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POST OFFICE ENGINEERING DEPARTMENT.

Radio Report No 283.

The Burnham Quick Search Radio Receiver. S.W. 24.

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

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Radio Report No. 283.

Title:- The Burnham Quick Search Radio Receiver. SW.24.

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date:- 1933.

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London, E.C.1.

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The following is a list of the photographs attached to this report:-

1. Short Wave Beating Oscillator - Back View.
2. Short Wave Beating Oscillator Condenser - Front and Back Views.
3. Short Wave Receiver No. S.W.24 - Front View.
4. Short Wave Receiver No. S.W.24 - Back View.

The following is a list of the drawings attached to the report:-

WL.	12521	-	Outline diagram of quick search receiver.
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"	12542	-	Line amplifier. Serial No. 1708.
"	12543	-	A.F. Oscillator. Serial No. 1707.
"	12562	-	S.W. Receiver No. 24. Block Schematic Diagram.

The following is a list of additional drawings attached to Service Copies of this Report:-

WL.	12544	-	Array Indicator Panel on Receiver S.W.24.
"	12545	-	Control Key Panel. S.W. Receiver No. 24.
"	12546	-	Meter Panel. Serial No. 1712

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WL.	12547	-	Feed Panel. Serial No. 1710.
"	12548	-	Fuse Panel. Serial No. 1710. Fuse Key.
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"	12551	-	S.W. Receiver No. 24. Jack strip on Bay 1. Back View.
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"	12556	-	Termination Panel. Tag Block Wiring Diagram. Top Plan from back of Bay.
"	12557	-	Control Key Panel Tag. Block Wiring Diagram. Top Plan from back of panel.
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The Burnham Quick Search Radio Receiver

S.W. 24.

1. SUMMARY.

A description is given of the principles and design of a short wave receiver of a novel type which has been developed at the Radio Laboratories at Dollis Hill and installed at Burnham Radio Station.

2. INTRODUCTION.

High frequency telegraph traffic from ships is received on several bands of frequencies of the order of 0.25 megacycle wide and located between 8 and 18 megacycles. Ships are liable to call on any frequency within a specific band and to change frequency within a band on request, in order to avoid interference. Coupled with the fact that many of the transmitters installed on ship board are liable to wander in frequency, this necessitates the use of a receiver which can be tuned to any frequency within any one of the bands upon which it may at the moment be working, with the least effort and loss of time on the part of the operator. In the ideal case it should therefore be necessary to use only one control for tuning the receiver within the limits of any one frequency band.

In addition to the necessity for easy searching facilities it is essential that the receiver shall be selective, so that if a superheterodyne receiver is used it must be entirely free from image channel interference. Another most important requirement is that the overall gain of the receiver shall be sufficiently high and distributed among the various stages in such a way that the thermal noise generated in the circuits preceding the first valves shall be the major factor limiting the response to signals and external noise.

3. REVIEW OF EXISTING TYPES OF RECEIVER.

The problem of designing a receiver to conform with the foregoing requirements is one of difficulty if it be approached on conventional lines.

The normal single demodulation receiver is unsuitable for several reasons, the most important being the fact that it is impossible directly to obtain sufficient selectivity at the signal frequency.

The only alternative is the superheterodyne receiver. In the efficient superheterodyne receiver, protection must be provided against image channel interference which is liable to be produced by signals spaced on one side or other of the desired signals by a frequency interval equal to twice the intermediate frequency, or twice the beating oscillator frequency, whichever is the less.* But on the normal superheterodyne receiver used on high frequencies, the intermediate frequency is made much lower than that of the signal, in order that the requisite selectivity may be introduced with comparative ease, and the source of image channel interference is therefore

* See appendix I.

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closely adjacent in frequency to the signal it is desired to receive. This necessitates the use of several stages of signal frequency selectivity. For point to point working, in which a receiver may operate on the same frequency for hours at a time, these stages of selectivity which have to be tuned to the signal frequency cause no trouble. When searching over a band of frequencies, however, it becomes necessary to vary the tune of all the signal frequency circuits and of the oscillator, either separately or from a common control. The former method is obviously unsuitable in the present case, and the latter involves the accurate alignment and control of perhaps three signal frequency circuits and the beating oscillator by some system of mechanical coupling; an arrangement which from a purely technical point of view is very difficult, particularly when low resistance circuits are used, and it becomes even more awkward when introduced in a receiver which must be accessible, easy to maintain, and of the highest efficiency.

4. PRINCIPLE OF QUICK SEARCH RECEIVER.

With a view to avoiding the necessity for all but the simplest protection against image channel interference, a novel form of superheterodyne receiver, introducing other desirable features at the same time, has been developed in the Radio Laboratories at Dollis Hill. This will be referred to in future as a "Quick Search" receiver.

The essential principle of the receiver is the employment of an intermediate frequency higher than the highest signal frequency, the beating oscillator operating on a higher frequency still, so that the difference beat is still selected. This increases the spacing between wanted signals and image channel interference to such a high value that a single tuned circuit provides more than sufficient discrimination.

If the beating oscillator were made to function at less than the intermediate frequency, and the sum beat frequency employed, the whole advantage of employing a high first intermediate frequency would be lost, for image channel interference would only be separated from the desired signal by twice the oscillator frequency, which would grow less and less as the signal frequency increased. Apart from this, the arrangement adopted enables the receiver to operate on all frequencies of magnitude appreciably less than the first intermediate frequency, for changes in oscillator frequency of less than 100 per cent. of its lowest value. This feature renders coil changes in the oscillator unnecessary, moreover it has the added advantage that it spreads the signal frequency spectrum more or less uniformly over the tuning ranges of the beating oscillator.

Especially on high frequency receivers, the use of an intermediate frequency higher than the signal makes it impossible to obtain a satisfactory degree of selectivity without resorting to extreme measures such as crystal filters, reaction, etc. In addition, the possible gain per intermediate amplifier stage is thereby reduced to a low value. These disadvantages are overcome by using a second frequency change, followed by a second intermediate frequency amplifier operating on a much lower frequency. The main selectivity and amplification of the receiver are introduced in the second intermediate frequency stages, the first intermediate frequency stage facilitating the removal of image channel interference.

By these means the essential tuning controls of the receiver are reduced to two, the main control which adjusts the frequency of the first beating oscillator and one other which adjusts the tune of the input circuit and need only be used occasionally, when searching over a wide band.

It may here be mentioned, that since in this type of receiver the signal frequency is always lower than the first intermediate frequency, and image channel interference is always higher, it is possible to eliminate image channel interference by employing an electric wave filter cutting off at a little above the highest frequency on which it is desired to receive, so as to dispense with a tuned input circuit. This has not been done in the present receiver for the following reason.

In all receivers there is a well defined limit below which noise voltages spontaneously generated in the first valves and in subsequent parts of the circuit cannot be reduced, and it is therefore necessary to apply as large a signal voltage to the first grid filament circuit as possible, in order to obtain the best signal/noise ratio. If therefore the considerable voltage magnification of a low resistance tuned input circuit is not employed, a large reduction in the signal/set noise ratio amounting to 20 or 30 decibels must result.

For this reason it is undesirable to dispense with a tuned input circuit on a receiver designed to operate when necessary on as low an input signal voltage as possible.

There are, however, some advantages to be gained from the use of a low pass filter in addition to a tuned input circuit which will be mentioned later.

5. OUTLINE OF RECEIVER DESIGN.

The essentials of the receiver are indicated in the outline diagram shown in drawing WL. 12521, the more important features being discussed in some detail in the following sections.

5. 1. The Choice of First and Second Intermediate Frequencies. Although the quick search receiver is intended primarily for use on frequencies between 8 and 18 megacycles, it has been designed to operate on frequencies as high as 25 megacycles and experimentally down to frequencies of the order of 0.1 megacycles. It should be mentioned, however, that in this particular receiver considerations of selectivity limit the lowest frequency on which it may usefully be employed. The selectivity has been adjusted to the optimum value for the class of traffic for which it is primarily intended; when, however, this selectivity is translated to the lower radio frequencies, where telegraph stations operate with frequency separations perhaps as low as a fraction of a kilocycle, it becomes quite inadequate.

The highest frequency to be received having been fixed at 25 megacycles, 30 megacycles was chosen as suitable for the first intermediate frequency.

In order to provide for reception on all frequencies from 25 megacycles downwards, the minimum range to be covered by the first beating oscillator was fixed at 30 - 55 megacycles, a frequency ratio of less than 1 : 2.

Under these circumstances the signal frequency selectivity has to provide sufficient discrimination to eliminate image channel interference from signals spaced 60 megacycles from the desired signal.

In a similar way the first intermediate frequency selectivity has to protect subsequent stages of the receiver from what may be termed second-order image channel interference which is liable to be produced by signals spaced from the desired signals by twice the second intermediate frequency. If the first intermediate frequency circuits be regarded as the signal frequency circuits of a normal superheterodyne receiver operating on 30 megacycles, the necessity of protecting against second-order image channel interference becomes more apparent. The choice of the second intermediate frequency was therefore based on estimates of the selectivity to be obtained in the first intermediate frequency amplifier, a small allowance being made for the signal frequency selectivity provided by the first tuned circuit. A frequency of 600 kilocycles was adopted, for which the discrimination of the preceding circuits against second-order image channel interference was always greater than 60 decibels.

When receiving on the high frequency end of the operating range, the signal may not be widely removed from the first intermediate frequency, so that the initial selectivity will not discriminate very highly against possible interference on a frequency corresponding to the first intermediate frequency. For example, when the particular receiver described in this report is operating on the highest signal frequency of 25 megacycles the initial selectivity will only provide relative attenuation of the order of 20 decibels for interference on 30 megacycles and the latter will be passed by the first demodulator functioning as an amplifier, and be amplified by subsequent stages of the receiver. The band of frequencies from which this interference may originate is fixed in the frequency spectrum and is also restricted in width by the second intermediate frequency selectivity; moreover the protection against this interference is considerably greater when the receiver is operating on the signal frequencies for which it is primarily intended. It may be mentioned that interference of this kind has never been experienced on the quick search receiver, but the possibility of its occurrence is a factor which should be given some consideration when executing a design.

5. 2. Input Circuit. It will be seen from the diagram that an inductively coupled input circuit is used.

Since the input circuit functions at the signal frequency, several coils are needed to cover the wide range of frequencies efficiently. These coils are mounted on plugs, coil-change being readily effected from the front of the receiver. It may be pointed out that it is the Input Circuit only which requires a change of coils in order to cover the whole frequency range of the receiver.

The primary winding is connected to the antenna system through a balanced transmission line, the secondary winding is tuned to the signal frequency, and the coupling between the windings is adjusted so that in the middle of the frequency band covered by any specific coil, the impedance presented to the transmission line approximates to the characteristic impedance. Inductive coupling has been employed instead of tapping the transmission line directly across a portion of the tuned circuit, in order that the characteristic impedance to earth of the two sides of the transmission line shall not place an additional load across the output terminals of the first beating oscillator.

5. 3. First and Second Beating Oscillators. It will perhaps be considered that the necessity for the use of oscillators on frequencies as high as 55 megacycles is a serious disadvantage, particularly where heterodyne reception is employed. That this can be a serious obstacle to the construction of a successful receiver must be admitted, for when receiving on a wavelength of 15 metres the frequency of the first beating oscillator alone has only to change by 10 parts in a million, for the audio frequency beat note to change by 500 cycles.

The Radio Section of the Post Office has, however, already developed to a high degree the technique of building constant frequency oscillators and as a consequence no trouble has been experienced due to variation in frequency. The receiver may be used the moment it has been switched on as the initial frequency drift is so small as to be inappreciable. Moreover, it has been found unnecessary to employ Barretter tubes, or any other means of maintaining the power supplies more constant than those of the normal common batteries fitted in a radio station. In fact, when operating on any signal frequency within the range of the receiver, the low tension supply voltage may be varied by 10 per cent. or more without the heterodyne beat note passing out of the range of audibility; the performance is somewhat more sensitive to changes in anode supply voltage but variations of the order of several volts may be made with the same result.

In view of the importance of the oscillators as a factor contributing to the successful design of a receiver of this type, a relatively detailed description of the design will be given. This may be supplemented by an examination of a photograph, attached to this Report, which shows a similar type of oscillator, designed to operate on a somewhat lower frequency.

A push-pull oscillating circuit is used, of the type indicated in drawing WL. 12522. Grid bias is provided by the voltage drop developed across the grid leaks due to grid current. It may be mentioned in passing that unless grid current can be completely eliminated, and this involves the use of very high anode voltages, grid leak biassing provides a very valuable method of reducing frequency variations due to grid current, a most potent source of frequency instability.

The oscillatory circuit controlling the frequency of oscillations has been designed to have as low a resistance as possible, and all the elements of the circuit are extremely rigid, so that the frequency of the oscillator shall not be susceptible to vibration. The whole oscillatory circuit is enclosed in a lagged box so as to protect it from rapid changes in temperature due to heat generated in the valves or to changes in the ambient temperature.

The tuning condenser is a very important part of the oscillator design, for the frequency control of the first beating oscillator is the main tuning adjustment of the whole receiver, and is in use almost continually. The capacitance can be varied continuously by a rotating plate series gap condenser and in steps by a switch which connects in parallel the individually insulated plates of a fixed air condenser, the change in capacitance for one step of the latter being somewhat smaller than the range of continuous variation of the former. By using these two condensers in combination the capacitance variation is spread over sixteen ranges each of which corresponds to 180° movement on the continuously variable condenser dial. Attached to the report is a photograph of a condenser similar to those employed in this receiver but having a somewhat higher maximum capacitance.

The frequency of the oscillator is rendered independent of adjustments made to the external circuits by a buffer stage of screen grid amplification. The anode circuit of the buffer stage is tuned, the output power for the demodulator being obtained by inductive coupling. In the neighbourhood of optimum heterodyne input the variation of detector efficiency with beating oscillator voltage is very flat and if the latter is correctly adjusted it only becomes necessary to retune the anode circuit of the first beating oscillator buffer stage when changing the oscillator frequency by a large amount.

Details of the physical construction may be seen in a photograph attached to this Report. The thermally insulated box containing the tuned circuit of the oscillator lies on the left-hand side of the picture; through the open door of the box the coil and part of the variable condenser may be seen. The oscillator valves are located immediately above this box and the buffer stage screen grid valve projects through a screening partition which separates the oscillator stage from the rest of the unit.

5. 4. <u>The First Demodulator</u>. The voltages due to the signal and first beating oscillator are combined in the first tuned circuit of the receiver and applied to the first demodulator.

A balanced demodulator is employed here as in later stages of the receiver; the theory underlying its action is outlined in Appendix II.

In the case of the normal, unbalanced demodulator the output contains the sum and difference of the input frequencies and the second harmonics of the latter. (Appendix I). Moreover if the input signal had consisted of two or more frequencies the output would have contained the sum and difference of all these and the beating oscillator frequency, taken two at a time, and the second harmonics of all the input frequencies. A superheterodyne receiver employing an unbalanced demodulator would under these conditions respond to a greater or lesser degree when any one of these products of demodulation corresponded to the intermediate frequency. If, however, a balanced demodulator is used the sum and difference frequencies produced by signals beating among themselves, tend to balance out and a corresponding freedom from spurious responses is obtained. These properties are not merely of value when developed in the first demodulator of a receiver, they are of considerable advantage elsewhere.

