17 DEC 1953

COPY NO. 43

P.O. RESEARCH STATION
LIBRARY

RADIO REPORT No. 2260

POST OFFICE ENGINEERING DEPARTMENT

RADIO REPORT No. 2260

The Detection and Location of Television Receivers

OFFICE OF THE ENGINEER-IN-CHIEF,
(RADIO BRANCH),
GENERAL POST OFFICE,
LONDON, E.C.I

[For Official Use Only]

SO8291 Wt 15776/21057 30m 2/52 TPLtd G751

q 12.6.53

U.D.C. No.621. 397. 62:621. 396. 677.1

FOR OFFICIAL USE

POST OFFICE ENGINEERING DEPARTMENT

RADIO REPORT NO. 2260

THE DETECTION AND LOCATION OF TELEVISION RECEIVERS

Case No. 3408

Carried out by:- D.W. Morris, G. Mitchell, R.E. Blann and W.N. Genna
at the Radio Experimental and Development Branch
Laboratories, Dollis Hill.
January - March, 1952.

W.J. BRAY

Assistant Staff Engineer

H.G. BEER

for Engineer-in-Chief,

21 May 1953.

Office of the Engineer-in-Chief, (Radio)
General Post Office,
London, E.C.1.

SUMMARY

Two equipments are described which enable the majority of working television receivers to be detected and located, irrespective of whether internal or external aerials are employed. One equipment is designed for installation in a standard Radio Interference van, whilst the second is an inconspicuous portable unit using a modified hearing aid; the two equipments have been developed for use in a complementary manner. Field trials have indicated that well over 90% of working television receivers can be successfully located using the equipments described.

Both equipments indicate the presence of the vertical component of the magnetic induction field set up by the line-scanning coils of a television receiver; the location of the source of the field is carried out by comparing the intensity of the field at different distances from the receiver, making use of the fact that the intensity varies approximately inversely as the cube of the distance from the receiver. Television receivers can be detected up to a distance of about 100 ft. using the mobile equipment, and up to about 30 ft. using the portable equipment.

CONTENTS

1. INTRODUCTION

2. THE FUNDAMENTAL DIRECTION-FINDING PROBLEM
2.1 The Field Produced by the Television Receiver

2.2 Distortion of Field by Ferrous Objects External to the Receiver
2.3 Preliminary Work with Rotating Opposed-Loop System
2.4 Principles of Fixed-Loop System

3. FACTORS AFFECTING DESIGN
3.1 Choice of Operating Frequency
3.2 Variation of Line-Scanning Frequency
3.3 Magnetic Induction Field Strength from Typical Television Receivers

4. DESCRIPTION OF THE MOBILE EQUIPMENT
4.1 General
4.2 Loop Aerials
4.3 Control Unit
4.4 Receiver and Output Power Meter

5. IGNITION INTERFERENCE FROM RADIO INTERFERENCE VAN

6. DESCRIPTION OF THE PORTABLE EQUIPMENT
6.1 General
6.2 Loop Aerial
6.3 Receiver and Power Supplies

7. PERFORMANCE

8. CONCLUSIONS

APPENDIX I. Calculation of the Magnetic Induction Field Strength at a Distance from the Line Scanning Coils of a Television Receiver.
APPENDIX II. Alignment and Operation of the Mobile Equipment.
APPENDIX III. Alignment and Operation of the Portable Equipment.
APPENDIX IV. Modifications to HRO Receiver.
APPENDIX V. Modifications to Medresco Mk. IIA Hearing Aid (Insert Type).
APPENDIX VI. Ignition Interference Suppression of R.I. Van.
APPENDIX VII. List of Drawings

DRAWINGS INCLUDED:- WL 71006, 71008, 71009, 71133, 71408.

PHOTOGRAPHS INCLUDED:- Neg. Res. Nos. 9346, 9420, 9421.

DRAWINGS REFERRED TO BUT NOT INCLUDED:- WL 34666, 34728, 80561; M.O.H. 5017/1.

1. INTRODUCTION

The equipment described has been developed to enable working television receivers to be detected and located. Two separate equipments have been designed for the purpose, one of which is suitable for installation in a standard Post Office Radio Interference van, whilst the other is an inconspicuous portable unit. The primary purpose of these two equipments is to assist the Department in carrying out television licence investigations but, as a secondary purpose, the equipments could be used in conjunction with licensing records to estimate the proportion of viewers in a given area using their receivers at any given time.

In each type of equipment working television receivers are detected by means of the magnetic induction field set up by the line-scanning coils of the receivers. Receivers employing electro-static deflexion cannot be detected by means of the techniques described but these receivers are relatively few in number. It is not readily possible to avoid the production of an appreciable induction field at a distance from a television receiver using magnetic scanning; for example, the electro-static screens sometimes provided to minimise the interference produced in

long and medium-wave broadcast receivers have a negligible effect in reducing the magnetic induction field strength from such equipment.

The mobile equipment is intended primarily for use in areas where television receivers are likely to be reasonably well separated. The portable equipment has been designed for use in more congested areas (e.g. in areas containing terraced houses and blocks of flats). However, for reasons discussed later, the greatest reliability and speed of working is obtained by using the two equipments in conjunction with each other.

The normal operational range of the mobile unit is approximately 100 feet and that of the portable equipment 30 feet; these ranges may well be exceeded with some television receivers.

The mobile equipment has been designed not only to detect the presence of working television receivers but also to provide certain direction-finding facilities. The portable equipment does not provide direction-finding facilities, but enables locations to be achieved by observing the changes in the amplitude of the induction field as the detector is moved about in the vicinity of the television receiver which is sought. Better discrimination may be obtained with the portable unit than with the mobile equipment since individual television receivers may be approached more closely with the former.

2. THE FUNDAMENTAL DIRECTION-FINDING PROBLEM

2.1 The Field Produced by the Television Receiver

The line-scanning coils of a television receiver produce a magnetic field which is most intense at the centre of the scanning coils, but which also extends externally to the receiver, as shown in Drawing WL 71006. Ideally, this field is at right-angles to the horizontal plane containing the axis of the cathode-ray tube, and the equi-intensity contours are in the form of a family of circles centred on the receiver (with the field intensity varying inversely as the cube of the distance from the receiver - see Appendix I). Under these conditions it would readily be possible to devise an accurate direction-finding system, but in practice the field is often distorted, mainly by the ferrous magnetic circuits associated with the line-scanning coils, and the accuracy of any direction-finding system is severely limited.

Tests with a number of typical television receivers have confirmed that the equi-intensity contours in the horizontal plane containing the receiver are not, in fact, circular but the tangential directions of the contours may differ by up to 15° from the idealized "circular contour" case considered above.

2.2 Distortion of Field by Ferrous Objects External to the Receiver

An additional factor limiting the accuracy of a direction-finding system used for the location of television receivers is the distortion of the magnetic field by large ferrous objects situated in the neighbourhood of the receiver or detection equipment. Typical objects are the steel frameworks of buildings, iron railings and vertical drain pipes. Appreciable field distortion may occur when such objects lie within about 100 ft. of the receiver or the direction-finding equipment.

2.3 Preliminary Work with a Rotating Opposed-Loop System

In an early version of the mobile equipment two identical horizontal loops tuned to 20.25 kc/s (the second harmonic of the line-scanning oscillator) were attached at either end of an arm rotatable about a vertical axis of symmetry.

The loops were connected in phase opposition, and the output from them was fed to a radio receiver (also tuned to 20.25 kc/s) incorporating a beat frequency oscillator so that the presence of a 20.25 kc/s field was indicated by an audio note. The arm could be rotated until the resultant output was a maximum (when the arm, in the absence of field distortion, would lie in the direction of the receiver) or, alternatively, until a null position was found (when the direction of the receiver would be at right-angles to the arm). The former alternative was found preferable, although less accurate, because of the high level of ignition noise emanating from the vehicle in which the equipment was mounted.

