is thoriated, is brought out at the bottom. A photograph is appended..

Points of interest are the parallel wire grid, the heavily finned anode, the fact that the frequency limit is high for this type of construction, compared with British, valves. The maximum anode voltage is also higher than is used in British valves of this type.

(ii) The IF amplifier pentode

This is called RV12P2000 and well known to us. See... This valve is used very frequently in German radio equipment. It is a pentode of fairly poor performance with a slope of 1.5 mA/V, but it is very small and easily produced.

(iii) The receiver double diode LG2

A static characteristic of this has been taken and is appended... The conducting DC resistance is 2000 ohms.

The vale illustrated in.. and is very robust. Each anode is brought out to two pins and inside the valve consist of a bent metal sheet giving very low leadout inductance. The cathode is a large unipotential rectangular bar and is is also brought out through two pins. The fact that as a mixer on 600 Mc. the valve gives a very good performance in spite of the rather large electrode clearance of about 0.5 mm. shows perhaps that transit time loss is not so serious, and loss due to large leadout inductance and mutual inductance is more serious, than has been imagined.

(iv) Local oscillator valve

These and the quadrupler valve LD5, embody what sometimes referred to as "Micromesh" construction as the anode is split along a line parallel to that of the cathode and the grid loops protrude through this slit and are all fastened to a single supporting bar. Thus the grid inductance is reduced to a minimum. The anode is of particular shape and is well finned for cooling, and the pins are tungsten with silver thimbles over them to reduce contact resistance. The use of tungsten and hard glass seals reduces the dielectric loss which would be obtained if ordinary soft glass were used. As can be seen from plate...,which is a photograph of the datasheet published by Telefunken, the valve is 25% efficient as an oscillator at 50 cm. and 4 watts of C.W. are available at this wavelength. ...

(v) Quadrupler valve (LD5)

This is similar in construction to the LD2 except that the electrode axis is perpendicular to the axis of the glass bulb. This enables the grid and anode each to be brought two pins instead of one, thus reducing leadout inductance still further.

The fact that these two valves, the LD2 and LD5, combine such an excellent performance with mechanical rigidity and a standard form of base must be regarded a technical achievement of a very high order . ...

(vi) Modulator valve LS50

Photographs appear.... and characteristics as measured at T.R.E. are ....

These pentode valves were found to vary from sample to sample, and any particular valve on test showed considerable "creep??" with rise of screen and anode temperature. All the valves tested showed marked fluoresce when working in the Vg = 0 region.

It can be seen from the curves and the photographs that the valve has a very low impedance for its size, and makes an excellent general purpose valve for modulation, as an oscillator, and an amplifier probably up to frequencies of 50 - 100 Mc/sec.

(vii) Cathode Ray Tube

This is a 2"" dia. monitoring tube made by Loewe Radio and is designated "LB7/15 OPTA". ...

Unfortunately the tube structure electrode structure was damaged during capture so that deflection sensitivity could not be measured. It was possible on test to reduce a spot however and the beam-forming electrode voltage were measured. These can be deduced... The tube has a green screen and appears to be similar to our VCR91 and has a has a side contact base (which is not correct, as it looks like a steel-valve base of the 11 series, be it with additional pins, AOB)

(9) The presentation equipment

Unfortunately this was not captured owing to the lack of time. Considerable knowledge had been gathered (from prisoner-of-war reports) however, which shows that the tube was about 4 inches in diameter only and that the time-base was circular with radial deflection of signals....

A sketch is appended.. This shows that the receiver gain was usually operated at a high level, giving about 1 cm. of noise on the tube. Owing to the high recurrence frequency used (3750 pulses per second) it would be possible to see signals below the noise level as shown...

It will be seen that the time-base is blacked out during and after the transmitted pulse. This presumably done by the volatge across W57 (W = Widerstand = resistor, AOB) *in...*

As the tube is so small, and as the time-base length is 40 Km. as shown, range measurements cannot be carried out better than about 0.5 Km. by the average operator.

It seems certain that the equipment in the operating cabin include a 3750 c.p.s. (= cycle per second, AOB) *oscillator which not only provided the circular time-base but also provided the negative going firing wave for the transmitter modulator.*

As far as can be gathered no devices for anti-jamming were used.