The unusual method of injecting the voltage due to the first beating oscillator is of some interest. In the Quick Search receiver, in contradistinction to the conditions obtaining with a normal superheterodyne receiver, the frequency at which the first beating oscillator operates is always very much greater than that of the signal. Owing to this, the normal method of connecting the beating oscillator to a balanced demodulator, as exemplified by the outlines of the second and third demodulator circuits in drawing WL. 12521, cannot be applied here; the high reactance of the coil due to incomplete coupling between the two halves, and the relatively low input impedance of the demodulator valves, make it impossible to develop sufficient potential from the first beating oscillator. At the high frequencies at which the first beating oscillator operates, however, the reactance of the three electrode variable condenser in the first tuned circuit is very small, moreover the reactance from the centre electrode to one side is only half the total, so that in this case the artifice of injecting the beating oscillator voltage via the centre electrode of the variable condenser has been adopted. Fixed condensers of 20 micro-microfarads capacitance have been connected from each side of the variable condenser to the centre electrode so that the reactance between the centre electrode and the grid of one of the demodulator valves is always less than the input impedance of the valve, and the potential drop across the condenser is always small compared with that developed between the grid and filament.

The anode circuit of the first demodulator is tuned to 30 megacycles, the first intermediate frequency, and there is therefore an inductive impedance of considerable magnitude in the anode circuit at the higher signal frequencies. If triode valves were used in the demodulator, the relatively high grid anode capacitance and the inductive load would cause the input impedance of the valves to have a negative resistance component, which would be liable to cause instability. Screen grid valves are therefore used in the first demodulator in order to reduce the grid-anode capacitance and prevent such undesirable reaction effects.

5. 5. Remaining Units. The rest of the receiver is designed on the lines normally followed by the Radio Section of the Post Office Engineering Department in the construction of high performance short wave superheterodyne receivers.

The first intermediate frequency amplifier consists of three push-pull stages of screen grid amplification, the selectivity being provided by low resistance tuned anode circuits.

The second demodulator and second beating oscillator have been briefly referred to already.

The second intermediate frequency amplifier consists of three stages of screen grid amplification coupled by sections of band pass filter which provide the necessary selectivity. Working adjustments of the overall gain of the receiver are made by means of a resistance network between the first and second stages of this amplifier. Sufficient amplification is introduced prior to this point, to prevent the loss introduced by the gain control from degrading the signal/set noise ratio.

The third demodulator is also of the balanced type and as heterodyne reception is normally used a third beating oscillator is provided. At times, however, signals have to be received from transmitters which suffer from severe frequency variation, and heterodyne reception is uncomfortable under these conditions, as the frequency of the beat note changes and may even wander beyond audibility. An alternative method of reception is provided for use in such cases, in which the second beating oscillator is modulated at an audio frequency, so that the beat note resulting from the interaction of the signal and the output from the second beating oscillator is correspondingly modulated, and one of the third demodulator valves is switched off. Signals then become audible at the output of the third demodulator without the use of a third beating oscillator, and the note is of course independent of the frequency of the station. The latter arrangement is not, however, preferable to heterodyne reception when jamming is present, for when employing it all signals are modulated by the same frequency, and it becomes impossible for an operator to exercise aural discrimination.

The receiver proper is terminated by an audio frequency amplifier to the output terminals of which the operator's headphones are connected.

The operation and maintenance of the receiver is facilitated by the provision of a comprehensive system of adjusting and monitoring the power supplies, and by connecting the input and output circuits of the second intermediate frequency and audio frequency equipment to jacks.

Detailed circuit diagrams of all the units comprising the receiver have been filed with the main copies of this report, only those diagrams of units of particular interest being attached to the other copies.

6. MECHANICAL CONSTRUCTION.

The general appearance of the receiver and some details of its physical construction may be seen in the photographs, and the various units may be identified with the aid of the key to the front view of the receiver given in Drawing WL. 12523.

The receiver is 7 feet long, 6 feet 6 inches high, and approximately 1 foot deep from the front of the panels to the back of the covers, which were of course removed when the photograph was taken.

A most important requirement of the design, and one to which all considerations of technical expediency had to be subordinated, was that of placing the main controls, which may be used almost continually, at the most convenient operating level. These may be seen in one of the photographs at the bottom of the first demodulator and first beating oscillator panels, and arranged immediately above the shelf.

The antenna system is connected to the receiver through a two wire transmission line which is joined to the terminals projecting above the top of the receiver. A subsidiary transmission line enclosed in metal tube connects these terminals to the first demodulator unit.

Other points in connection with the construction of the receiver are not of sufficient novelty to warrant detailed description in this report, the main object of which is to describe the underlying principles of a new type of receiver.

7. PERFORMANCE.

Calibrations and certain technical data relating to the performance of the receiver are attached in the form of a number of curves.

The overall selectivity has been adjusted to the optimum for the class of traffic for which the receiver has been designed.

In view of the difficulties involved, no actual measurements have been made either of the discrimination against image channel interference or of the suppression of interference from signals corresponding to the first intermediate frequency. In practice, however, no interference has been experienced from either source.

The overall gain is more than sufficient to make set noise the only factor determining the minimum radio frequency input voltage that may be detected on the receiver.

When using the third demodulator with the third beating oscillator so that the response of the former is a linear function of the input, the overall set noise under working conditions is of the order of 3 decibels above that originating in the circuits preceding the first valves of the receiver, so that if <u>all</u> sources of noise other than that due to thermal agitation in the first tuned circuit were removed, an improvement of the order of 3 decibels only could be attained.

In a receiver which employs three beating oscillators it is to be expected that a number of spurious beat notes between harmonics of the various oscillators will be experienced. In passing through the tuning range of the receiver from the highest frequencies down to 1.5 megacycles, with the receiver adjusted to its most sensitive condition, three spurious beat notes have been observed, and twelve others are present in the range between 1.5 megacycles and zero frequency. These are produced when certain low order harmonics of the first and second beating oscillators have a mutual frequency difference corresponding to the first or second intermediate frequencies. Small voltages corresponding to these harmonics are induced in the circuits preceding the first and second demodulators and these give rise to beat frequencies which may be amplified by subsequent stages of the receiver.

As has been previously mentioned the receiver described in this Report has been designed primarily for use on certain bands of frequencies between 8 and 18 megacycles and since for frequencies extending down to 1.5 megacycles only three spurious beats, arranged to occur outside the working bands, can be detected, these are of no consequence.

Reference has already been made to the performance of the high radio frequency oscillators incorporated in the receiver and further comment is unnecessary.

The receiver was installed at the Post Office Radio Station at Burnham-on-Sea, Somerset at the beginning of March this year and has been in use continuously since that date without any trouble other than that occasioned by a faulty valve.

It is permissible to say that from the engineering point of view the performance of the receiver is highly satisfactory in all respects.

8. FUTURE DEVELOPMENTS.

After the present receiver was designed it became apparent that in this particular application of the quick search principle, several advantages were to be derived from the use of a low pass filter cutting off just above the highest signal frequency it is desired to receive, in addition to a tuned input circuit.

At present a small amount of power from the first beating oscillator of the order of microwatts, is fed back into the radio frequency transmission line connected to the receiver. The addition of a low pass filter of the type mentioned above, between the external transmission line and the first tuned circuit would reduce the power fed back to a negligible amount and so eliminate the possibility of any interference, by way of "throw-in" to other receivers, arising from this source. The filter could moreover be incorporated in the short transmission line which connects the input terminals on the top of the receiver to the first demodulator unit and this would enable the combined filter and transmission line to be designed to have a characteristic impedance equal to that of the external transmission line, which approximates to 600 $\angle 0^\circ$ ohms, whereas at present the impedance of the internal transmission line alone cannot be made sufficiently high. Moreover, the use of such a filter would result in an increased protection against possible interference originating in signals having a frequency nearly identical with that of the first intermediate frequency amplifier. Finally, the already substantial protection against image channel interference would be still further increased.

9. CONCLUSION.

A new type of receiver has been developed which is highly sensitive, selective and yet may be tuned over a wide range of frequencies with ease.

A description is given of a particular short wave receiver of this type which has been constructed and installed at a coast station and is being employed on the reception of telegraph traffic from ships.

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It is anticipated that receivers embodying the same principles could with advantage be substituted for those of the more conventional type in all cases where high performance and ease of control are of importance. The necessary development is already in hand.

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Appendix I.

Spacing of Image Channel Interference from Signal in Superheterodyne Receivers.

Neglecting steady values, let the characteristic of a demodulator be represented by:-

$$i = Bv + Cv^2$$

where i is the output current and v is the input voltage.

Let $v = P \sin\omega_1 t + Q \sin\omega_2 t$, the two components in order being the beating oscillator and signal voltages. Substituting for v we get:-

$$i = B(P \sin\omega_1 t + Q \sin\omega_2 t) + C(P^2 \sin^2\omega_1 t + 2PQ \sin\omega_1 t \sin\omega_2 t + Q^2 \sin^2\omega_2 t)$$

$$= B(P \sin\omega_1 t + Q \sin\omega_2 t) + C\left[\frac{P^2}{2} - \frac{P^2}{2}\cos 2\omega_1 t + PQ\cos(\omega_1 - \omega_2)t - PQ\cos(\omega_1 + \omega_2)t + \frac{Q^2}{2} - \frac{Q^2}{2}\cos 2\omega_2 t\right]$$

From this it will be seen that frequencies corresponding to the sum and difference of ω_1 and ω_2 appear in the output from the demodulator. If ω_i is the intermediate frequency, then, in the absence of signal frequency selectivity, the receiver will respond to signals corresponding to the values of ω_2 given by the following relationship:-

$$\omega_i = \left|(\omega_1 \pm \omega_2)\right|$$

Case 1. $\omega_i < \omega_1$ Since in this case ω_i is less than ω_1, there can be no solution for the positive sign, but for the negative sign:-

$$\omega_i = \left|(\omega_1 - \omega_2)\right|$$

$$\text{and } \omega_2 = \omega_1 \pm \omega_i$$

Case 2. $\omega_i > \omega_1$. For the positive sign

$$\omega_i = \omega_1 + \omega_2$$

$$\text{that is } \omega_2 = \omega_i - \omega_1$$

and for the negative sign

$$\omega_i = \left|(\omega_1 - \omega_2)\right|$$

but since $\omega_i > \omega_1$, the expression within the brackets must be negative and we have

$$\omega_i = \omega_2 - \omega_1$$

$$\text{that is } \omega_2 = \omega_i + \omega_1$$

or combining the last two solutions

$$\omega_2 = \omega_i \pm \omega_1$$

From /

From these results it is clear that the two frequencies to which the receiver will respond are separated by an interval equal to twice the intermediate frequency or twice the beating oscillator frequency, whichever is the lesser.

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Appendix II.

Approximate Theory of Balanced Demodulator.

A typical form of balanced demodulator employing triodes is shown in drawing WL.12524, but it should be clear that the following treatment may be applied equally well to similar forms of demodulator employing diode rectifiers, metal rectifiers, etc.

Let the input signal develop an instantaneous voltage $2\ v_s$ across the secondary of the input transformer, the two halves of which are in series aiding, and let the instantaneous value of the beating oscillator voltage be v_o. The signal will excite the two rectifiers 180° out of phase and the beating oscillator will excite them in phase so that, assuming the voltages are additive for valve 1, the total input voltages will be given by

$$v_1 = v_o + v_s$$
$$v_2 = v_o - v_s$$

Let the characteristic of each rectifier be represented by

$$i = B\ v + C\ v^2$$

As the anode currents i_1 and i_2 flow in opposite directions through the two halves of the primary winding of the output transformer, which are also connected in series aiding, the current i_L in the secondary will be proportional to the difference, that is,

$$i_L = K\ (i_1 - i_2)$$

but $$i_1 = B\ (v_o + v_s) + C\ (v_o + v_s)^2$$

and $$i_2 = B\ (v_o - v_s) + C\ (v_o - v_s)^2$$

whence $$i_L = K\ (B.\ 2v_s + C.\ 4v_o v_s)$$

If $$v_o = P \sin \omega_1 t$$

and if the signal input contains two components having different frequencies represented by

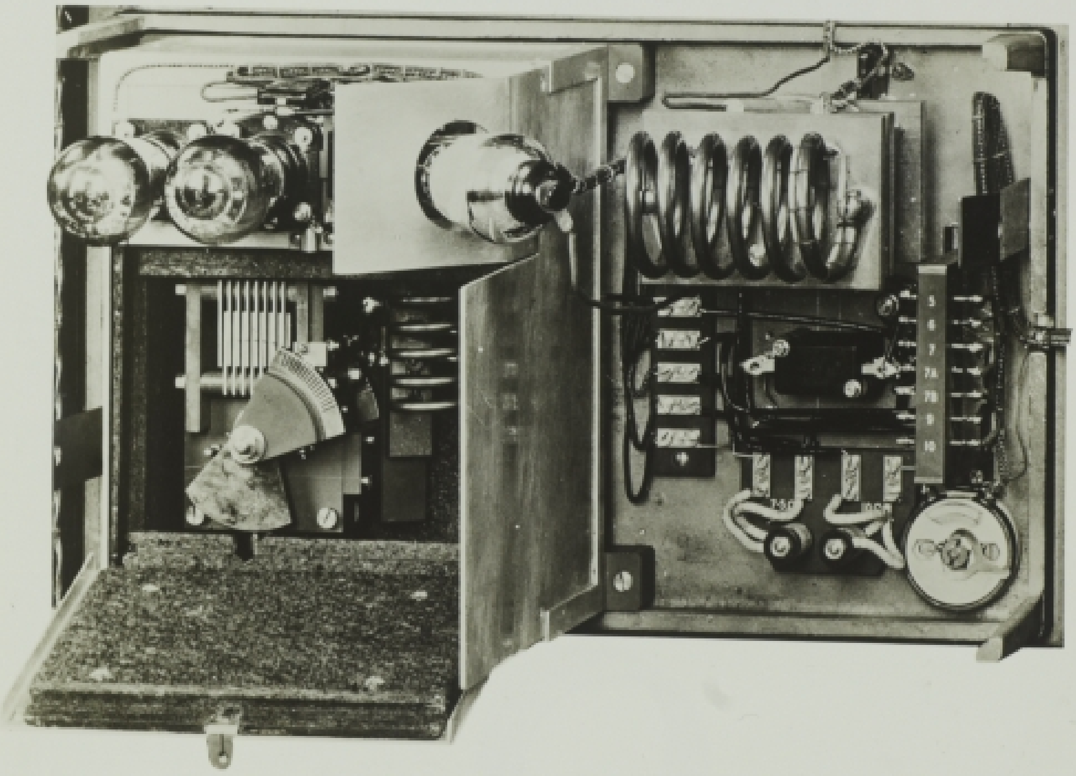
$$v_s = Q \sin \omega_2 t + R \sin \omega_3 t$$

then substituting for v_o and v_s and expanding

$$i_L = K \left[2B \left\{ Q \sin \omega_2 t + R \sin \omega_3 t \right\} + 2\ C \left\{ PQ \cos (\omega_1 - \omega_2)\ t - PQ \cos (\omega_1 + \omega_2)\ t + PR \cos (\omega_1 - \omega_3)\ t - PR \cos (\omega_1 + \omega_3) t \right\} \right]$$

The output from the demodulator only contains the original signal frequencies and the sum and difference beats of each signal component with the beating oscillator input; the second harmonics of the signal components, the beats between them, and incidentally the beating oscillator frequency being absent. In practice these latter components will not of course be entirely balanced out owing to dissimilarity in the valve characteristics but their strengths will be much reduced below those of the corresponding products from an unbalanced demodulator.