The opposed-loop system had the merit that it was insensitive to the radio noise field or interfering signals from distant sources, but in practice this point proved of small importance in view of the comparatively high level of the ignition interference from the vehicle. This system was not pursued for the following reasons:-

(i) the signal-to-ignition interference ratio that could be obtained at the receiver output was much less than that obtainable from a non-opposing loop system;

(ii) the "base-line" length (i.e. the distance between the loops) was of necessity comparatively small and this had an adverse effect on bearing accuracy.

2.4 Principles of Fixed-Loop System

The mobile equipment finally developed uses three loops mounted on a framework attached to the roof of a Radio Interference van and mounted as far apart as possible (as shown in Drawing WL 7006). The principle of operation is as follows. When the field strengths at the front and back loops (Nos. 1 and 2) are equal, the receiver, in the idealized case, must lie on a line at right-angles to the centre line of the vehicle midway between these loops. By comparing the field strength at left-side loop (No. 2) with that at right-side loop (No. 3) it is possible to determine on which side of the vehicle the receiver must lie. In order to compare the levels of the signals received by the loops it is arranged that each can be switched to the input of a sensitive radio receiver provided with an audio output power meter (for level comparison) and headphones (for initial detection of the television receiver). A beating oscillator is provided in the radio receiver in order to produce an audio beat note. The procedure for locating a working television receiver therefore consists in driving along the road until a beat note is heard in the headphones; the R.I. van then proceeds until equal strength signals from loops 1 and 2, as shown by equal meter deflections, indicate that the R.I. vehicle is directly opposite the receiver. Comparison of the levels of signals from loops 2 and 3 then indicates on which side of the road the receiver is situated.

It would, of course, be possible to develop a system in which the signals from the three aerials are compared continuously and the relative levels indicated on "front-back" and "right-left" meters; however, the simple system described above enables the operator more readily to distinguish cases of field distortion and is less affected by ignition interference.

3. FACTORS AFFECTING DESIGN

3.1 Choice of Operating Frequency

The line scanning oscillator of a television receiver produces a saw-tooth current wave with a nominal repetition frequency of 10.125 kc/s. Such a wave comprises the fundamental and the 2nd, 3rd, etc., harmonics, the level varying inversely as the order of the harmonic. It is desirable, therefore, to design the equipment to operate on one of the lower harmonics in order to take advantage of the higher available field strength; on the other hand, since

suppression of the ignition interference is less effective at lower frequencies, the field strength of the interference increases as frequency decreases. It has been found that, when the vehicle is suppressed as effectively as is readily possible, the use of the second or third harmonic as the operating frequency of the detection equipment results in a more satisfactory signal-to-interference ratio than does the use of the fundamental frequency. With higher harmonics (of frequencies 50 kc/s and above) the carriers of long-wave radio transmitters are apt to be confused with the wanted signal. Furthermore, tests indicate that the distortion of the magnetic field due to iron structures is less at the lower frequencies; thus the use of a lower frequency enables receivers to be located with greater accuracy.

In view of the above considerations the mobile equipment was designed to operate on the second harmonic (20.25 kc/s) of the line-scanning oscillator frequency. The portable detection equipment was designed to detect the third harmonic (30.75 kc/s), this frequency being chosen to prevent any interaction between the two equipments when in simultaneous use.

3.2 Variation of Line-Scanning Frequency

The line-scanning frequency at the television transmitter may be derived by frequency multiplication from the mains-supply frequency (nominally 50 c/s). Variations of the mains frequency as large as $\pm$ 2% occur in practice and may cause similar percentage changes in the line-scanning frequency at the transmitter and therefore at the receiver. A bandwidth of $\pm \frac{2}{100} \times 20.25$ kc/s (i.e. approximately 800 c/s) would therefore be required for the mobile equipment if the need for retuning is to be avoided. However, it has been found desirable to restrict the bandwidth to approximately 200 c/s by means of an A.F. note filter as a means of minimising the effect of ignition interference, and slight retuning may therefore occasionally be necessary.

It should be noted that it is rarely possible to detect a television receiver which is switched on but not synchronized; not only is the free-running line-scanning frequency very different from 10.125 kc/s but also the line time base usually exhibits considerable jitter under these conditions. Faulty synchronization of a television receiver is shown by the detection equipment as a characteristic instability of the A.F. note.

In the case of the portable detection equipment the bandwidth required to avoid the necessity of re-tuning is $\pm \frac{2}{100} \times 30.75$ kc/s, i.e. approximately 1200 c/s, and the Q-factor of the pick-up coil (about 30 at 30.75 kc/s) is such that this requirement is substantially met.

3.3 Magnetic Induction Field Strength from Typical Television Receivers

Measurements have been made of the strength of the vertical component of the magnetic induction field set up by each of several typical television receivers (for convenience magnetic induction field strengths are expressed throughout this Report in terms of the equivalent electric field strengths). Values of about +55 db relative to one microvolt per metre at a distance of 75 feet from the receiver were typical, variations from receiver to receiver of about $\pm$ 10 db being observed. A few receivers with very efficient iron circuits in the line scanning coil assemblies set up fields some 20 db below the value stated above. The variation of signal strength observed during tests in a suburban road is indicated approximately in Drawing WL 71009.

4. DESCRIPTION OF THE MOBILE EQUIPMENT

4.1 General

The mobile equipment comprises three identical loop aerials, an aerial selection switch, a radio receiver capable of tuning to 20.25 kc/s, an audio output power meter and head-phones. The three aerials are mounted on the roof of the R.I. van on a wooden framework as shown in Photograph Neg. Res. 9420; the remaining equipment is mounted inside the vehicle behind the driver's seat as shown in Photograph Neg. Res. 9421. The complete system is shown diagrammatically in Drawing WL 71006, and the operating instructions are given in Appendix II.

4.2 Loop Aerials

The loop aerials are coded as Aerials No. 11A, the assembly being shown in Drawing WL 34666 (not attached). The loops have a side length of approximately 12.5 inches and are wound on a cross-shaped former of S.R.B.F., enclosed in a weather-proof box of S.R.B.F. protected by synthetic resin varnish. The winding consists of eight layers, each of 30 turns of 30 S.W.G. D.E. copper wire separated by Empire-cloth tape. The inductance (measured at 1 kc/s because of the high self-capacitance) is 70 mH, and the Q-factor and effective height (at 20.25 kc/s) are 65 and 0.01 metre respectively. Thus, with the field strength of +55 db relative to one microvolt per metre to be expected from a typical television receiver at a distance of 75 feet, the voltage available across the tuned loop is 55 -40 +36 = +51 db relative to one microvolt. This value is well above receiver noise but only slightly above ignition noise (see Section 5).

It is necessary for the three loops to have substantially equal values of inductance and Q-factor. No difficulty was encountered in achieving this with sufficient accuracy during the manufacture of the loops and no provision has therefore been made for adjustment of the loop output voltages to equality for equal induction field intensities.

The three aerials are bolted to a wooden framework which is clamped to the roof of the vehicle; the general arrangement is shown in Photograph Res. Neg. 9420, and details of the complete assembly are given in Drawing WL 34728 (not attached).

A coaxial cable (PT1M) is connected to each loop by soldering to tags on which the winding is terminated and these cables are run to the Control Unit in the van. The method of running the cables and the arrangement adopted to bring them through the van roof are given in Drawing WL 34728 (not attached). The loop aerials are each parallel-tuned to a frequency of 20.25 kc/s, the tuning capacitance comprising the self-capacitance of the loop, the capacitance of the associated cable and a tuning capacitance of some 500 $\mu\mu$F in the Control Unit.