(10) THE REPORTING SYSTEM

This was very simple. The 53 cm. station was linked up with the 240 cm. station about 1/4 mile further along the cliff edge by a landline, and control was affected from there. When an aircraft approached within 40 Km. it was handed over to the 53 cm. set for further plotting, and apparently the 53 cm. plots and the 200 cm plots were passed along the same landline to the local operators room.

The 53 cm. operator's microphone was mounted above a CRT and for receiving he used a loudspeaker. (My comments are, that the investigated prisoner-of-war must have had wild fantasies, these operators used headphone-sets combined with a chest microphone or a throat microphone; loudspeakers were seldom used by the Germans, AOB)

(11) CALCULATION OF THE PERFORMANCE

1. *Range*

Known data:-

(a) Aerial Gain

Paraboloid is 2.8 metres dia. $\lambda = 53$ *cm.*

$\therefore$ *Gain* $= 2x\,(\pi R/\lambda)^2$

= 140

(b) Transmitter Power

Normal output measured at 7 kW.

(c) Receiver sensitivity

A signal generator or (of??, AOB) *75 ohms internal impedance when connected to the receiver produces at the output a signal equal to the noise voltage when the voltage produced by the signal generator itself was 4.1 microvolts. This gives field strength at* $\lambda/2$ *dipole of*

$2\pi \times 4.1$ *microvolt/m*
= 48.6 microvolt/m to give signal to noise.

As bandwidth of the receiver is 0.5 Mc. this gives a noise factor of 20.3 db.

(b)(d?, AOB) *Target area*

Assumed to be 4 sq. metres for normal aercraft head-on.
Taking -

$$D_{max.} = \frac{K}{\sqrt{E_R}} \sqrt[4]{\frac{A.P.GT.GR.}{2\,Z_o} \times 10^{-15}}$$

Where $D_{max.}$ *is in miles*

K	$= 3.915 \times 10^5$
E_R	*= field strength at receiver dipole in microvolt/m.*
A	*= target area (effective) in sq. metres.*
P	*= Tx power in kW.*
$GT.GR$	*= Zo 377 w.= intrinsic impedance of free space*

$$D_{max.} = \frac{3.915 \times 10^5}{\sqrt{48.6}} \times \sqrt[4]{\frac{4 \times 6 \times 140 \times 140 \times 10^{-15}}{2 \times 377}}$$

$$= \underline{28 \text{ miles}} \text{ (to nearest mile)}$$

$$= \underline{45 \text{ Km.}} \text{ in tip of lobe}$$

This is of the right order since normal max. range is 40 km. but 60 km. has been seen. (Corresponding to effective A of about 8 sq.m. instead of 4, or signal below noise level, which would be detectable on account of the high pulse recurrence frequency).

2. Jamming Power required

Jammer on every aircraft. RDF station assumed to be pointing at aircraft

Field strength at aircraft

$$E_a = \frac{K\sqrt{PG_T}}{d}$$

and Power reflected from aircraft

$$E_a = \frac{K\sqrt{PG_T}}{d}$$

Assuming that jamming must be equal to echo at range of two miles, therefore jamming power per channel required to re-radiated power at range of 2 miles.

Hence radiated jamming power

$$P_J = \frac{A}{2Z_0} \cdot \frac{K^2 P . G_T}{D^2} \times 10^{-15} \text{ Kw.}$$

$$= \frac{4}{2 \times 377} \times \frac{3.915^2 \times 10^{10} \times 6 \times 140 \times 10^{-15}}{2^2} \text{ Kw.}$$

$$= \underline{0.17 \text{ watts per channel}}.$$

Receiver bandwidth is 0.5 Mc.

Taking max. frequency range to be covered by jammer as 53.0 cm. to 56.5 cm. (567 - 531Mc. = 36 Mc).

Therefore Average Power required from jammer is:-

0.17 x 36/0.5
= 12.2 watts (radiated from aerial).

12. CONCLUSION

As regards operational performance and general RDF technique, the equipment does not show and original trend or novel feature; it is straight forward and in no respects is it brilliant. Compared with British technique, in many ways, it lags behind; the lack of split for D/F, the poor accuracy of range measurement, and the crude height-finding system illustrate this clearly. On the other hand it must be remembered that the equipment was made in 1940 and designed in 1939 or earlier in all probability. Also, it was originally designed as an RDF aid to Observer Corps posts where great accuracy was not required. Further, in 1939 on 50 cm. in England was not sufficiently developed to give a maximum range of 50 km. on aircraft - we did not reach the stage until 1941. Nevertheless, in general and considered as a weapon of defence, this equipment has shown nothing new.