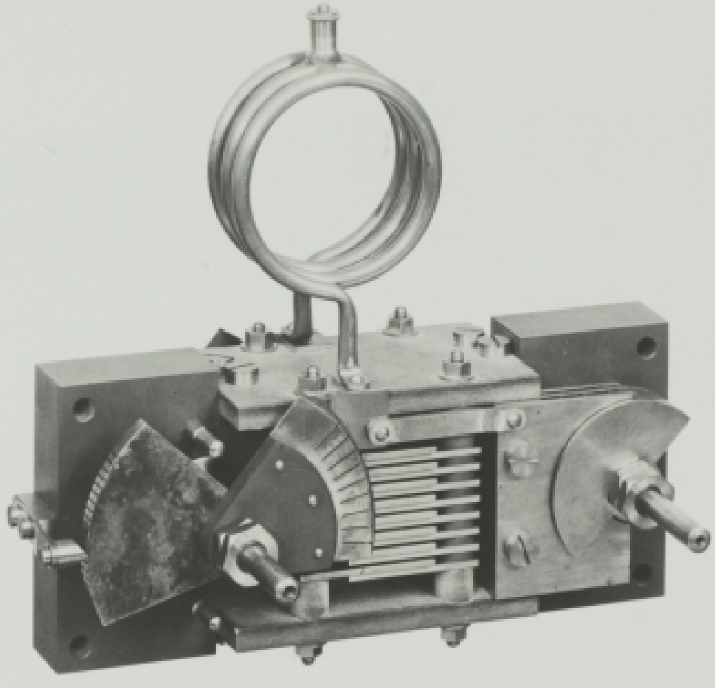
Rota 3843 Ra./34.



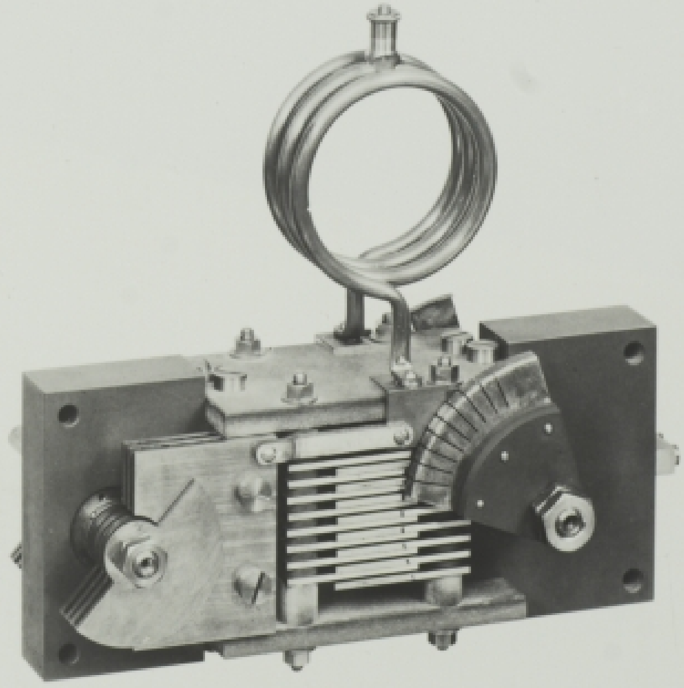
SHORT WAVE BEATING OSCILLATOR

—————————— BACK VIEW.

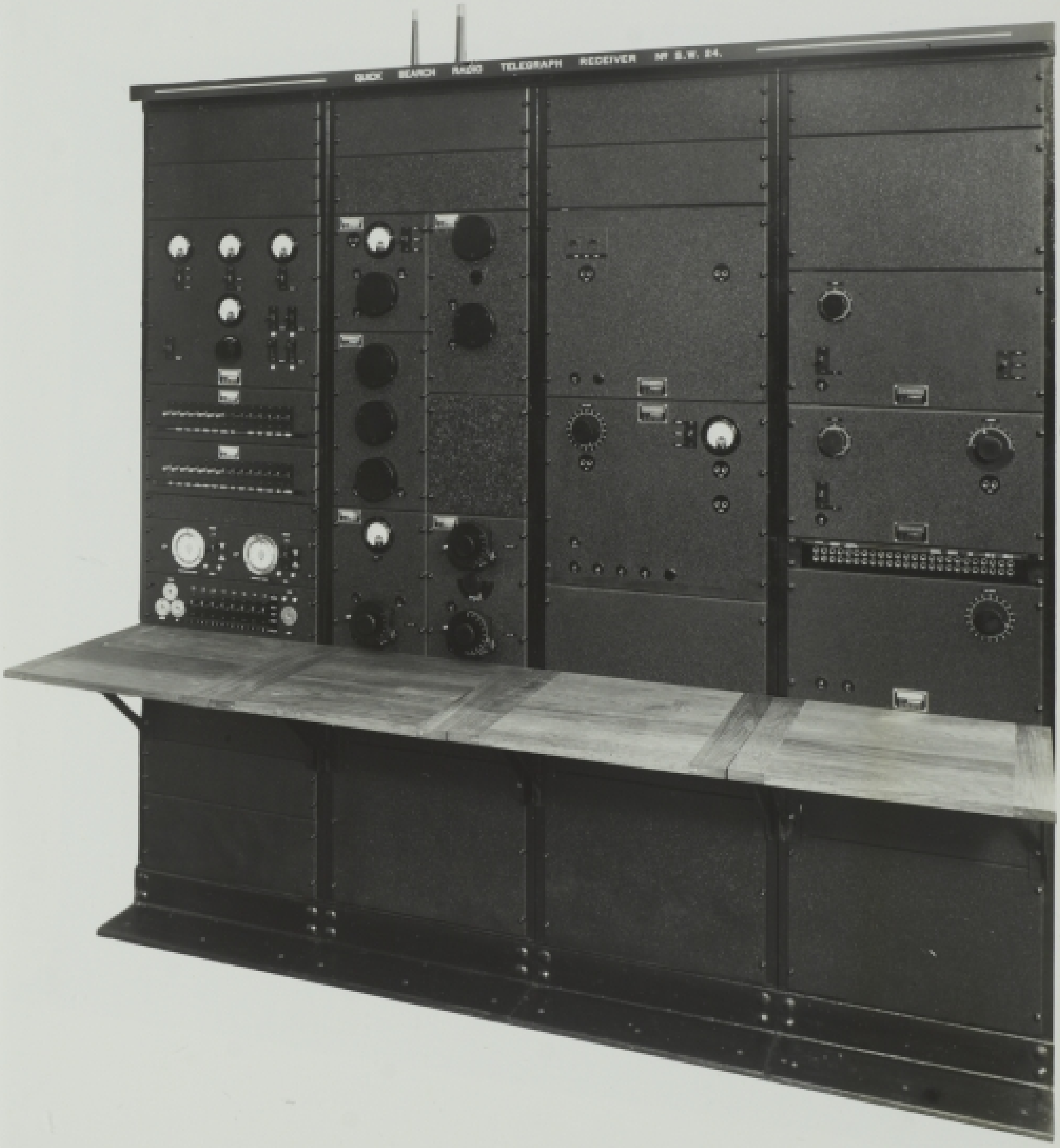
SHORT WAVE BEATING OSCILLATOR CONDENSER.



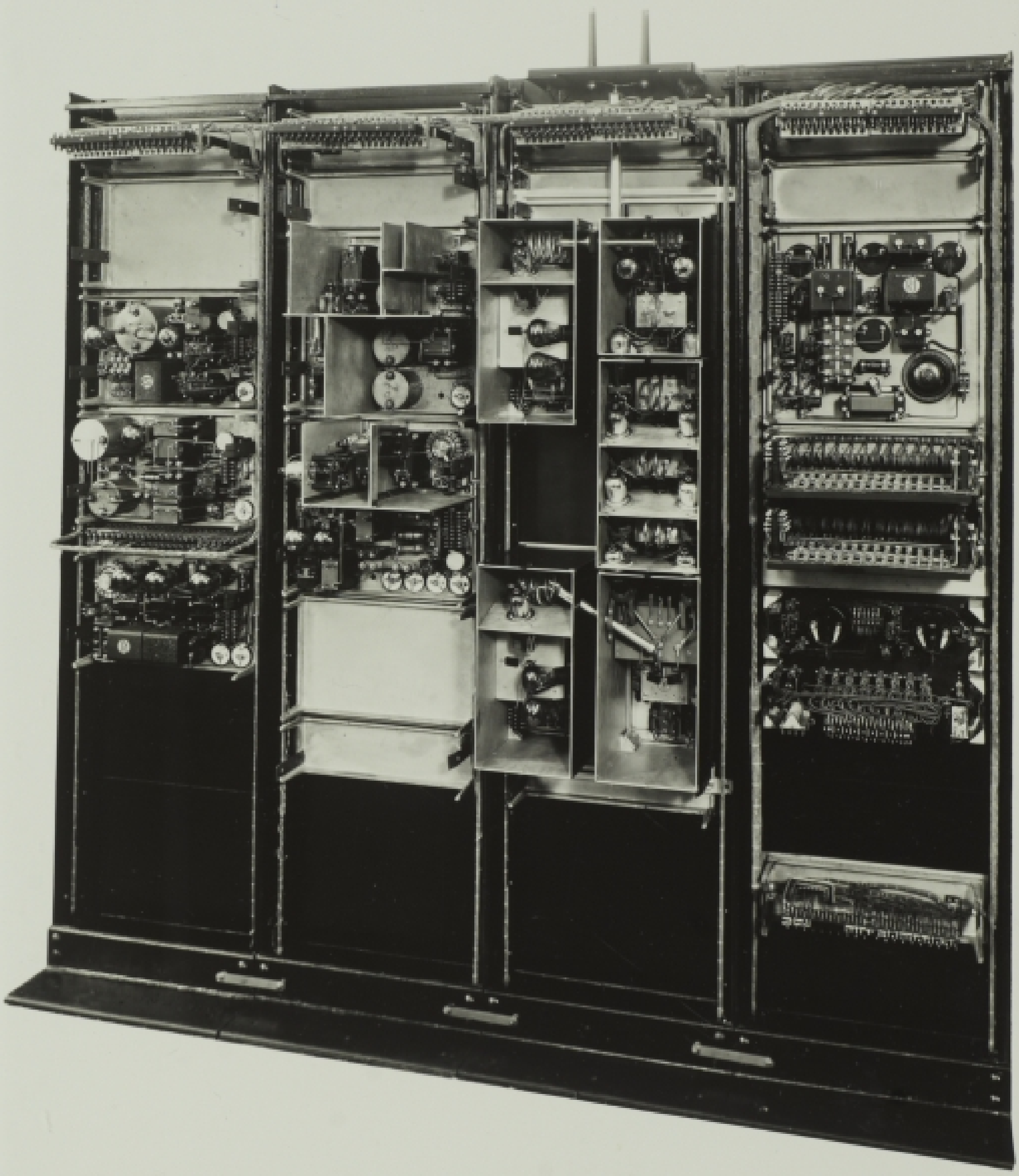
FRONT VIEW.



BACK VIEW.



SHORT WAVE RECEIVER Nº S.W. 24.
FRONT VIEW.

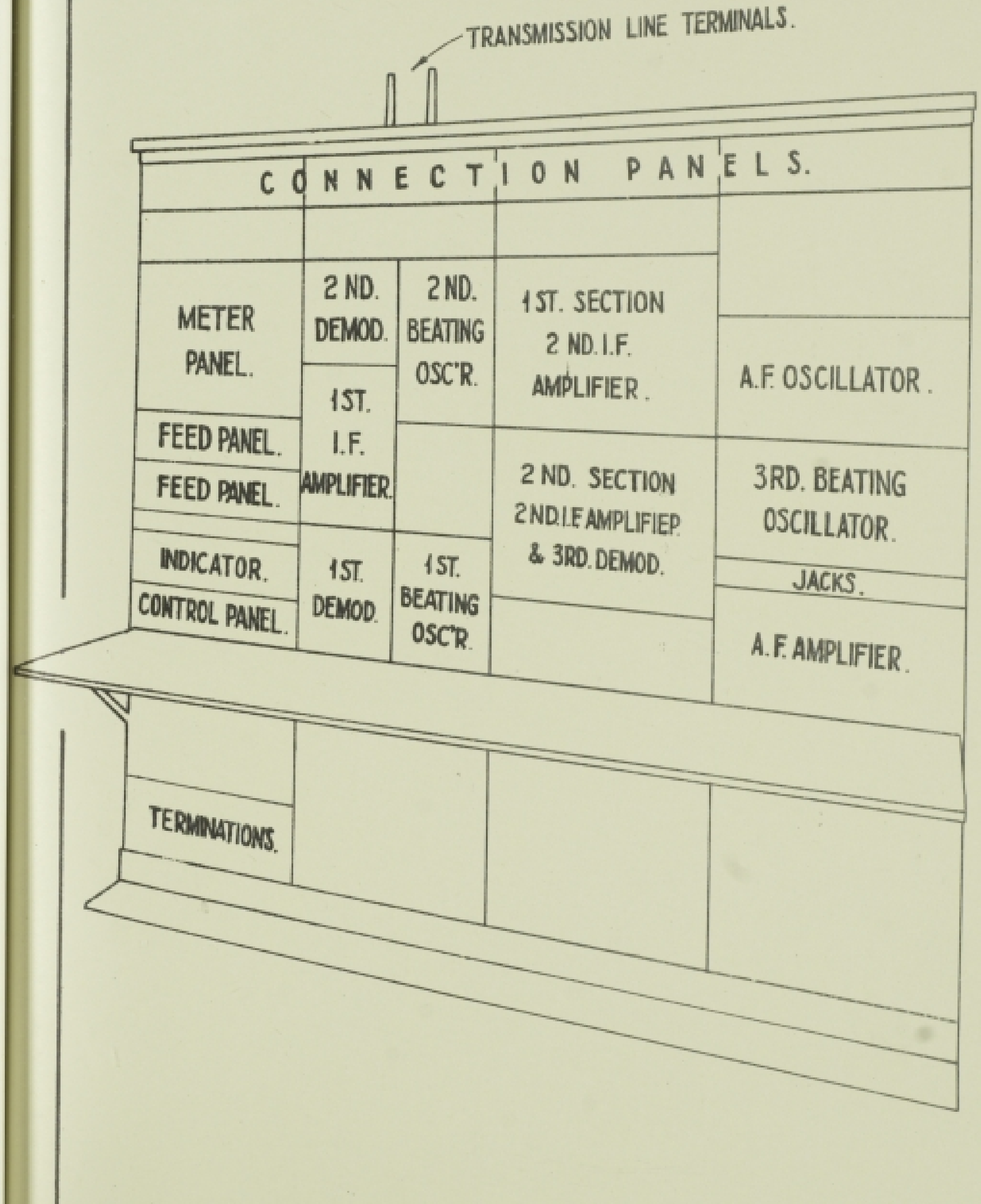


SHORT WAVE RECEIVER Nº S.W. 24.

BACK VIEW.