4.3 Control Unit

The circuit diagram of this unit is shown in Drawing WL 71008. The three cables, one from each loop, are connected to the unit by means of coaxial plugs and sockets, the plugs being connected to a 1-pole 4-way Oak-type switch SWA2. The travelling contact of this switch is connected via coaxial plug, socket and cable to the grid of the first R.F. stage of the radio receiver. The switch thus enables each of the loops in turn to be connected quickly to the receiver. Trimmer capacitors C1-3 are also located on this unit (one for each loop) so that each loop may be tuned to resonance at 20.25 kc/s. The fixed capacitors C4-6 are wired in parallel with the trimmers to bring the total shunt capacity up to the required value.

A second 1-pole 4-way switch wafer SWA1, is ganged to the first and is used to switch lamps associated with each loop thus giving an indication of the loop in use. The lamps are equipped with coloured opals; a white lamp indicating that loop 1 is in use, while red and green lamps indicate loops 2 and 3 respectively. A fourth position on the rotary switch is provided to enable a test signal to be injected into

the receiver; the associated lamp is equipped with a white opal. The Control Unit as mounted in the R.I. van can be seen in Photograph Neg. Res. 9421, on the right-hand side of the table.

4.4 Receiver and Output Power Meter

During the development of this equipment a Marconi CR 200 receiver was used, but for field use HRO receivers, modified for operation at 20.25 kc/s, have been employed since receivers of this type were readily available. Details of the receiver modifications are given in Appendix IV and in Drawing WL 71133. The input cable from the Control Unit is taken direct to the grid of the first R.F. stage, the original grid connexion being removed; a 2.2 megohm resistor is connected between grid and earth. Briefly, the modifications involve changes to the coil unit (normally covering the ranges 50 - 100 kc/s), changing the frequency of the first beating oscillator, and the provision of a simple A.F. note filter. (The crystal filter is not used for the reason given in Section 5 of Appendix IV).

Indications of the receiver output level are given aurally on headphones or are shown on an audio output meter (Decibel Meter No.5) which is connected to the receiver headphone jack via a Transformer 66B. The output meter is used with its switch in the "level" position, i.e. as a voltmeter, and the circuit is arranged so that the output meter is short-circuited when the headphone plug is removed from the jack. The normal output valve of the receiver is not used and is removed in order to economise in H.T. and L.T. power consumption and to allow room for the Transformer 66B.

Power supplies are obtained from batteries, special battery compartments being provided in the vehicle.

5. IGNITION INTERFERENCE FROM R.I. VEHICLE

During the earlier experimental work on the mobile equipment it was apparent that the range at which working television receivers could be detected was limited by interference from the ignition system of the vehicle in which the equipment was mounted. Simple resistor suppression by itself was found to be insufficient, and more complete suppression (described in Appendix VI) was evolved. This degree of suppression enabled a range of about 100 feet from a typical television receiver for a signal-to-interference ratio of about unity to be obtained, and appears to be the best that can be expected without resorting to complete screening. Screening of the ignition system by braided copper screening material proved to be almost completely ineffective, probably because the thickness of the braid used was inadequate for the very low frequencies involved. Because of the large depth of penetration of eddy currents into copper at 20.25 kc/s it is probable that a significant improvement in screening could only be achieved by complete coaxial screening of the entire ignition system with copper at least a few millimetres thick. Such an arrangement would be expensive in material and labour and would only be justified if prolonged field experience with the mobile equipment showed that further suppression were essential. Field experience indicates that improved suppression would probably result in quicker operation and might possibly permit the location of a few receivers which, with the existing degree of suppression, may elude detection at present.

6. DESCRIPTION OF THE PORTABLE EQUIPMENT

6.1 General

The portable equipment comprises a horizontal loop aerial, worn by the operator around the waist, and a Medresco Mark, IIA insert-type hearing aid (Diagram M.O.H. 5017/1, not attached), modified by the addition of a 30 kc/s beating oscillator.

The loop aerial is approximately tuned to the third harmonic (30.75 kc/s) of the line-scanning frequency; the signal from the loop aerial beats with the output of the local oscillator to produce an audible note in the hearing-aid receiver. The level of the note increases rapidly as the operator approaches the television receiver, thus giving an indication of the location of the receiver.

The complete equipment consists of four items shown in Photograph Neg. Res.9346:-

(i) Loop aerial - this functions not only as the pick-up coil but also as the tuning inductor for the beating oscillator.

(ii) Modified Medresco Mark IIA insert-type hearing aid.

(iii) Hearing aid receiver.

(iv) Batteries and battery case.

The modifications to the hearing aid circuit are shown in Drawing WL 71408.

6.2 Loop Aerial

The loop is a non-rigid unit comprising 120 turns of 81/46 stranded enamelled copper wire, single artificial-silk covered; the winding is centre-tapped. It is wound on a 15inch diameter former which is subsequently removed and the loop fitted into a length of $\frac{3}{4}$ inch diameter P.V.C. tube (previously split longitudinally) and bound with $\frac{1}{2}$ inch self-adhesive P.V.C. tape lapped $\frac{1}{4}$ inch.

The loop is terminated (two ends and centre-tap) on three small sockets mounted on a tube of $\frac{1}{8}$ inch S.R.B.F., $2\frac{1}{2}$ inches long x $1\frac{1}{4}$ inches radius and split longitudinally, and is connected to the hearing aid via wander plugs. The tuning capacitor C1 is also mounted on the split tube, on the outside, and capacitors C2 and C3 are mounted inside. After assembly and wiring of these components the tube is sprung over the loop and bound in position with $\frac{1}{2}$ inch self-adhesive P.V.C. tape.

6.3 Receiver and Power Supplies

The modifications to the circuit of the Medresco Mark II hearing aid are shown in Drawing WL 71408, and details of the modification are given in Appendix V. An additional valve V4 (CV 2107) operating as a Hartley oscillator at a frequency of approximately 30 kc/s is wired in the space normally occupied by the microphone; the tuned circuit comprises loop L1 and capacitors C1-C2. The loop L1 also functions as an aerial and in the presence of a 30.75 kc/s magnetic field (derived from the third harmonic of the current in the scanning coils of a television receiver) presents a 30.75 kc/s signal to the grid of V4. V4 in addition to being the oscillator valve also acts as a detector and the anode current varies at the difference between the signal and oscillator frequencies. The oscillator is adjusted by means of C1 so that a beat note of several hundred cycles is heard in the receiver when the loop is being energised. To eliminate the oscillator frequency from the A.F. amplifier, the tone control on the hearing aid is switched to the "closed" position, thereby restricting the audio bandwidth.

The power supplies are obtained from the batteries normally used with this hearing aid. Care should be taken that in use the battery leads and hearing aid receiver leads are not run close together, otherwise instability may occur.

7. PERFORMANCE

The mobile and portable equipments have proved most effective when used in a complementary manner. Thus the mobile equipment with its greater range (about 100 feet) and inherently speedier means of movement enables the approximate position

of working television receivers to be determined rapidly, while the subsequent use of the portable equipment, which can be operated at short range where the induction field varies rapidly with distance, enables accurate locations to be made. Tests indicate that more than 90% of working television receivers may be located by the complementary use of these two equipments.

A valuable feature of the portable equipment is that it enables ambiguities and uncertainties of location caused by magnetic field distortion (Sections 2.1, 2.2) to be very largely overcome; on the other hand the range of the portable equipment is limited to some 30 feet.

The range of the mobile equipment is determined by the effectiveness of the suppression of ignition interference; the suppression provided at present is adequate in as much as few television receivers escape detection when due care is taken, but on the other hand better suppression would not only increase the range but enable more rapid locations to be made. A possible alternative to more complete suppression of the ignition system would be to use a Diesel-engined vehicle.