In certain technical details, mechanical construction and general engineering design however the apparatus is outstanding and is worth careful study, especially by those engaged in development and production.

The robustness of the equipment is very notable. Not only is the whole equipment mounted in a very strong box, but each individual unit within this box is of sturdy construction. Even the removable components, such as the valves, are more robust than we are accustomed to expect. This robustness is in part achieved by the very general use of castings in aluminium and light alloys, and mouldings. For this manufacturing technique to be economical it is necessary for a stability of design to exist, such as can only be achieved by careful and probably lengthy development. When it has been achieved however it is possible to use one unit in a number of different equipments. This construction by sub-units of generalised design has advantage of maintenance. Retrospective modifications may also be carried out by replacing units by improved designs.

In this equipment, for example, the IF amplifier unit and the local oscillator unit were probably not designed for this application. On the other hand there appears to have been no hesitation to use special types of valve and special units where the standard article was not available.

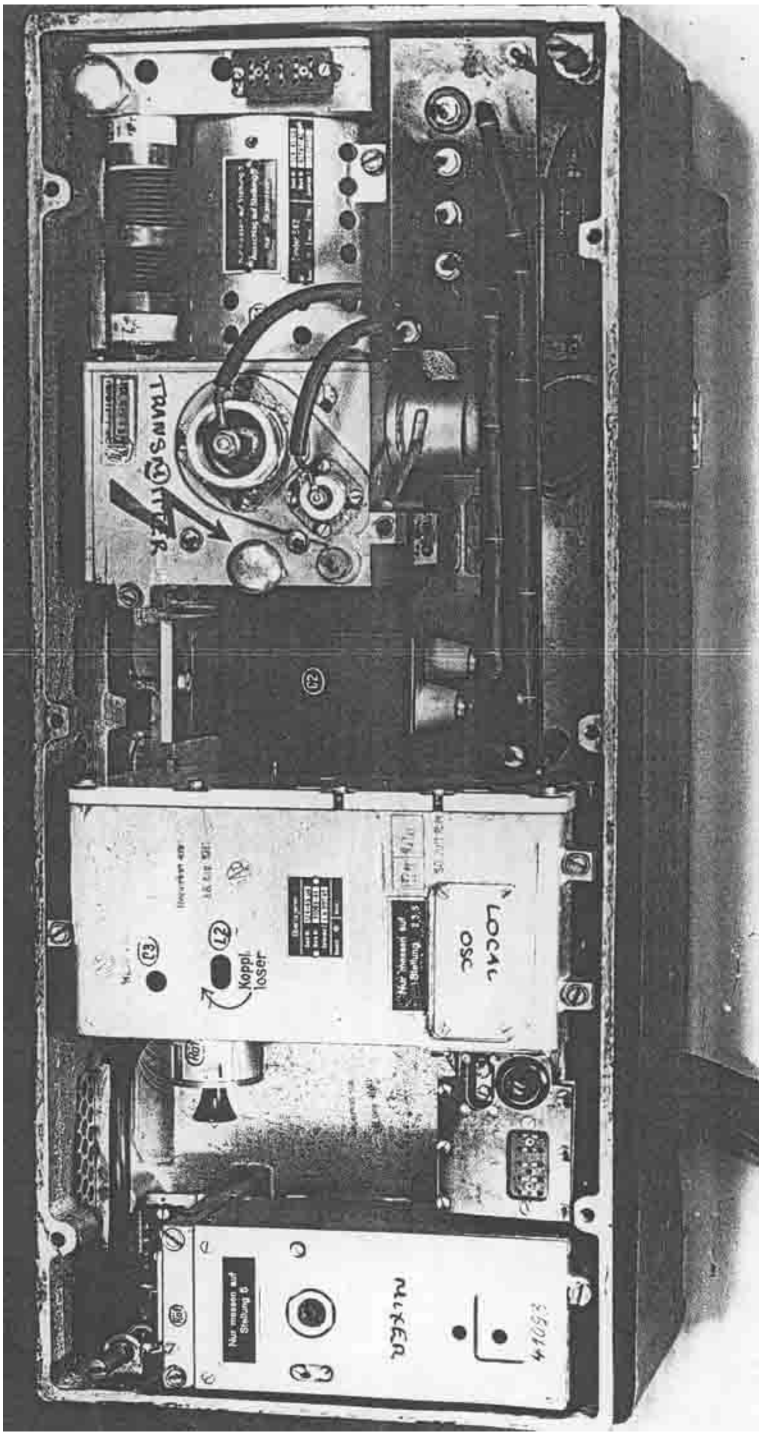
It has often been alleged that the Germans have restricted their set designs so as to use much smaller number of valve types than we would use. This equipment does not confirm this. In the captured portion of equipment six different types of valve are used, excluding power supplies and cathode ray tube. A corresponding British equipment, the Mark II ASV, uses only five *types of valve in this portion, and has a better overall technical performance. In the IF amplifier of the German equipment a large number of one type of valve is used, a large number of another type is also used in the modulator. On our standards the equipment is extravagant in the total number of valves.*