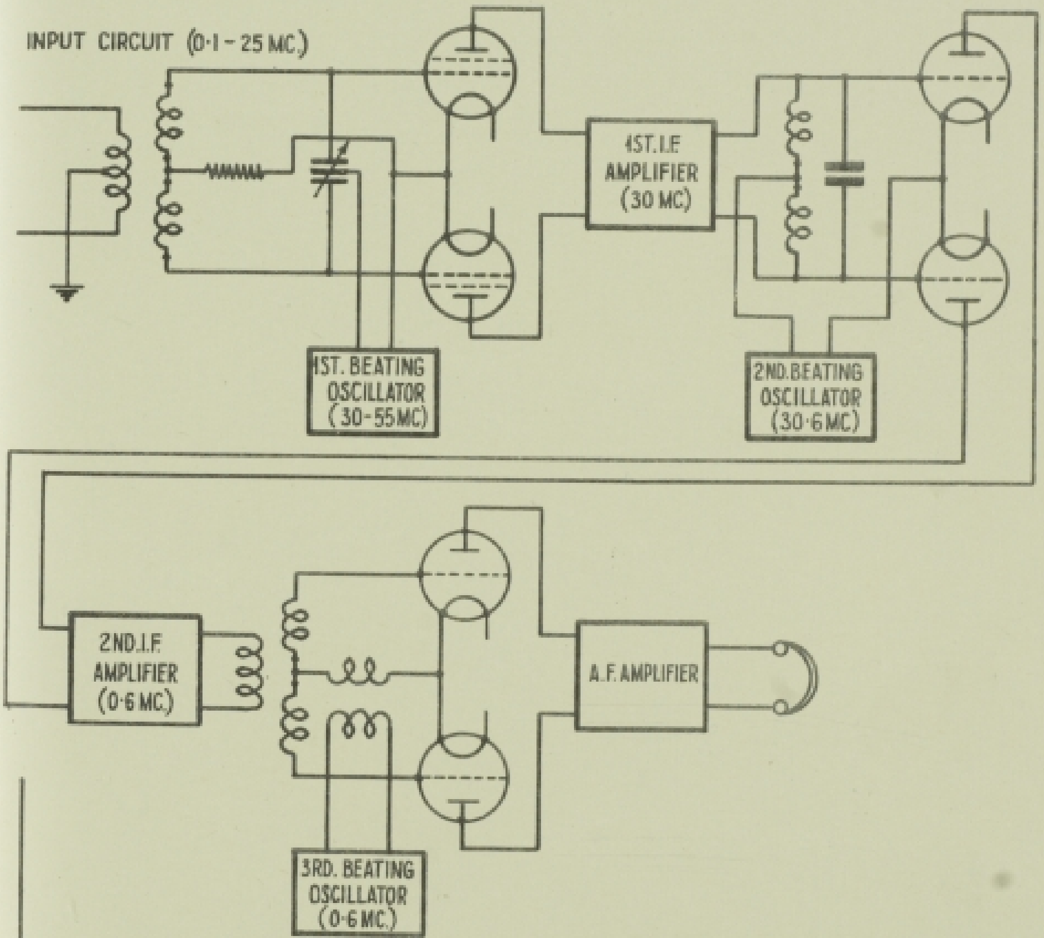
KEY TO FRONT VIEW OF RECEIVER.

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.			
DRAWING WL. 12523			
Specification			
Scale:- except where otherwise stated			
Drawn by	Checked by	App'd by	Date 8.7.34



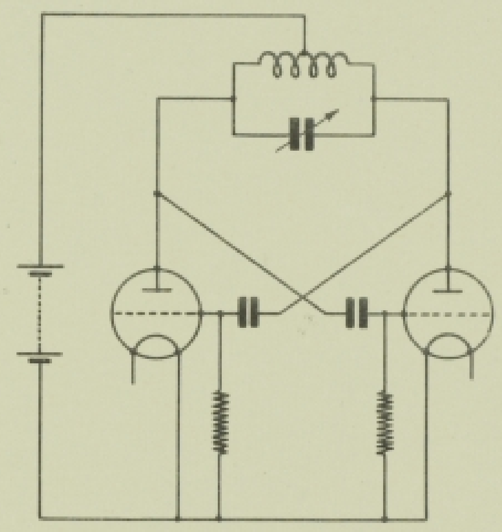
OUTLINE DIAGRAM OF
QUICK SEARCH RECEIVER

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.				
DRAWING WL. 12521				SUFFIX
Specification				
Scale:- except where otherwise stated.				
Drawn by	Checked by	App'd by	Date 8.7.54	
Particulars of Amendment	Date	Initials		



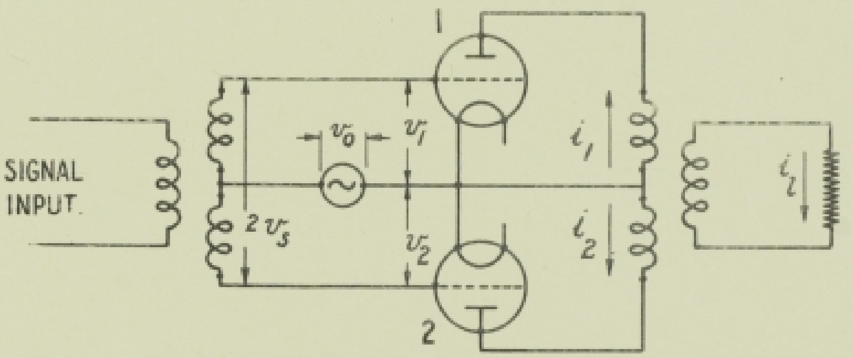
OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.					
DRAWING WL. 12522					SUFFIX
Specification					
Scale:- except where otherwise stated.					
Drawn by	Checked by	App'd by	Date 8.7.34		
Particulars of Amendment	Date	Initials			

BEATING OSCILLATOR CIRCUIT



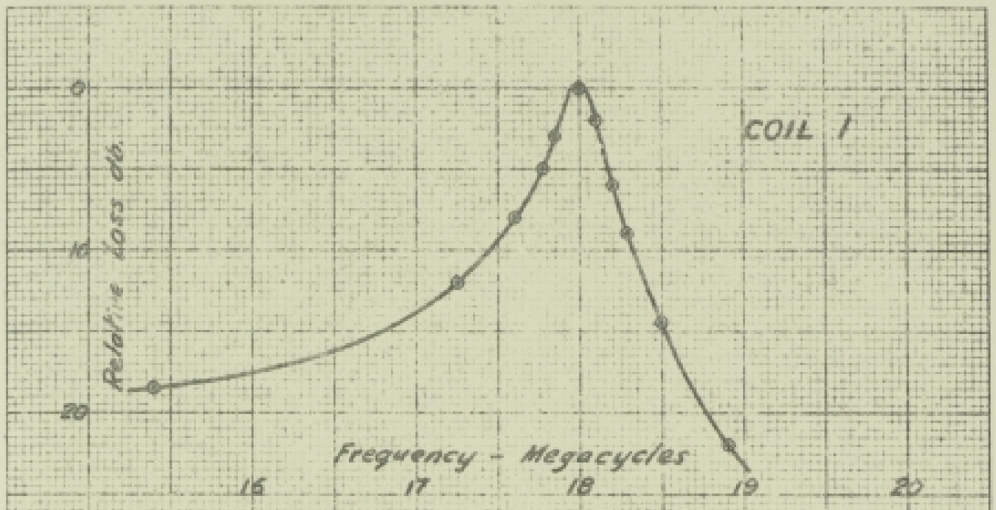
BALANCED DEMODULATOR
(EMPLOYING TRIODES)

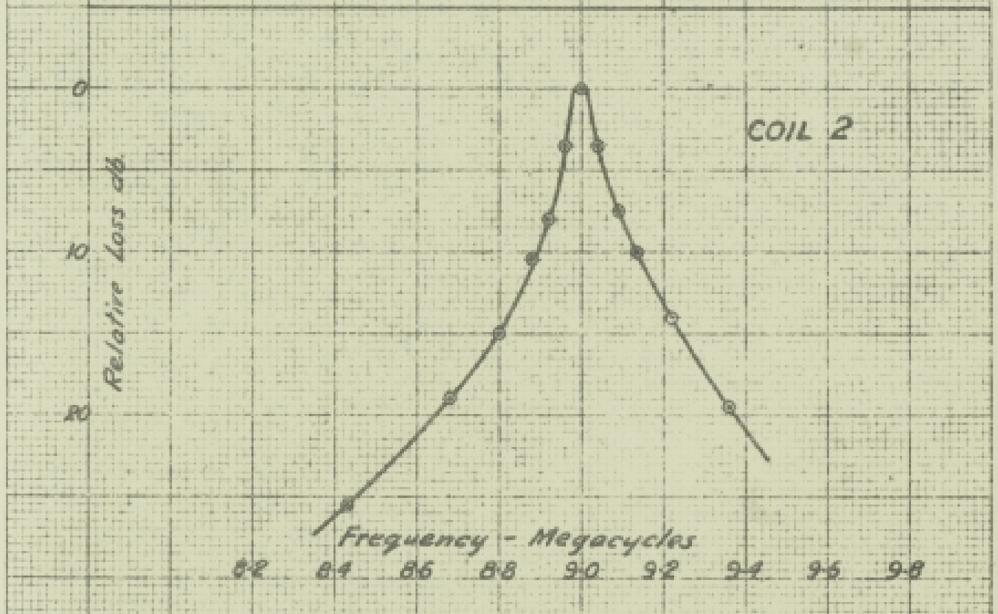
OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.				
DRAWING WL. 12524				SUFFIX
Specification				
Scale:- except where otherwise stated.				
Drawn by	Checked by	App'd by	Date 8-7-34	
Particulars of Amendment	Date	Initials		

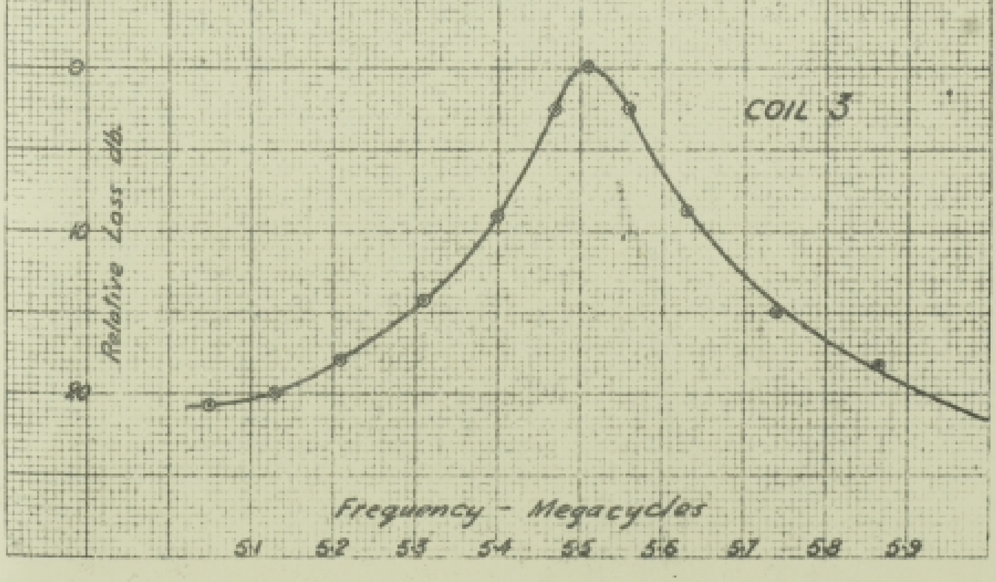


WL. 12525

1^ST CIRCUIT FREQUENCY CHARACTERISTICS 10.
S. W. RECEIVER No. 24.



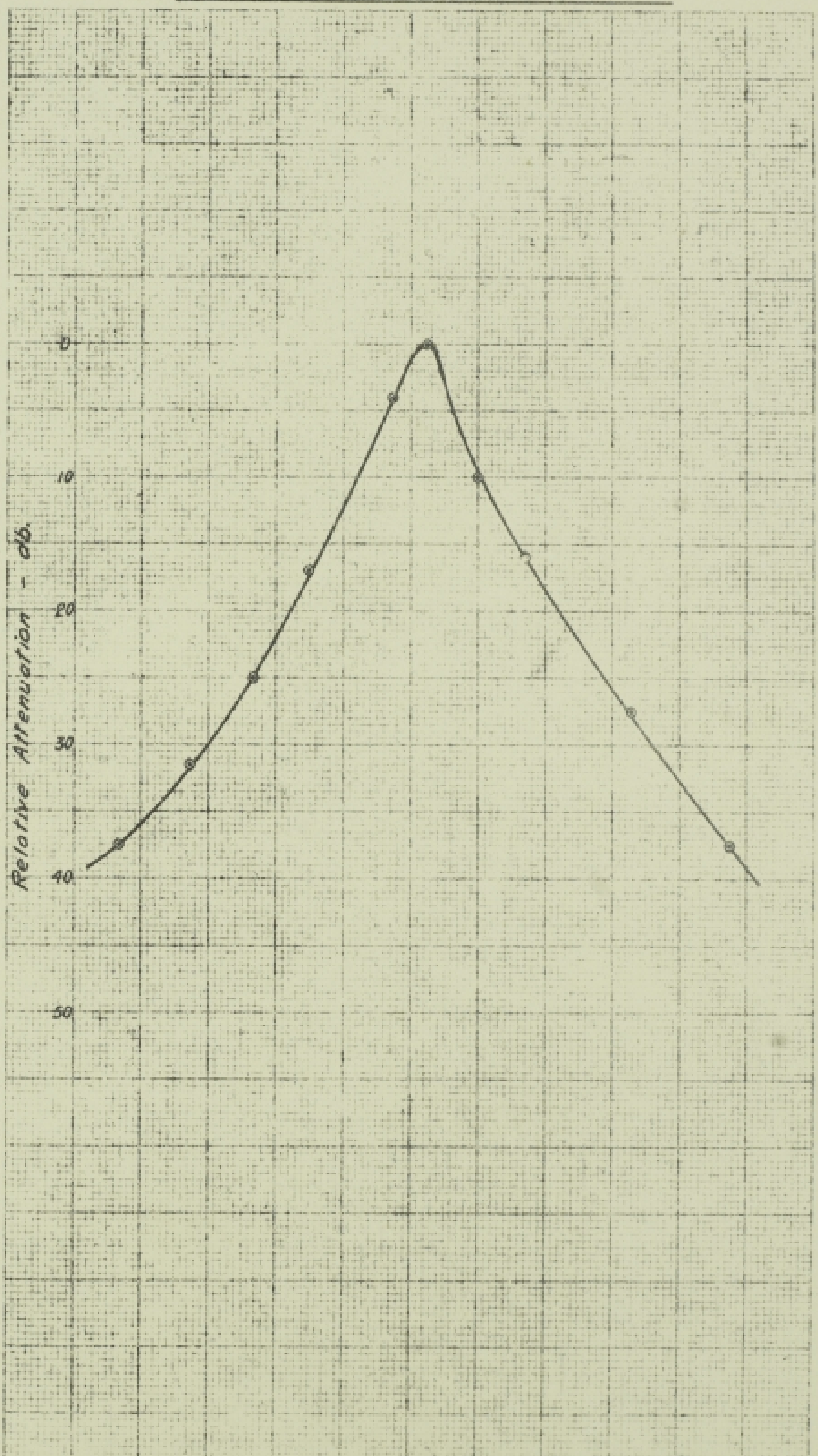




WL. 12526.