The portable equipment is not only a useful adjunct to the mobile equipment, but also has a role of its own in investigations involving large blocks of flats; in investigations of this type it has proved to be quick and accurate in most cases, although distortion of the magnetic field due to steel framework of the building has caused difficulties in some cases.

8. CONCLUSIONS

Two equipments for the detection and location of working television receivers have been described. One is a mobile equipment installed in a standard R.I. vehicle and has a range of about 100 feet with the majority of receivers. The second is an inconspicuous portable equipment with a range of approximately 30 feet. The two equipments, which detect the magnetic induction field set up by the line scanning coils of a television receiver, are intended for complementary use and are designed to be mutually non-interfering.

Tests indicate that more than 90% of working television receivers may be located by the use of the equipments.

APPENDIX I

CALCULATION OF MAGNETIC INDUCTION FIELD STRENGTH AT A DISTANCE FROM THE LINE SCANNING COILS OF A TELEVISION RECEIVER

It will be assumed that the line scanning coils can be represented, with sufficient accuracy for present purposes, by a single turn circular coil with the same number of ampere-turns as the actual coils. Let $\hat{I}$ be the peak-to-peak value of the saw-tooth current in the coil; the r.m.s. value of the n-th harmonic of the current is given by

$$I_n = \frac{\hat{I}}{\sqrt{2}\,\pi\, n} \qquad \text{---------- (1)}$$

In order to find I_n it is first necessary to consider the deflectional sensitivity of a magnetically deflected cathode ray tube, i.e. the magnetic field strength required for a given deflection. A theoretical formula for the deflectional sensitivity is

$$\hat{H} = \frac{3.37d\sqrt{E}}{al} \; * \qquad \text{---------- (2)}$$

where $\hat{H}$ = magnetic field strength in lines/cm^2

d = deflection cm.

E = beam voltage.

a = effective axial length in cm. of region of uniform magnetic field.

and l = beam length between coil centre and screen.

In a typical case d = 25 cm

l = 25 "

a = 9 "

E = 10,000 volts

Hence, from equation (2)

$$\hat{H} = 37 \text{ lines/cm}^2$$

The magnetic field strength $\hat{H}$ at the centre of a circular coil of radius r carrying a current $\hat{I}$ is given by

$$\hat{H} = \frac{\hat{I}}{2r} \; / \qquad \text{---------- (3)}$$

Hence, from equations (1) and (3),

$$I_n = \frac{\sqrt{2}\, r\, \hat{H}}{\pi n} \qquad \text{---------- (4)}$$

/ See, for example, "Electromagnetic Waves and Radiating Systems", Jordan E.C. p. 82

* "Radio Engineers' Handbook", Terman F.E., page 343.

The r.m.s. magnetic field strength H_d at a distance d from a circular coil of radius r carrying a sinusoidal current of r.m.s. value I_n measured normal to, and at a point in, the plane of the coil is given by

$$H_d = \frac{r^2 I_n}{4d^3} \quad \text{---------- (5)}$$

where d is assumed large compared with r.

Equation (5) is applicable for distances up to about one-sixth of a wavelength; in this region the magnitude of the induction field predominates over that of the radiation field. In the present case the wavelength corresponding to the second harmonic of the line frequency is some 15,000 metres and it is only the induction field that is significant in practice.

Hence, from equations (4) and (5),

$$H_d = \frac{r^3 \hat{H}}{2\sqrt{2}\,\pi n d^3} \quad \text{---------- (6)}$$

It will be observed that the field strength varies inversely as n, the order of the harmonic, and inversely as the cube of the distance from the line scanning coils.

It is convenient to specify H_d in terms of the equivalent electric field strength E_d.

If H_d is in amperes/metre

$E_d = 120\,\pi\,H_d$ volts/metre ---------- (7a)

or if H_d is in lines $/cm^2$

$E_d = 30 \times 10^3\,H_d$ volts/metre ---------- (7b)

The field strength of the second harmonic at a distance of 10 metres from the typical television receiver referred to above will now be estimated.

Let $\hat{H}$ = 37 lines/cm^2

r = 4 cms.

d = 10 metres

and n = 2 (second harmonic).

Then, from equation (6),

$H_d = 1.3 \times 10^{-7}$ lines/cm^2

Hence, from equation (7b)

$E_d = 4.0 \times 10^{-3}$ volts/metre.

---

*Loc. cit. p. 80

Since E_d varies inversely as the cube of the distance it follows that for

d = 10 metres, E_d = +72 db relative to 1uV /metre

d = 20 " E_d = +54 db " " " "

d = 40 " E_d = +36 db " " " "

It must be emphasised that the field strength found in practice varies appreciably with the form of magnetic circuit used in the scanning coils; receivers with highly efficient magnetic circuits have less external field than is predicted by equation (6). Nevertheless, the predicted field strengths are within $\pm$ 10 db of those measured for the majority of receivers at present in use.

APPENDIX II

ALIGNMENT AND OPERATION OF THE MOBILE EQUIPMENT

1. GENERAL

Reference to Photograph Neg. Res. 9420 shows that the three loops on the R.I. vehicle are placed as far apart as the dimensions of the van permit. The loops have been made as nearly as possible identical so that any two loops will deliver equal output voltages when energised from a television receiver equidistant from them, (assuming no field distortion). When the television receiver is not equidistant from the loops the loop nearest to the television receiver will deliver the largest output voltage, so that by connecting each loop in turn to the communications receiver, the general direction of the source can be determined.

2. INITIAL ALIGNMENT

The alignment procedure described below is that for a newly installed set of detection equipment, or such as might be needed for an overhaul. The receiver in the van should be switched on 10 minutes before use to enable it to warm up and stabilise. The beat frequency oscillator should also be switched on, the A.G.C. switched off, the crystal filter switched out of circuit (by turning the phasing control to position "O") and the selectivity control to the position of least selectivity. The Control Unit Switch should be set at loop 1. Tune the receiver to about 20.250 kc/s and set the A.F. gain control to maximum. Adjust the R.F. gain control so that receiver noise is not greater than -15 db rel. to 1 mW on the output meter (Decibel Meter No.5), the latter being switched to "Level". If a television receiver is available it should be placed a few feet away from the vehicle, switched on and locked to the transmitted line and frame synchronising pulses. The second harmonic of the line scanning oscillator should now be heard at the output of the detection receiver as a heterodyne note, and the tuning of the receiver should be adjusted for maximum reading on the output power meter.

The trimmer capacitor of loop 1 (located in the Control Unit) is then adjusted for maximum output, a check being made that there are two maxima in a 360° rotation of the capacitor. Switch to loops 2 and 3 in turn and tune the associated trimmers as for loop 1. To check that each loop has the same sensitivity an induction field generator is required. This can take the form of a simple loop aerial with about 12 inch sides wound with a few turns of wire. This loop is energised via a coaxial cable from a signal generator which should be set to 20.250 kc/s. The loop should then be parallel to and at an accurately known distance from loop 1, and the signal generator output level should be adjusted for a convenient reading on the receiver output meter. The induction field generator loop should then be placed in the same position relative to loops 2 and 3 in turn and the receiver output levels noted; the three levels should not differ by more than $\frac{1}{2}$ db. It is important that this test should be carefully carried out, especial care being exercised to keep the distance and plane of the loop the same for all three measurements. It is also important to avoid distortion of the induction field which might occur due to conducting structures in the vicinity of the vehicle.