The overall performance of an RDF system depends mainly on two characteristics peak pulse power of the transmitter and the signal-to-noise ratio in the receiver. For the German equipment the peak pulse power is 5 kW, which may be compared with 100 kW. available in our corresponding 50 cm. transmitter employing NT99 valves. The noise level in the German receiver is 20 db. above thermal noise; in our last 50 cm receiver the noise level is less than 12 db. above thermal noise. This represents a power gain of more tha sic times in our favour in the receiver, and twenty times in the transmitter. Judged by those standards the German equipment is of a low performance, but it must be remembered that the equipment was probably designed in 1939 and at that time the great drive on RDF had hardly get under way and we could not even have matched the performance of the German equipment.

One of the main interests in examining this equipment has been to discover any means by which it may easily be jammed. Unfortunately the prospect of this is not very hopeful. While the apparatus is constructed so that it is not possible to change the radiofrequency at all quickly, it is nevertheless possible to tune over a wide range, and our listening tests have shown that these equipments are in fact set up over a considerable frequency range.

8th May 1942
DHP/SWW

Please notice the photographs ate the next pages



T and R unit, German nomenclature SÜ62a (front cover been removed)

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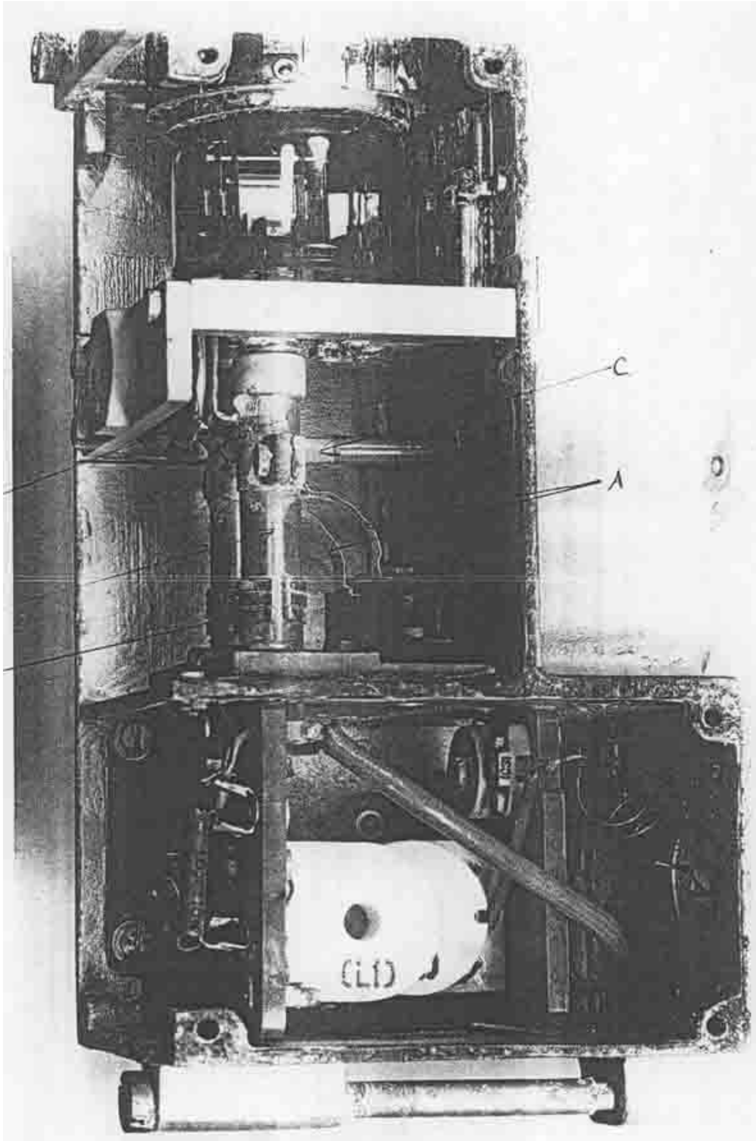
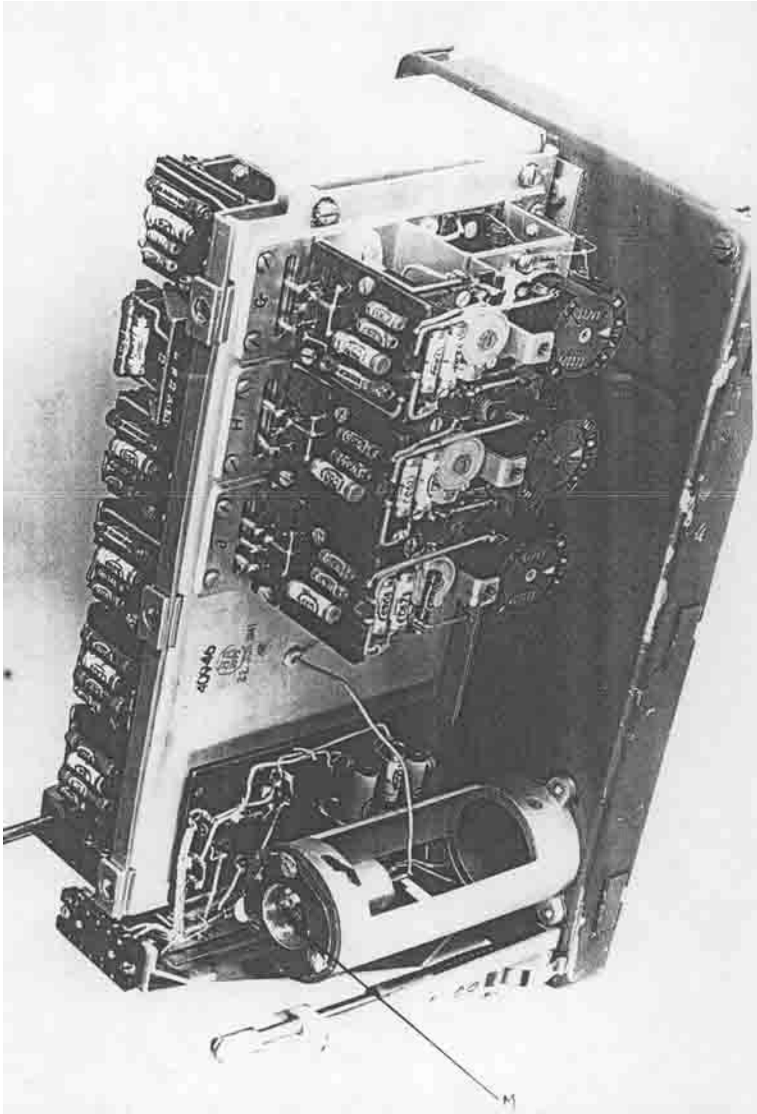