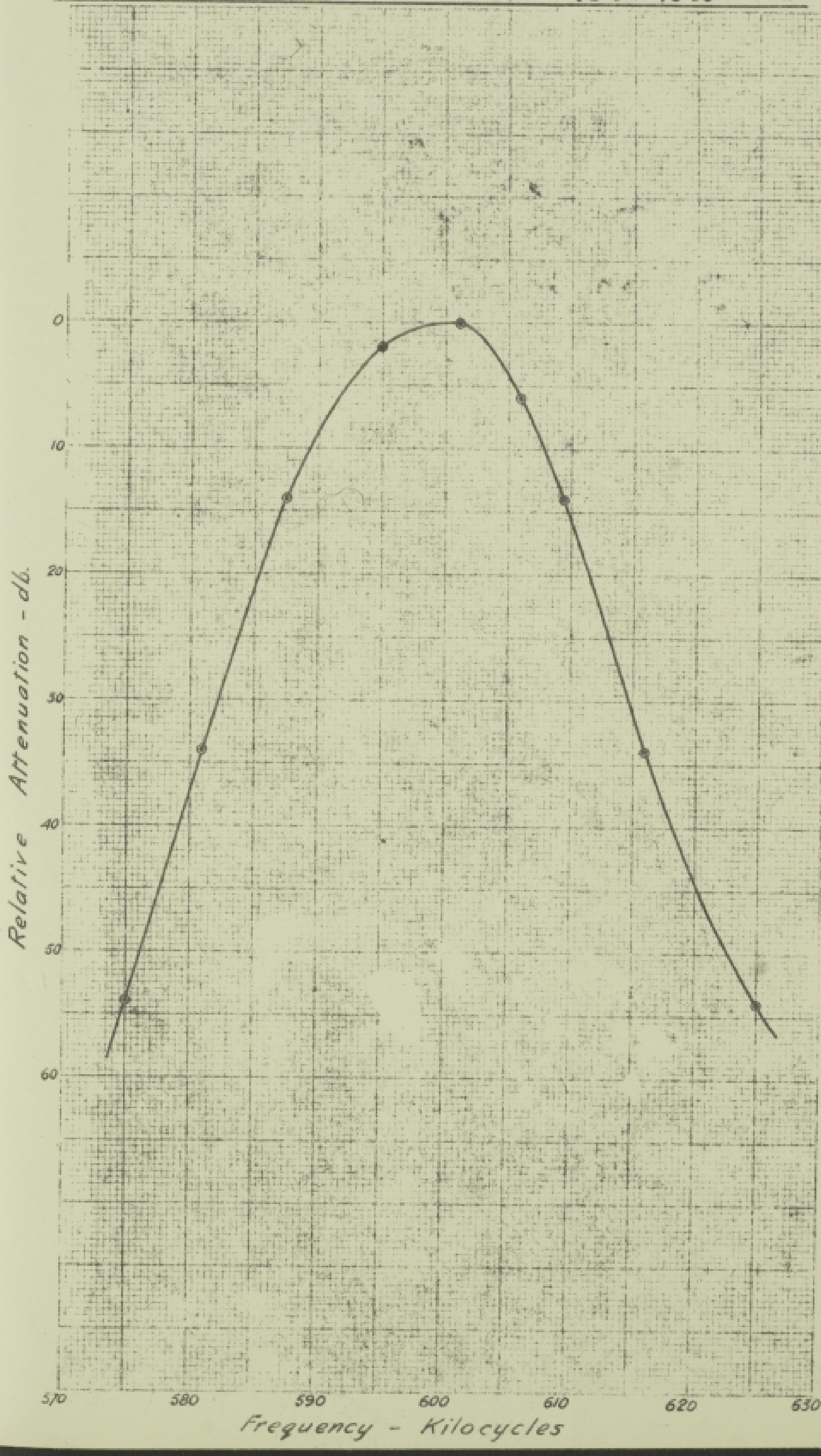
10.

S. W. RECEIVER No. 24
1ST INTERMEDIATE FREQUENCY CIRCUITS
FREQUENCY CHARACTERISTIC



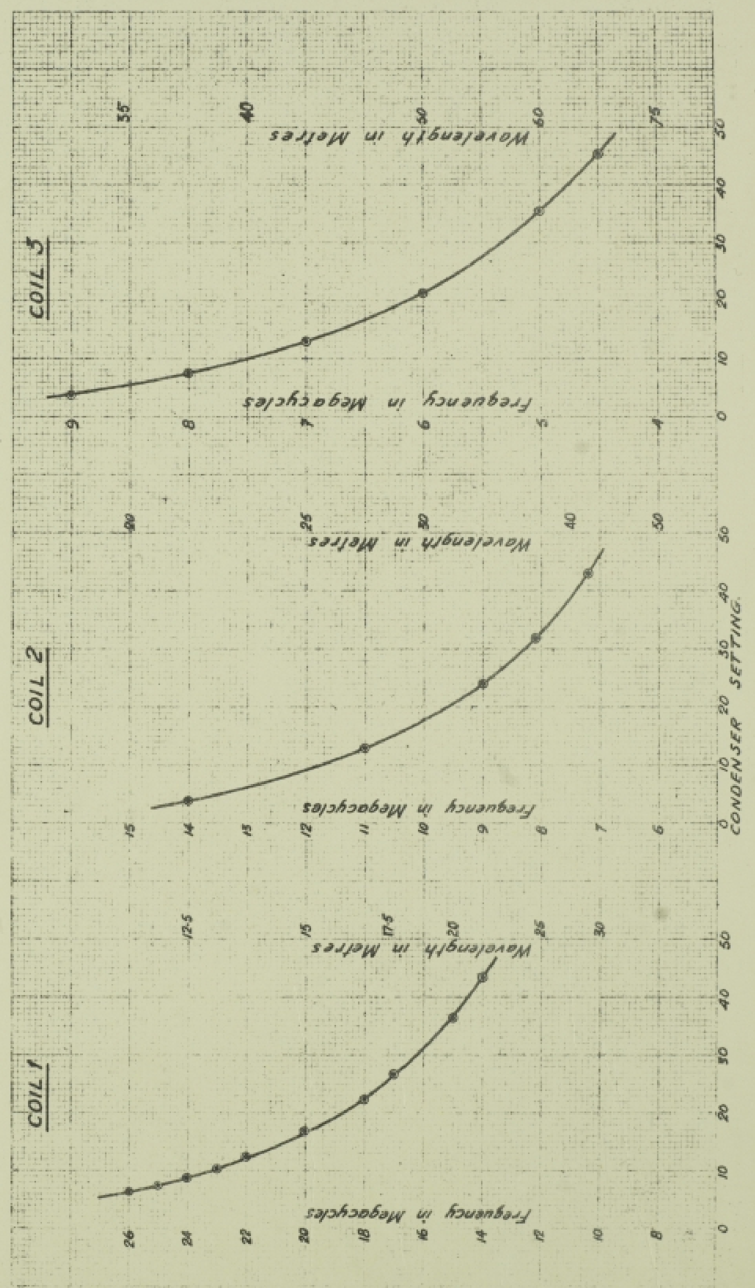
WL. 12527

S. W. RECEIVER No. 24. 2ND INTERMEDIATE FREQUENCY CIRCUITS. — FREQUENCY CHARACTERISTIC (EXCLUDING DEMOD. A.F. CHARACTERISTIC). TAKEN IN MAX. GAIN SETTING, EMPLOYING 3RD BEATING OSC.
MAX. GAIN INCLUDING DEMOD. & EMPLOYING 3RD BEATING OSC. { "A" UNIT 23 db. "B" UNIT 78 db.



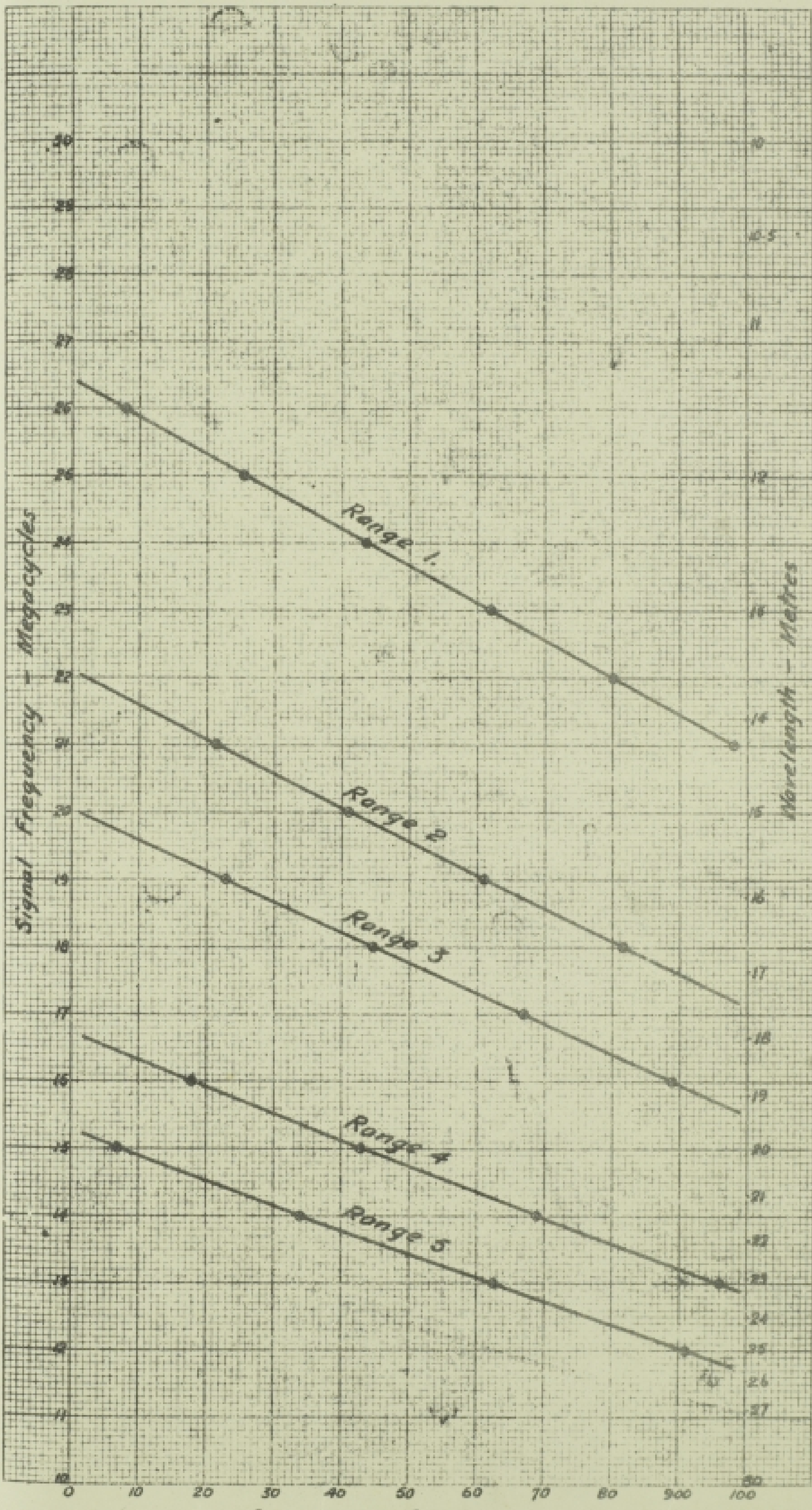
WL. 12528

S. W. RECEIVER No. 24
1ST CIRCUIT FREQUENCY CALIBRATION

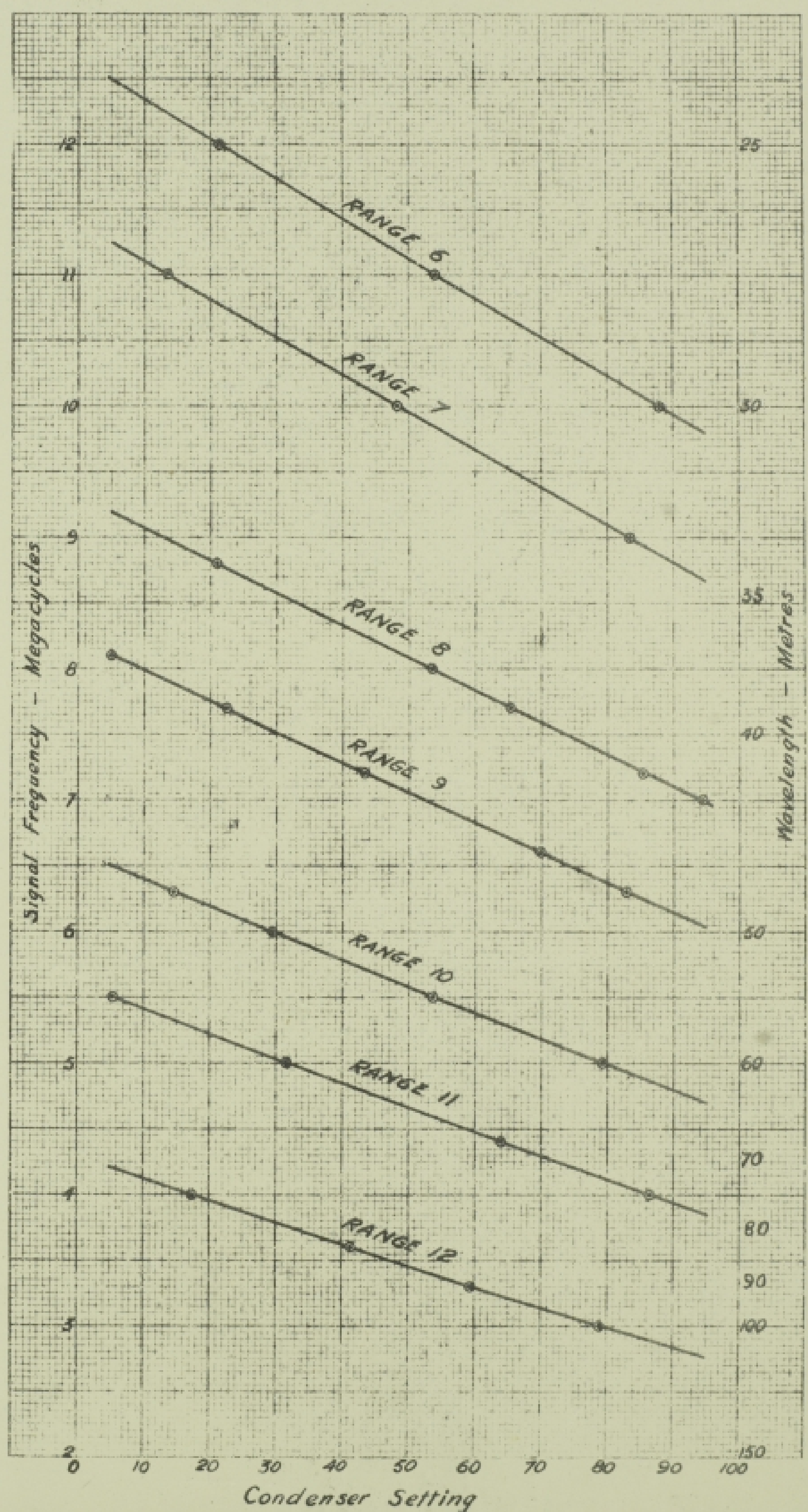


WL. 12529

CALIBRATION OF 1ST BEATING OSCILLATOR. SERIAL No. 1795.
TAKEN WITH A 1ST I.F. FREQUENCY OF 30·222 MEGACYCLES.