3. METHOD OF DETECTION AND LOCATION

The receiver should be switched on and allowed to warm up for 10 minutes. The receiver controls should be adjusted as described in Section 2 above. It should be noted that the receiver should always be used with the A.F. control at maximum, the R.F. gain control being used to restrict the A.F. output as indicated on the output meter to the two lower ranges since a certain amount of overloading occurs at higher levels. The Control Unit Switch should be set to loop 1 and the R.F. gain

adjusted so that the noise level indicated on the output meter is about -10 db relative to 1 mW. It is assumed that the tuning calibration for 20.250 kc/s is known and the receiver is set to receive this frequency. The vehicle should then be slowly driven close to the side of the road to be searched, until a beat note can be heard a few decibels above the noise level. Stop the vehicle, note the reading on the output meter and switch to loop 2. The output from loop 2 will be less than the output from loop 1 provided the vehicle has not passed the television receiver. If this is so drive forward slowly, at the same time switching between loops 1 and 2 fairly rapidly. When the levels from both loops are equal, stop the van. In this position the television receiver should lie approximately on a line at right angles to the path of the vehicle, since the equality of the levels indicates that the two loops 1 and 2 are equidistant from the source.

It is now necessary to determine on which side of the van the television receiver is situated. This is found by switching between loops 2 and 3 and noting the relative levels. One loop will be found to produce a larger output than the other and the television receiver is located nearer the loop giving the larger output. An example is given in Drawing WL 71006. In this case the output from loop 2 will be greater than that from loop 3 thus indicating that the television receiver is on the near side of the vehicle.

With some experience of operation of the equipment, location of individual television receivers can be made quickly in the majority of cases. There may be cases however where some difficulty is experienced, e.g. when there are television receivers in operation on opposite sides of a road or when there are receivers in adjacent houses. In the former case both receivers can sometimes be found by careful measurements on each side of the road keeping the vehicle as close to the kerb as possible. Obviously the wider the roadway the greater will be the resolution but in congested areas the resolution may be insufficient to say with certainty whether one receiver or two are in operation; similar difficulties may occur with two receivers in operation in adjacent rooms of semi-detached houses.

It should be borne in mind that the field actually produced by the receiver will probably be distorted and this fact may result in "bearing" errors of up to about 15°. In addition, large ferrous objects, possible buried, may result in further distortion of the field but such distortion is, in general, readily recognised by the fact that rapid changes in the apparent location of the television receiver are caused by small movements of the vehicle.

Since the ignition interference level increases considerably at the higher engine speeds, particularly when the engine is pulling hard, it may be necessary repeatedly to stop the engine when locating a receiver on a rising gradient. This results in slow, tedious working and "combs" in these circumstances are best avoided. Conversely, on a down gradient, coasting the vehicle leads to an increase in the speed with which a location may be effected.

In general, the mobile equipment should not be used in attempts to locate receivers in small terraced houses or in buildings with steel frames, large iron railings or with long narrow front gardens. In all cases of difficulty or ambiguity the portable equipment should be used in the final stages of a location.

APPENDIX III

ALIGNMENT AND OPERATION OF THE PORTABLE EQUIPMENT

1. GENERAL

The portable equipment has been designed for use as an adjunct to the mobile equipment and also as a means of locating receivers in blocks of flats, steel-framed buildings or in other positions which preclude the accurate use of the mobile equipment.

2. ALIGNMENT

The only adjustment necessary on the equipment is to set the frequency of the oscillator to its correct value. To do this the loop should be placed horizontally a few feet away from a working television receiver which has been switched on and synchronised to the transmitted line and frame synchronising pulses. Switch on the hearing aid and switch the tone control to the "closed" position. A heterodyne note should be heard in the hearing aid receiver. By means of C1 adjust the frequency of this beat note to about 500 c/s.

3. OPERATION

The loop should be worn round the waist by the operator (care being taken to keep it as horizontal as possible) and the hearing aid be carried clipped to the breast pocket. The battery case may conveniently be carried in a side pocket. Care should be taken that the hearing aid receiver leads and the battery leads are not allowed to run close together, otherwise instability may occur.

A television receiver is located by observing the intensity of the audio beat note, the signal rapidly increasing in level as the television receiver is approached. The maximum distance at which a working television receiver may be detected varies with the type of receiver but is generally from 25 to 35 feet.

APPENDIX IV

MODIFICATIONS TO HRO RECEIVER

1. GENERAL

HRO receivers (Drawing WL 80561, not attached) with coil units covering the range 50 kc/s to 100 kc/s are readily available and the modifications necessary to enable reception of signals at about 20 kc/s are easily carried out.

2. POWER SUPPLIES

The power supplies provided for the detection equipment are 240V and 6V DC, derived from batteries, and the HRO receiver can be used with such supplies. The power consumption of the modified receiver is 30 mA at 240V and 2.6A at 6V.

3. MODIFICATIONS TO COIL UNIT

The coil unit covering the range 50-100 kc/s is modified as follows:-

The aerial coil (R.F. coil no.1) is not required but need not be disturbed since the feed from the tuned loops is connected directly to the grid of the first R.F. stage, the original grid connection being removed. A 2.2 Megohm leak is connected between the first grid and earth.

Additional components are connected to the tags of R.F. coils nos. 2 and 3 in accordance with Figs. 1 and 2 respectively of Drawing WL 71133.

A 15 μμF condenser is connected across tags 2 and 4 of the oscillator coil, see Fig. 3, Drawing WL 71133, and the oscillator coil trimmers adjusted to obtain an oscillator frequency of 475.25 kc/s.

4. CONNECTION OF OUTPUT METER AND HEADPHONES

The output meter (Decibel Meter No.5) and a Transformer 66B are connected to the receiver headphone jack as shown in Fig. 4 of Drawing WL 71133, screened switchboard wire being used between the meter and the Transformer 66B. The output meter is used with its switch in the "Level" position, i.e. as a voltmeter. The circuit is arranged so that the output meter is short-circuited when the 'phone plug is removed from the jack.

The output valve is not used and is removed from the receiver and the Transformer 66B is mounted between the output valve holder and the front panel.

5. A.F. NOTE FILTER

It is necessary to work with a small bandwidth, about 200 c/s, because of the relatively high level of ignition interference from the van. Although the I.F. crystal filter incorporated in the HRO receiver may be adjusted to provide this bandwidth, shock tests have shown that the mechanical stability is inadequate when the receiver is installed in a vehicle. Further, critical adjustment of the phasing and selectivity controls is necessary. For these reasons an A.F. filter has been incorporated in the receiver to realise the required bandwidth, and is used with the crystal filter inoperative and with the selectivity control in the "maximum bandwidth" position. The filter comprises an A.F. tuned circuit with a Q-factor of approximately 6 (when shunted with 500,000 ohms) and a resonant frequency of approximately 1000 c/s, and is connected across the A.F. gain control. Details of the tuned circuit are given in Drawing WL 71133, Fig.5. The inductor is mounted above the output valve holder and is bolted to the screen provided to screen the output valve.

6. PERFORMANCE

The sensitivity of the modified receiver is such that a signal of +20 db relative to one microvolt at the grid of the first R.F. valve produces a reading of -10 db relative to 1 mW on the output meter, and a readily audible signal in the headphones. This is adequate since ignition interference prevents useful reception of signals with levels less than about +30 db relative to one microvolt. When the engine is running at about normal speed, this level of signal corresponds to an adverse signal-to-noise ratio of about 15 db: aural operation is possible under these conditions and field experience has shown that such operation is, in fact, necessary during the initial stages of a "location", (the meter being used largely during the final stages when equality of signals from two loops is being checked).

APPENDIX V

MODIFICATIONS TO MEDRESCO MARK IIA HEARING AID (INSERT TYPE)

The modifications to the hearing aid are as follows:-

(i) the microphone is removed;

(ii) the local oscillator, which also functions as a frequency changer (circuit as shown in Drawing WL 71408), is provided in the space left vacant by the removal of the microphone. The components are mounted on the reverse side of the chassis as compared with the remainder of the components. In view of the severe space limitations, tags are not provided, the components, including the oscillator valve, (type CV 2107) being cemented to the chassis with Bostick Adhesive No.252. No difficulty was experienced in accommodating the components in the space available: the actual layout of the components is not critical. Most of the connexions are made by utilizing the wire ends of the capacitors and resistors (sleeved where necessary). The connexions to the loop are made by means of three 18 inch lengths of "Tena" wire (14/40 tinned copper, P.V.C. covered) which are brought through the microphone grill as shown in Photograph Neg. Res. 9346 and terminated in small wander plugs.