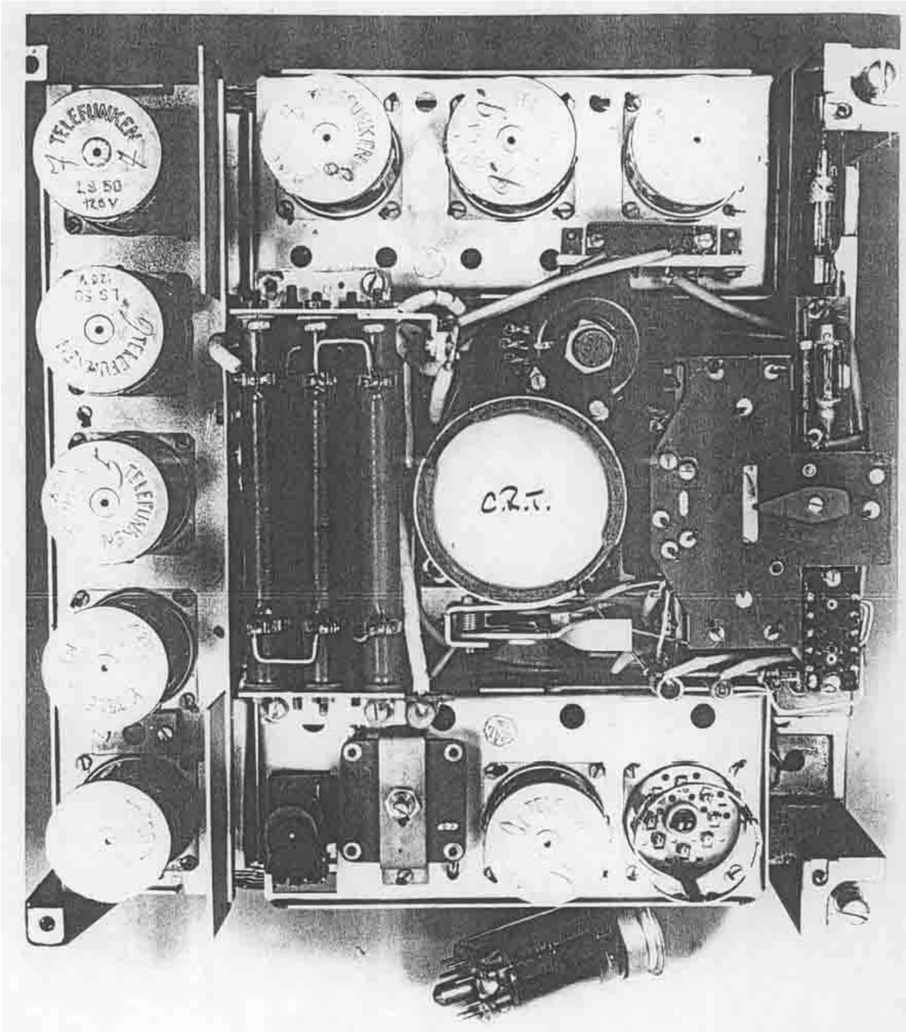
Mixer stage, opened

Consider also next page



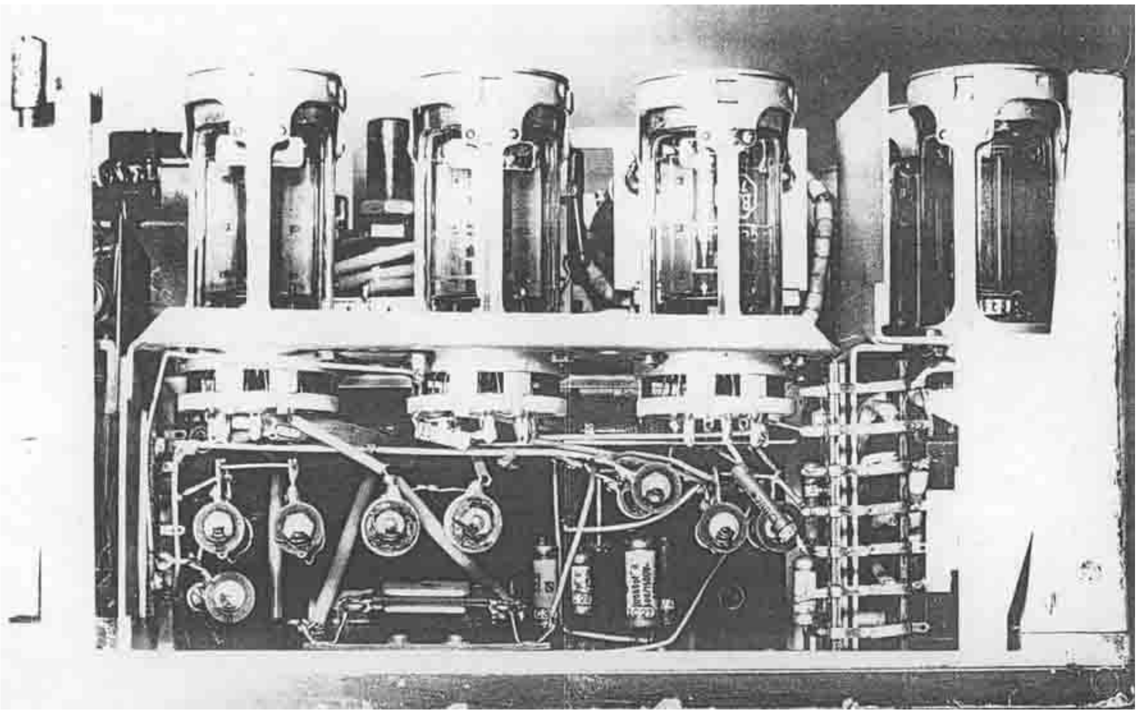
IF amplifier, with covers of the various IF stages being taken off. Its compactness is evident. The plug M is the IF output (6.5 MHz) fed onto the final stages in the presentation unit. Which was in this particular case, the rather obsolete SG62 type. Some Würzburgs had already been upgraded to type C and even type D. The latter type being the state of the art up to the end of hostilities in Europe.