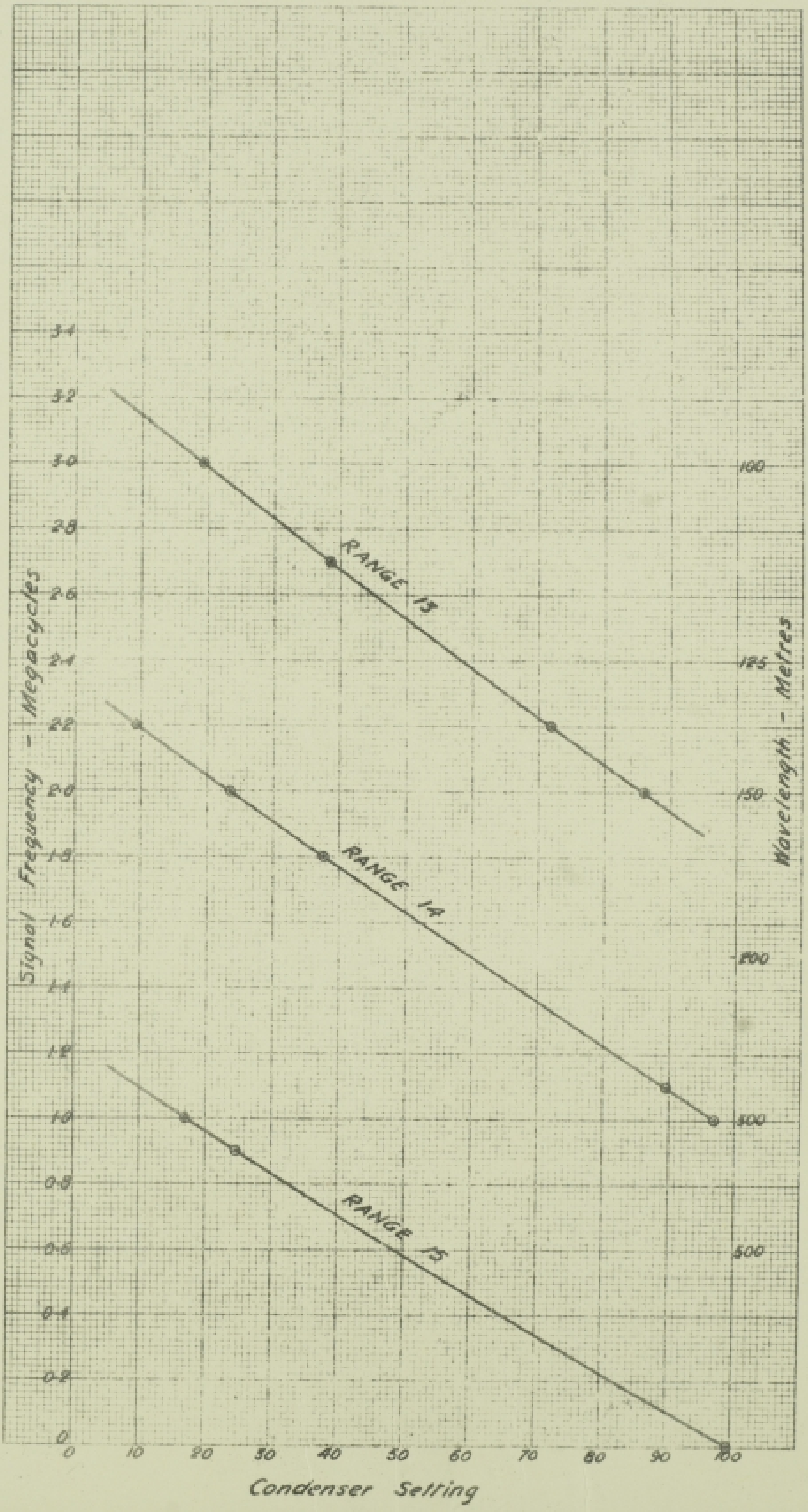


CALIBRATION OF 1ST BEATING OSCILLATOR. SERIAL No. 1795. 40.
TAKEN WITH A 1ST I.F. FREQUENCY OF 30·222 MEGACYCLES



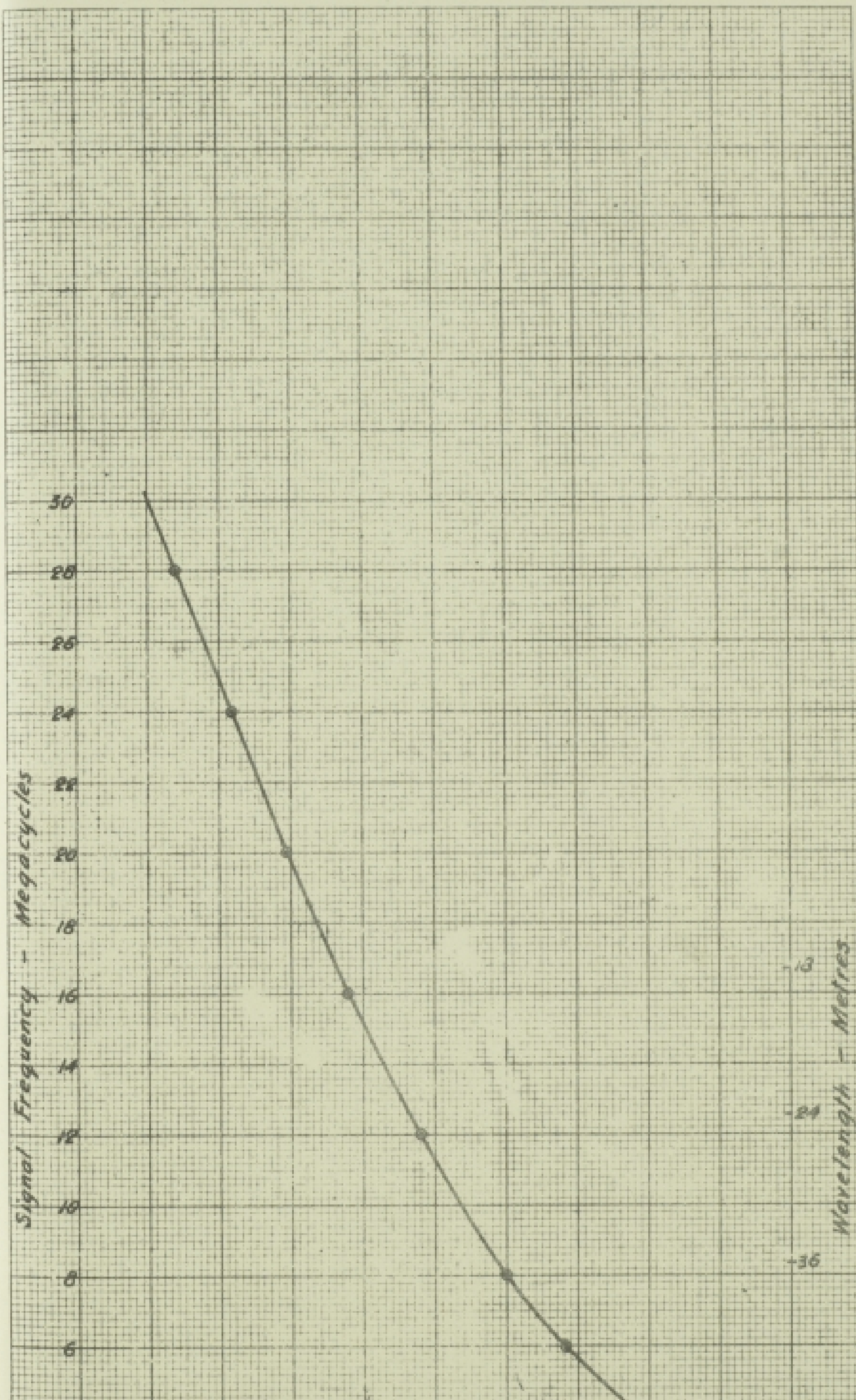
WL. 12331

CALIBRATION OF 1ST BEATING OSCILLATOR. SERIAL No. 1795
TAKEN WITH A 1ST I.F. FREQUENCY OF 30·222 MEGACYCLES



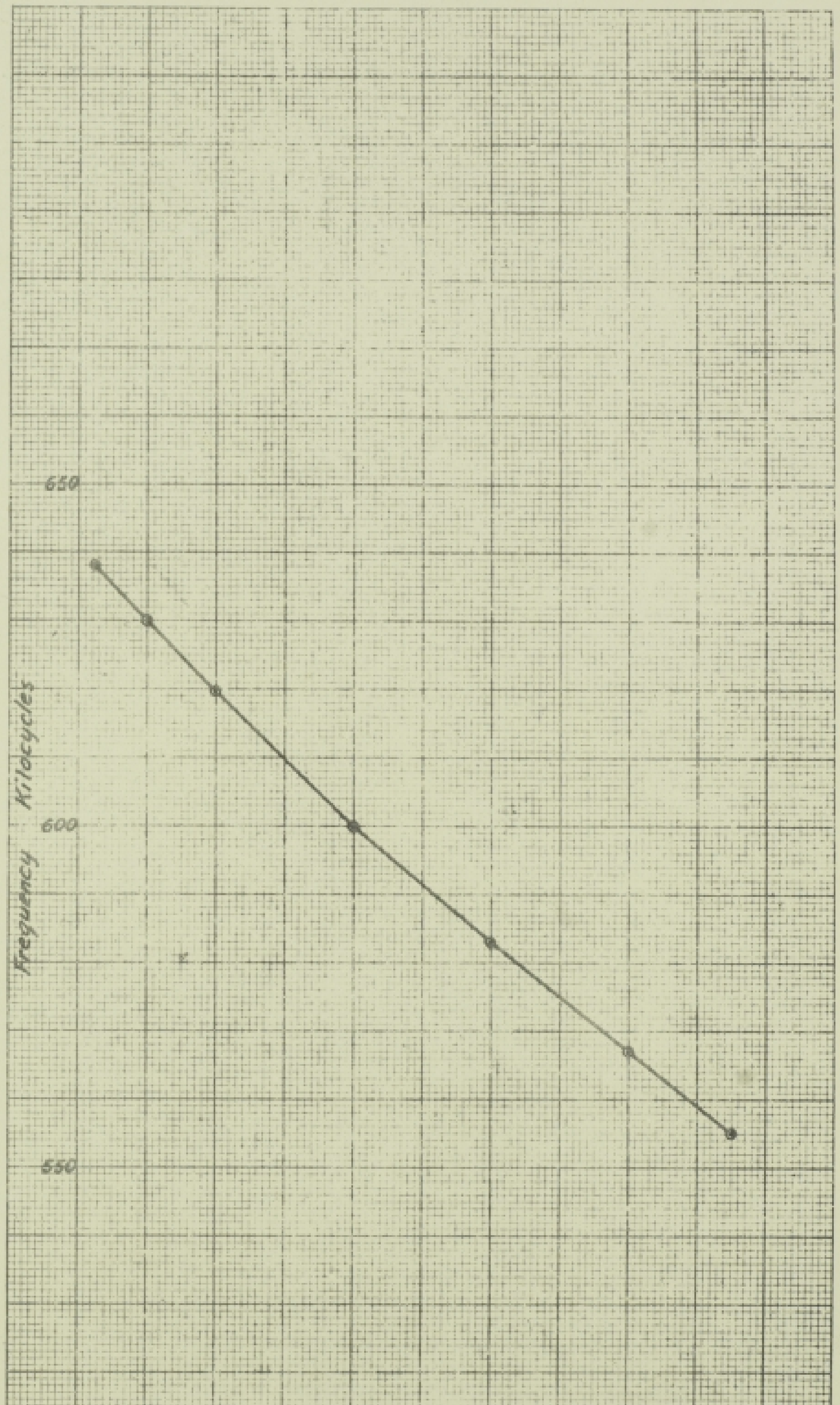
WL. 12532

1ST BEATING OSCILLATOR. SERIAL No. 1795
BUFFER STAGE CALIBRATION
WITH 1ST I.F. FREQUENCY OF 30·222 MEGACYCLES



WL. 12533

3RD BEATING OSCILLATOR. SERIAL No. 1713.
FREQUENCY CALIBRATION

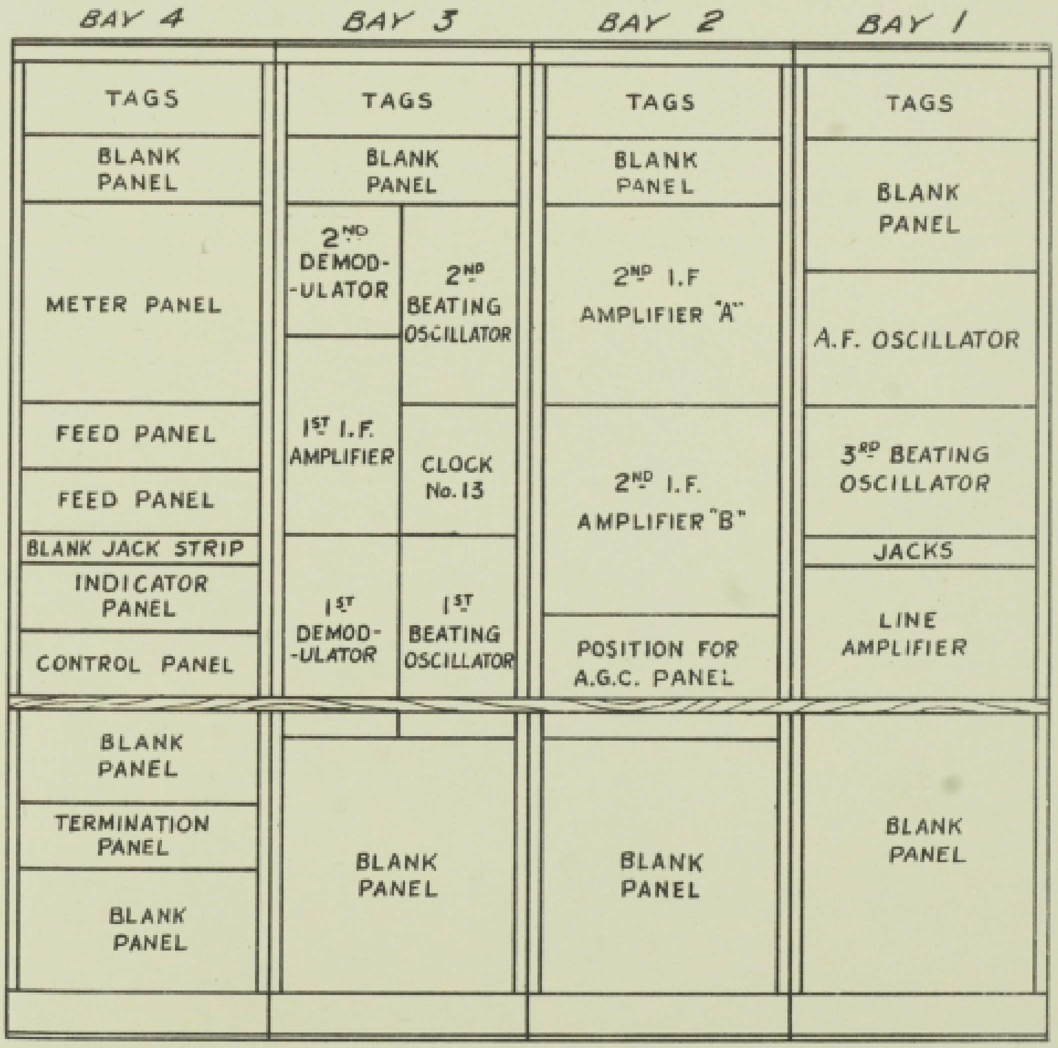


S.W. RECEIVER No. 24
LAYOUT OF APPARATUS RACK

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.