APPENDIX VI

IGNITION INTERFERENCE SUPPRESSION OF R.I. VAN

1. The coil to distributor lead is fitted with a 5000-ohm suppressor of the type which screws into the distributor head, and each plug lead is fitted with 10,000-ohm suppressors at the plug-end.

2. All the earth connexions on the ignition system are taken to a suitable single point on the near side of the engine to prevent earth currents flowing in the bulkhead.

3. To ensure a good connexion between the bonnet and chassis, copper braid 1" wide is soldered to each side of the bonnet and made fast to the chassis by means of plugs and studs.

4. The ignition coil is removed from the engine and fitted into a screening box made of 16. S.W.G. tinplate. A capacitor (50 µF 12V) is wired (inside the box) between the battery terminal of the coil and the screening box, and the lead to the distributor is screened by enclosing it in a tinned copper braid, the latter being soldered to the box. The whole assembly is then fixed to the engine bulkhead at the bottom nearside of the vehicle, being insulated from the bulkhead by means of an S.R.B.F. bracket.

5. A 2 mH 3A inductor (Inductor R.F. No.8, 3 Amp.) is fixed to the bulkhead and wired in series with the battery lead to the coil, the portion between the inductor and the coil being screened in tinned copper braid. The braid is soldered to the screening box containing the coil.

6. The windscreen wiper motor is suppressed by wiring an inductor (Inductor R.F. No.8, 3 Amp.) in each lead and shunting the motor terminals with a 100 µF 12V capacitor.

7. The dynamo of the vehicle is fitted with a 50 µF 12V capacitor wired across the output terminals.

8. With the engine running and the receiver connected to loop 1 the ignition coil is orientated to a position which produces minimum interference. It is finally fixed in this position.

APPENDIX VII

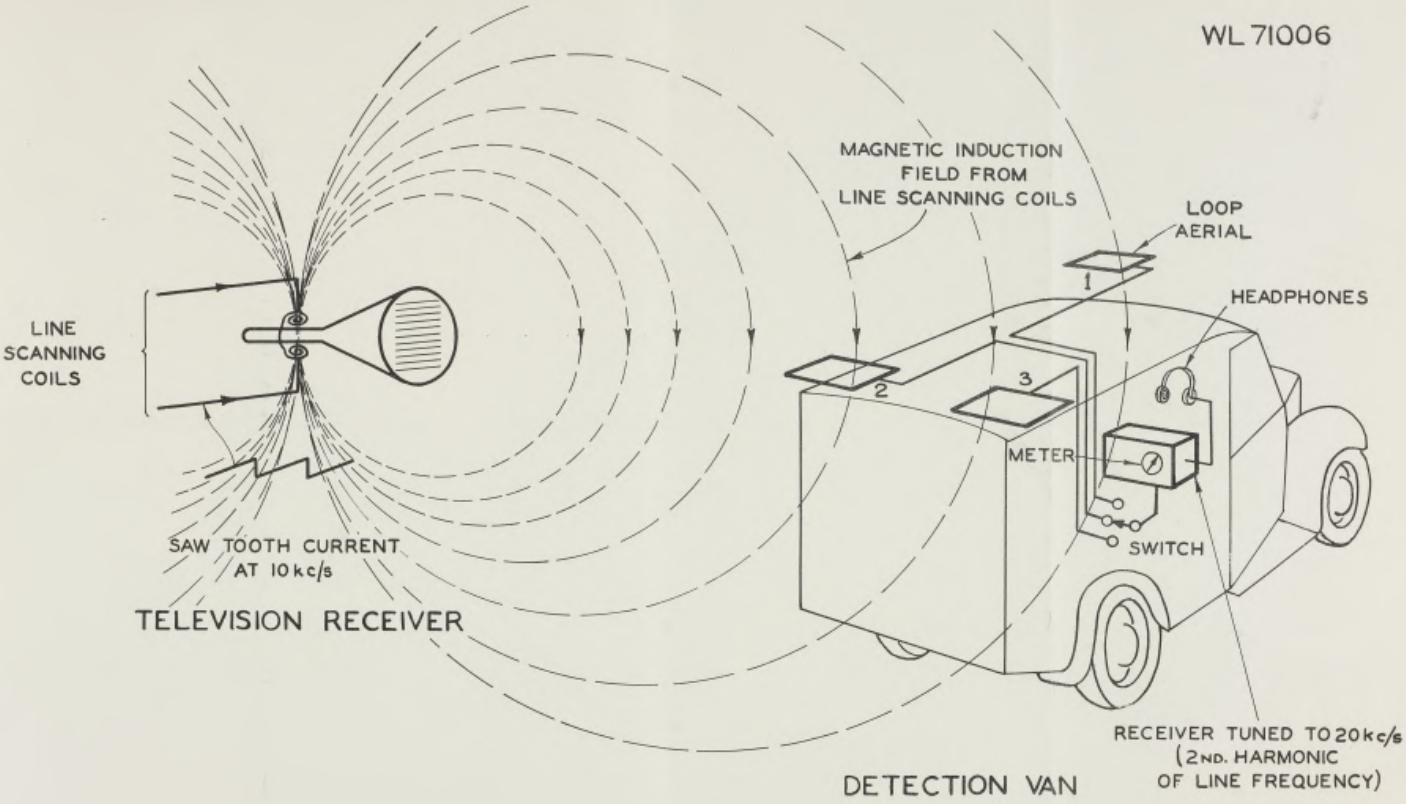
LIST OF DRAWINGS

Drawings marked with an asterisk (*) are included in this Report.

Explanatory Drawings	
Principle of Operation	WL 71006 *
General View of Detection Van	WL 71007
Results of Experimental Field Trial	WL 71009 *
Mobile Equipment	
Frame Aerial (Aerial No. 11A)	
Assembly	WL 34666
Covers (top and bottom)	WL 34680
Details	WL 71213-4
Mounting of Aerial No. 11A	
Assembly	WL 34728
Framework	WL 34715
Details	WL 71619 - 71621, 71799
Modifications to HRO Receiver	WL 71133 *
HRO Receiver Circuit Diagram	WL 85061
Control Unit	
Circuit	WL 71008 *
Portable Equipment	
Modifications to Medresco Mk. III Hearing Aid	WL 71408 *
Medresco Mk. III Hearing Aid (Insert Type)	M.O.H. 5017/1