Regard also the illustrations at the next pages



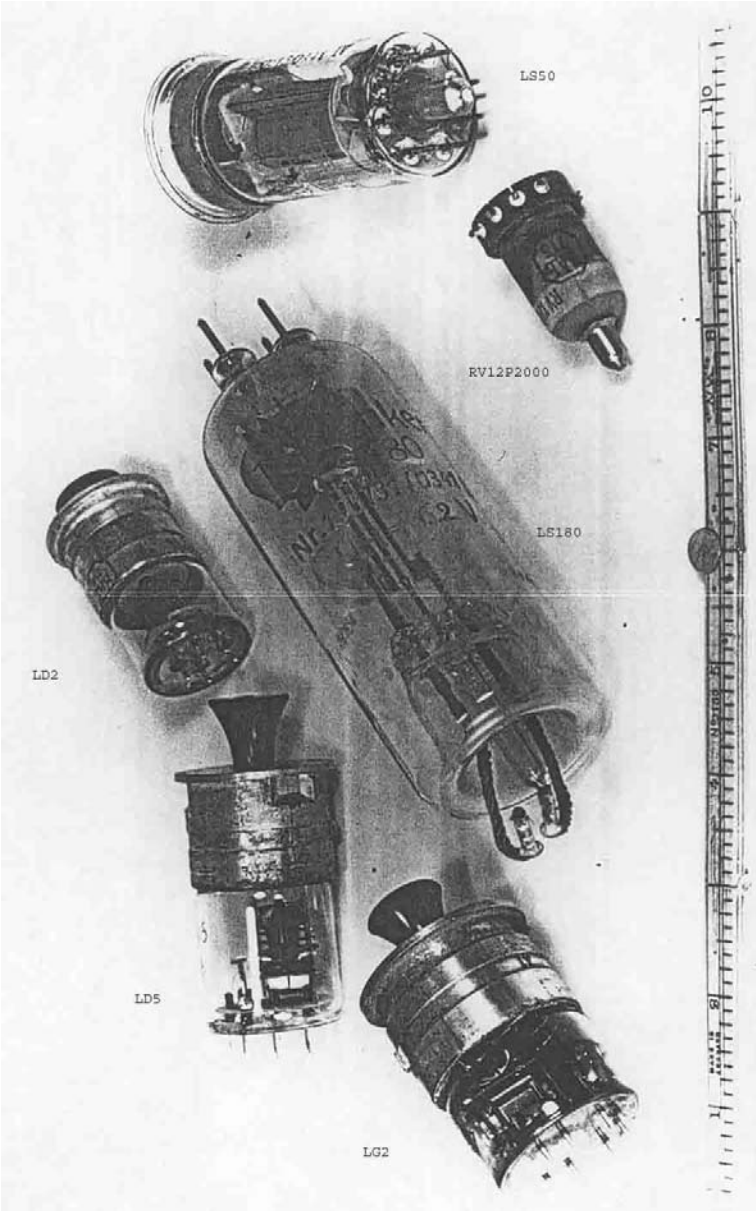
The front side of the Modulator unit type IG62 (cover being removed). It was mounted on the mounting frame (rack) rotated 90 ˚ clockwise. The pull-out LS50 at the bottom-end left is shown below the modulator unit. The CRT (type LB 5/15) could show the pulse shape of the transmitter- or the receiver blocking pulse. It could only be operated as long as the spring-loaded switch, right of it, was kept in clock- or anti-clockwise position.

Notice also next pages



Side view of the Würzburg modulator type IG62. Notice also the LS50 valve holders. Which shows a very robust and foolproof valve (base) holder. The aluminium top-cap was used for both cooling and facilitated valve pulling.

Consider also last page



Shown are the valve types, employed in the FuSE62 (FuG62)
Würzburg (Wuerzburg) apparatus. LS50, RV12P2000, LD2, LD5, LG2, LS180