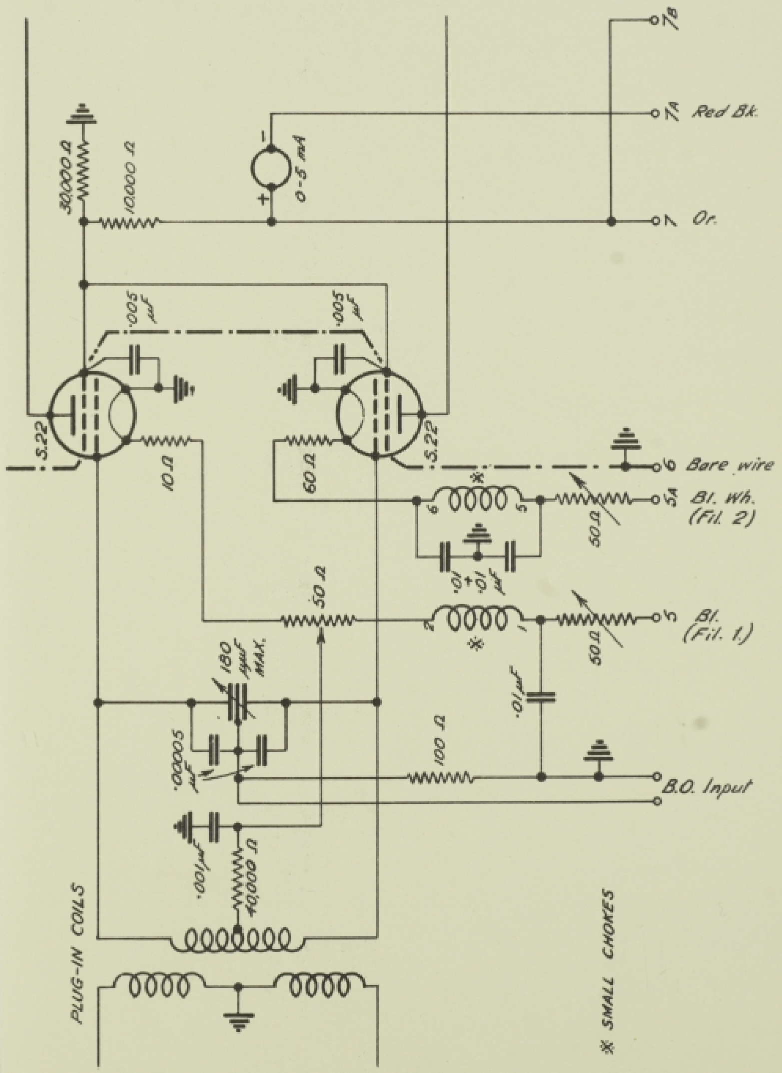
DRAWING WL. 12534	SUFFIX
Specification	
Scale:- except where otherwise stated.	
Drawn by / Checked by / App'd by / Date	
Particulars of Amendment / Date / Initials	

FRONT VIEW



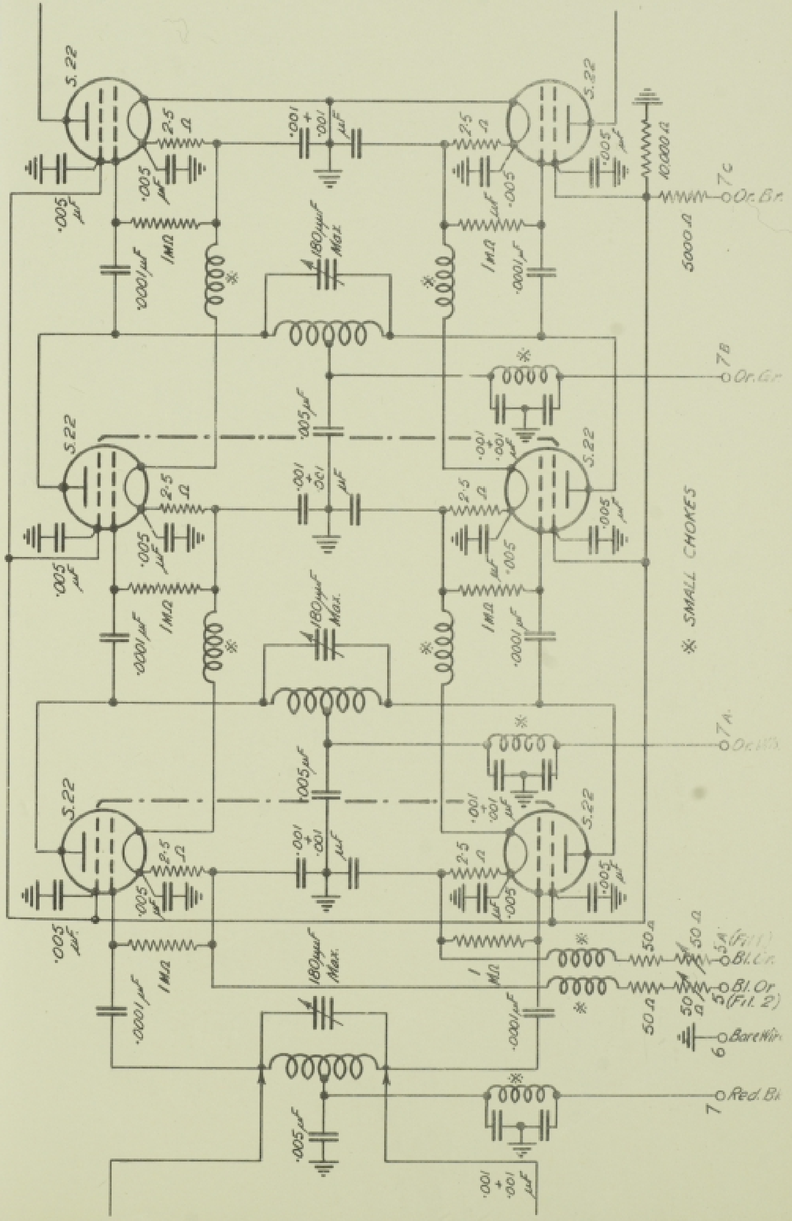
1ST DEMODULATOR
SERIAL Nº 1797

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.				
DRAWING WL.12535				SUFFIX
Specification				
Scale:- except where otherwise stated.				
Drawn by	Checked by	App'd by	Date	
Particulars of Amendment	Date	Initials		



1st I.F. AMPLIFIER.
SERIAL No. 1799.

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.				SUFFIX
DRAWING WL. 12536				
Specification				
Scale:- except where otherwise stated				
Drawn by	Checked by	App'd by	Date 18.4.34	
Particulars of Amendment	Date	Initials		



2ND DEMODULATOR

SERIAL No. 1798

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.

DRAWING WL. 12537

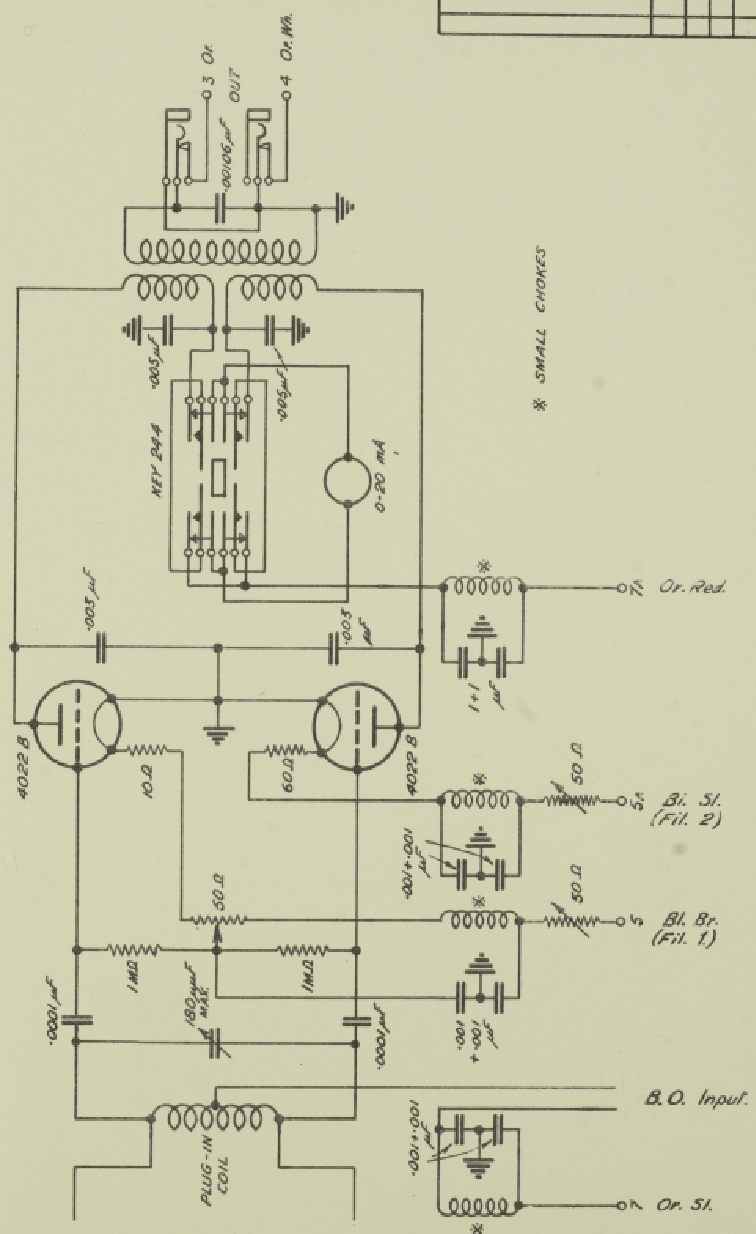
Specification

Scale:- except where otherwise stated

Drawn by	Checked by	App'd by	Date
			9.5.34

Particulars of Amendment	Date	Initials

SUFFIX

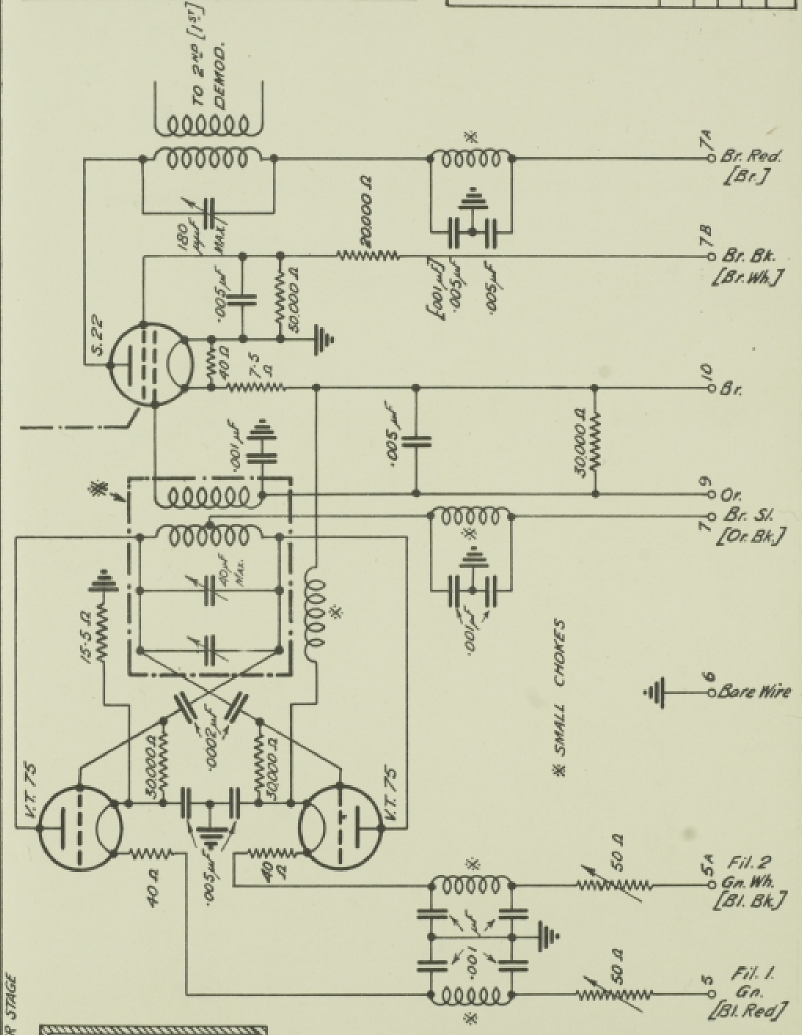


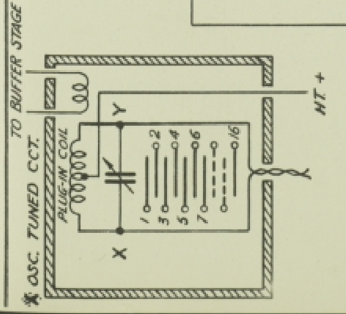
OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.			
DRAWING WL. 12538			SUFFIX
Specification			
Scale:- except where otherwise stated			
Drawn by	Checked by	App'd by	Date 10.5.34
Particulars of Amendment	Date	Initials	

2ND BEATING OSCILLATOR.

SERIAL No. 1796

1ST BEATING OSCILLATOR, SERIAL No. 1795, IS SIMILAR. VALUES & COLOUR SCHEME ARE SHOWN IN [ ] WHERE THEY DIFFER FROM 2ND B.O.

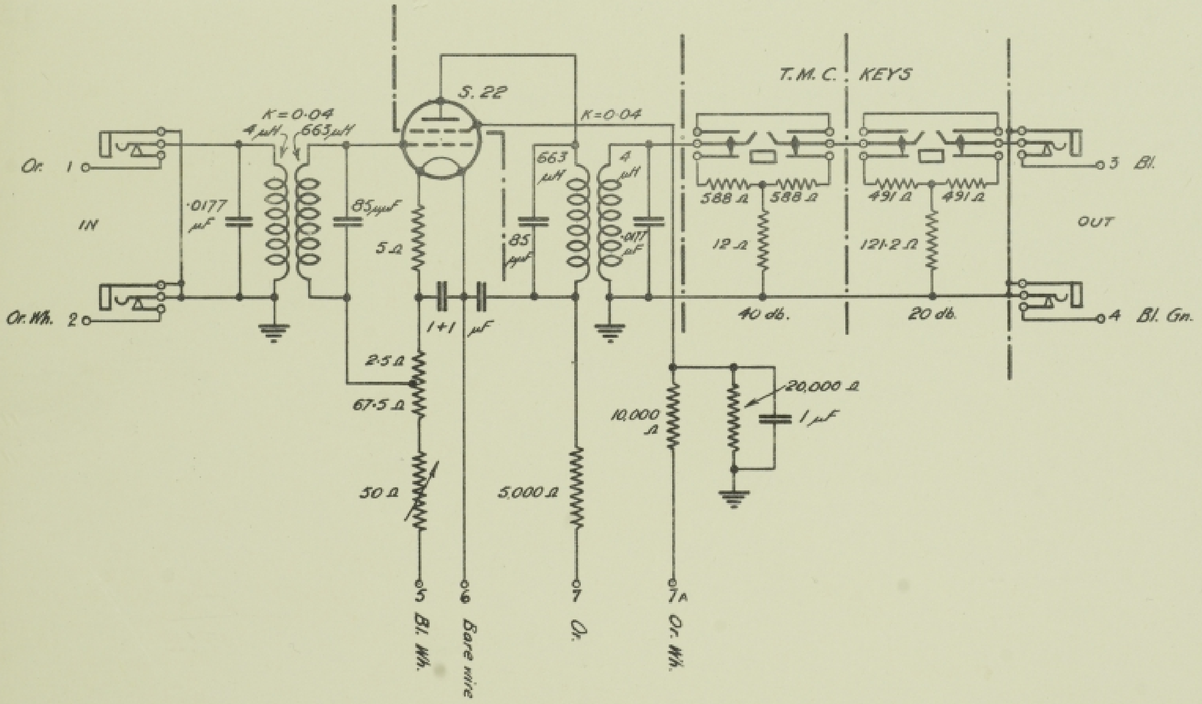




POS'N OF SWITCH	X CONN'D TO	Y CONN'D TO
0	VARIABLE ONLY IN USE	
1	1	
2	1	2
3	& 3	2
4	- 3	& 4
5	- 5	- 4
6	- 5	- 6
7	- 7	- 6
8	- 7	- 8
9	- 9	- 8
10	- 9	- 10
11	- 11	- 10
12	- 11	- 12
13	- 13	- 12
14	- 13	- 14
15	- 15	- 14
16	- 15	- 16

2ND I.F AMPLIFIER "A."