POST OFFICE ENGINEERING DEPARTMENT
E-IN-C'S OFFICE WE. BRANCH.
APPD. [illegible] WE 5/1
DATE 26.1.52

WL 71006



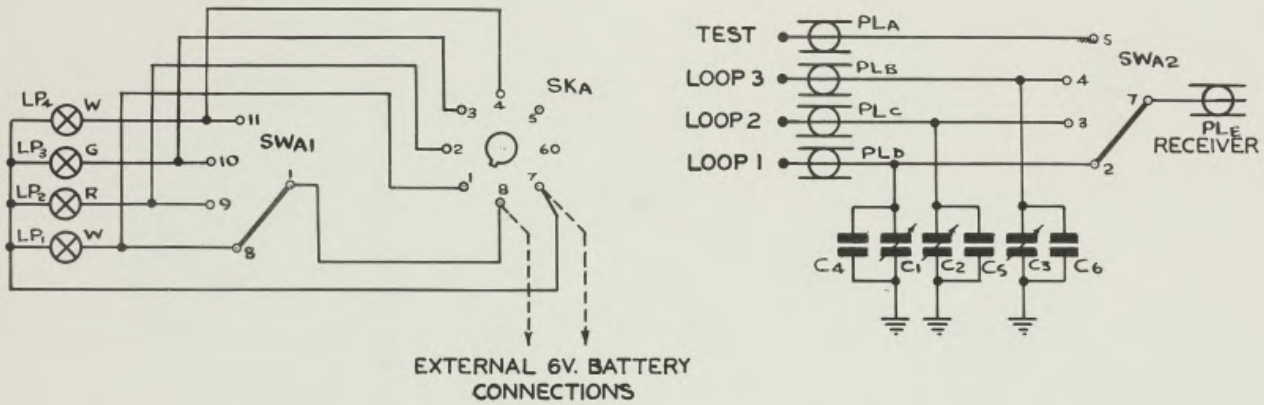
DETECTION OF TELEVISION RECEIVERS
PRINCIPLE OF OPERATION

DRN. GMJ	D1459	CASE NO.
CK'D		
APP'D. [illegible]	WE 5/1	
DATE 26.1.52		

ISSUE	AMENDMENT PARTICULARS	DATE	INITIALS

POST OFFICE ENGINEERING DEPARTMENT
E-IN-C'S OFFICE WE BRANCH

WL71008
DETECTION OF TV. RECEIVERS.
CONTROL UNIT.
CIRCUIT.



CCT. REF.	DESCRIPTION	CCT. REF.	DESCRIPTION	CCT. REF.	DESCRIPTION
C1, 4	100μμF VAR+470μμF+ADDITIONAL CAP. TO TUNE LOOPS TO 20·250kc/s	LP 2	L.P.N°26c.6V.0·3A.L'PHOLDER MES. 37. LENS BULGIN TYPE D190		
C 2,5	" " "	LP 3	L.P.N°26c.6V.0·3A L'PHOLDER MES. 37. LENS BULGIN TYPE D193	SK A	VALVEHOLDER N° 26
C 3,6	" " "	LP4	L.P.N°26c.6V.0·3A L'PHOLDER MES. 37. LENS BULGIN TYPE D197		
				SWA1	SWITCH OAK TYPE 2P 5W C.C.
		PLA,B	PLUG COAXIAL N° 1.	SWA2	" " " " " "
		PLC,D	" " "		
		PLE	" " "		
LP1	L.P. N°26c.6V.0·3A L'PHOLDER MES. 37 LENS BULGIN TYPE D197				

WL.71009.

DETECTION OF TELEVISION RECEIVERS.
RESULTS OF EXPERIMENTAL FIELD TRIAL.

THE STRENGTH OF SIGNAL RECEIVED WHILE TRAVELLING ALONG THE LEFT HAND SIDE OF THE ROAD IS INDICATED BY A HATCHED CURVE AS SHOWN. (FIGURES DENOTE MAXIMUM AMPLITUDES. IN db REL. TO AN ARBITRARY VALUE.) TWO CURVES ARE SHOWN, CORRESPONDING TO TRAVELLING ALONG THE ROAD FIRST IN ONE DIRECTION AND THEN IN THE OTHER.

INDICATES A LICENSED TELEVISION RECEIVER.

POST OFFICE ENGINEERING DEPARTMENT
E-IN-C'S OFFICE WE BRANCH

ISSUE	AMENDMENT PARTICULARS	DATE	INITIALS
1			
A	Notes amended.	21.7.52.	JCF

CASE NO.

DRN	JCF
CKD	
APPD.	BUM
DATE	2.6.1.52

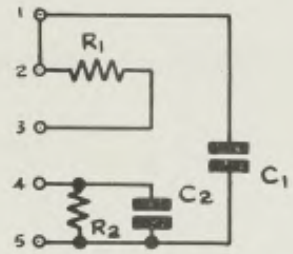
D1459
WE 5/1

D1500

POST OFFICE ENGINEERING DEPARTMENT
E-IN-C'S OFFICE WE BRANCH

WL 71133
TELEVISION RECEIVER DETECTION EQUIPMENT.
MODIFICATIONS TO H.R.O. RECEIVER FOR 20Kc/s.

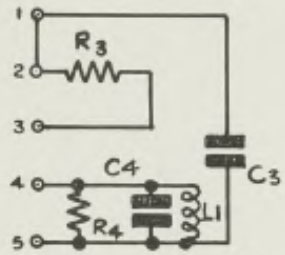
50-150 Kc/s
R.F. Coil No. 2.



R_1	0·47MΩ	¼W
R_2	47KΩ	"
C_1	0·001μF	
C_2	680μμF	P.S.M.

FIG.1. ANODE & GRID COILS DISCONNECTED FROM TAGS.

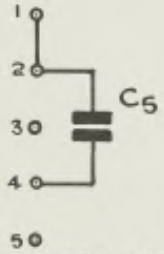
50-150 Kc/s
R.F. Coil No. 3.



R_3	0·47MΩ	¼W
R_4	47KΩ	"
C_3	0·001μF	
C_4	1500μμF	P.S.M.
L_1	Grid coil(disconnected from Tags 2 & 3) connected to Tags 4 & 5	

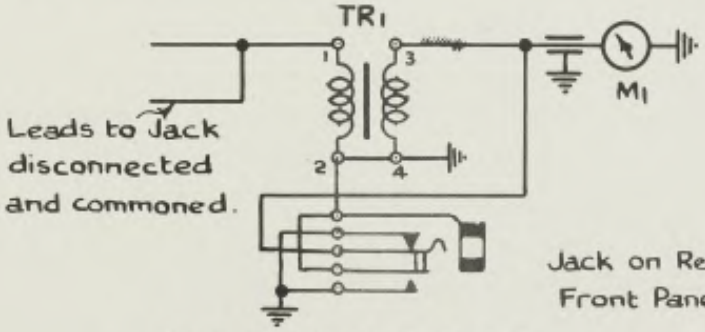
FIG.2. ANODE & GRID COILS DISCONNECTED FROM TAGS.

50-150 Kc/s
Oscillator
Coil.



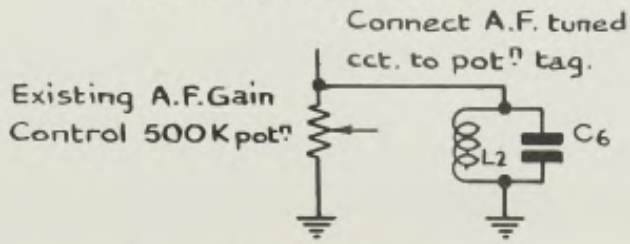
C_5 15μμF

FIG.3. COIL CONNECTIONS TO TAGS NOT DISTURBED.



TR_1	Transformer 66B (R.B.)
M_1	DB. Meter No. 5 (R.B.) (External to Receiver)

FIG.4. OUTPUT CIRCUIT.



L_2 Approx. 3·7 H. Bobbin No.1 filled with 36 S.W.G. D.E. wire (approx. 1800 turns). 5 mil. Radiometal laminations no. 158 interleaved, assembled with clamp type 7.

CASE NO.
D1500 WE 5/1
PPD. 4.4.
DATE 2.9.52

WL.71408.

PORTABLE EQUIPMENT FOR THE DETECTION OF TELEVISION RECEIVERS.

MODIFICATIONS TO MEDRESCO MK. IIA HEARING AID.

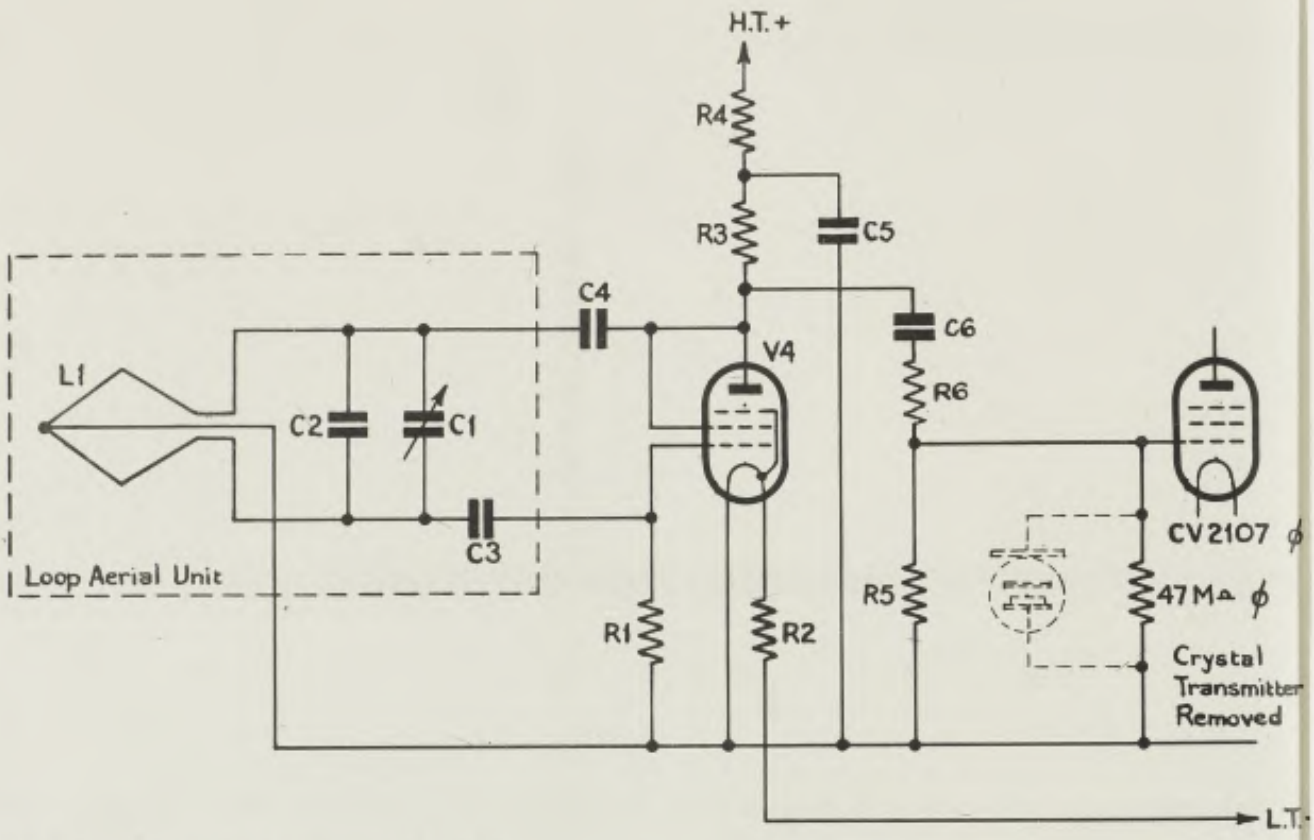
POST OFFICE ENGINEERING DEPARTMENT
E-IN-C'S OFFICE BRANCH

ISSUE	AMENDMENT PARTICULARS	DATE	INITIAL
A	Cct. Ref. Positions altered, Schedule C4, C5, C6 Amended	12-8-52	

CASE No.

DRN. T.C.G.
CKD. D.L.
APPD. C.H.
DATE 7.5.52

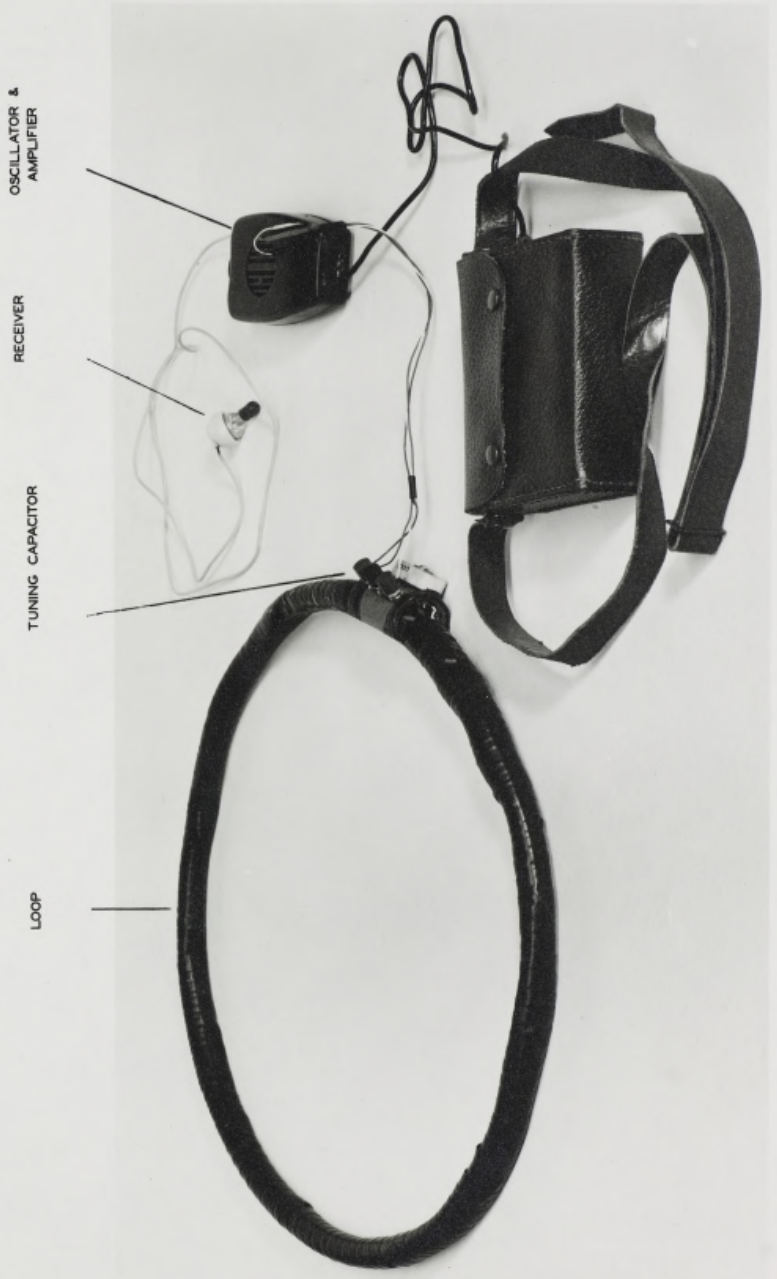
D1555 WE 5/1



Note:- φ signifies component is part of Deaf Aid proper. Diagram M.O.H. 5017/1

Cct. Ref.	DESCRIPTION	Cct. Ref.	DESCRIPTION
C1	1000 μμF variable compression type (Cyldon type 14)	R1	1MΩ 1/10 W
C2	680 μμF P.S.M.	R2	47Ω "
C3	1000 μμF U.I.C. type 310 C.T.H.	R3	1MΩ "
C4	0·01 μF Dubilier type 410.	R4	56KΩ "
C5	0·01 μF " " "	R5	1MΩ "
C6	0·01 μF " " "	R6	56KΩ "
L1	120 turns, 81/46 enamelled, S.A.S.C.	V4	CV 2107
	15" dia., centre tapped.		

PORTABLE EQUIPMENT FOR THE DETECTION OF TELEVISION RECEIVERS



NEG. RES. 9346

MOBILE EQUIPMENT FOR THE DETECTION OF TELEVISION RECEIVERS
GENERAL VIEW OF R.I. VAN

NEG. RES. 9420

MOBILE EQUIPMENT FOR THE DETECTION OF TELEVISION RECEIVERS
INTERIOR OF R.I. VAN

NEG. RES. 9421