SERIAL No. 1714.

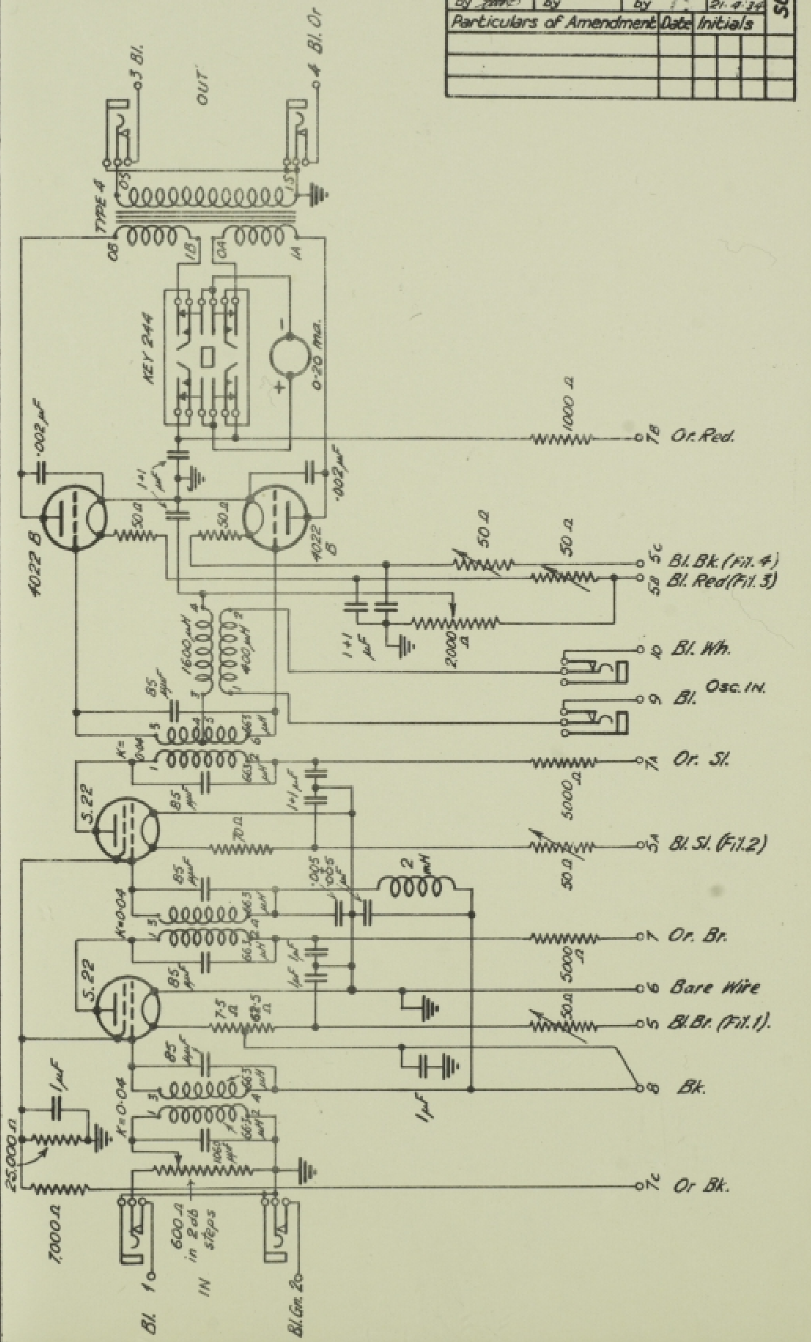


OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.	
DRAWING WL.12539	SUFFIX
Specification	
Scale:- except where otherwise stated	
Drawn by	Checked by	App'd by	Date 27.4.34
Particulars of Amendment	Date	Initials

2ND I.F. AMPLIFIER "B" & 3RD DEMODULATOR

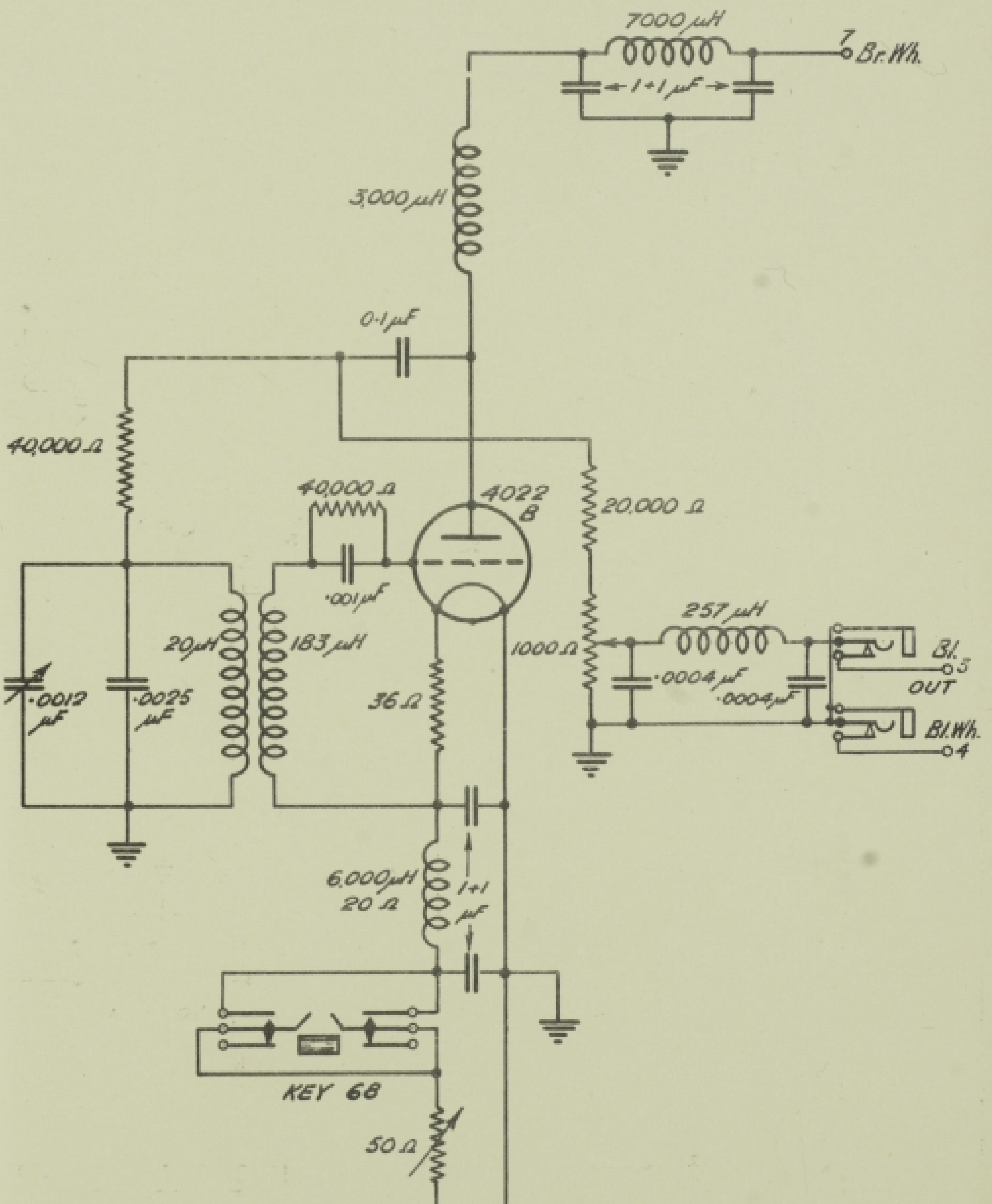
SERIAL No. 1715

OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.				
DRAWING WL. 12540				SUFFIX
Specification				
Scale:- except where otherwise stated				
Drawn by	Checked by	App'd by	Date 21.4.34	
Particulars of Amendment	Date	Initials		



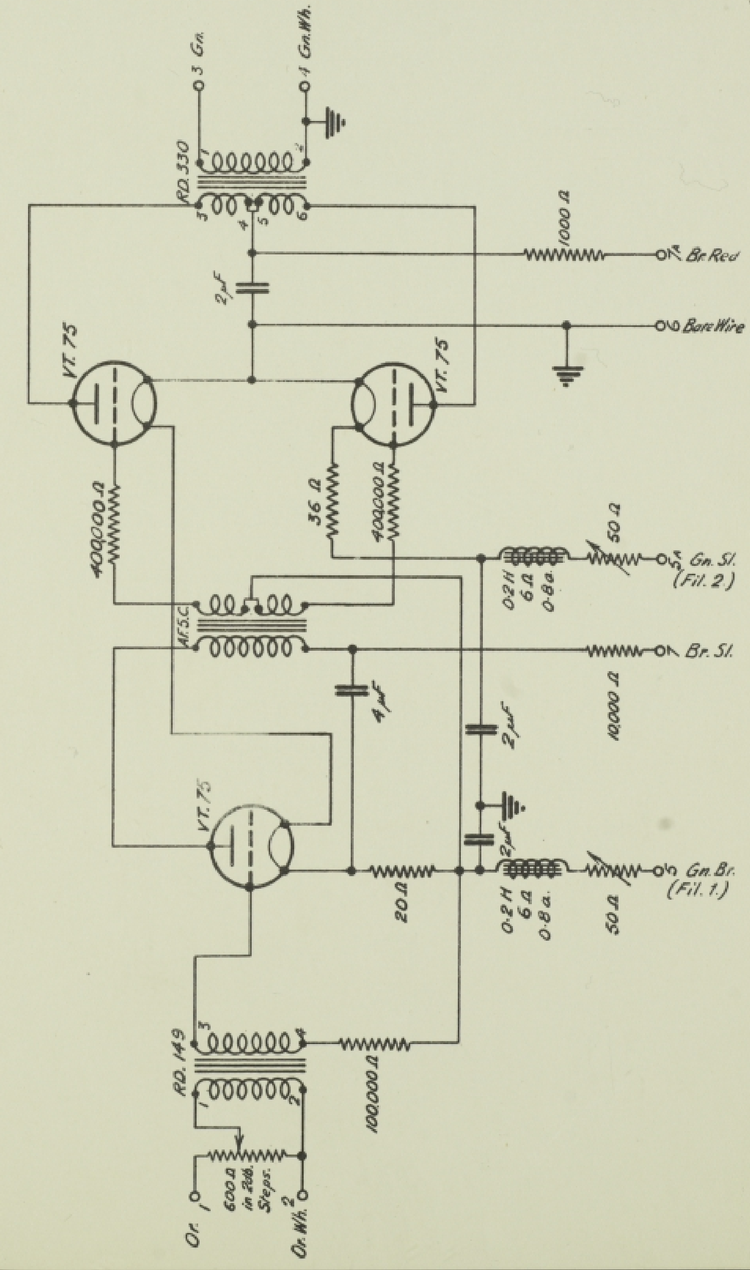
3RD BEATING OSCILLATOR
SERIAL No. 1713.

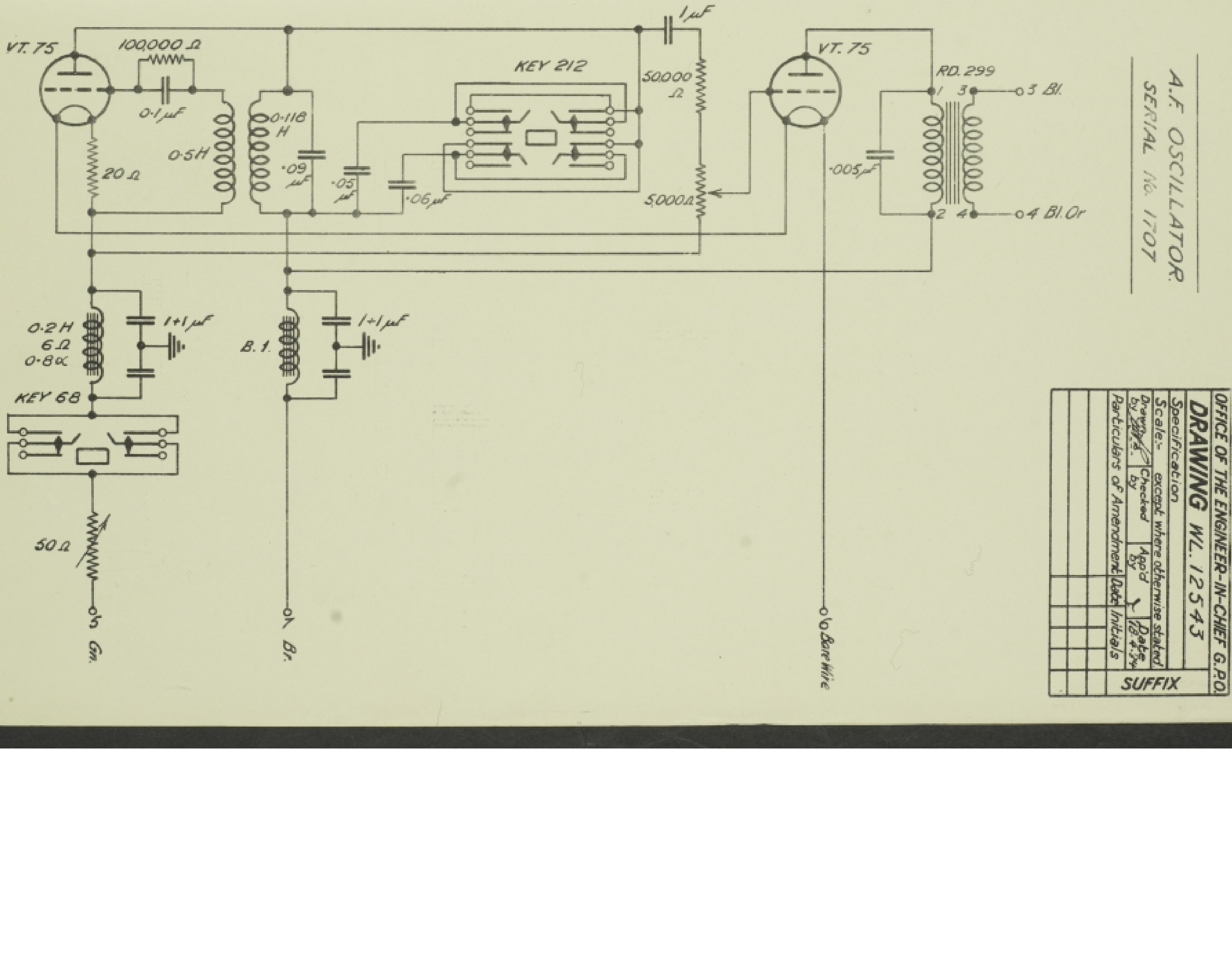
OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.				
DRAWING WL. 12541				SUFFIX
Specification				
Scale:- except where otherwise stated				
Drawn by	Checked by	App'd by	Date 12.4.34	
Particulars of Amendment	Date	Initials		



LINE AMPLIFIER.
SERIAL No. 1708

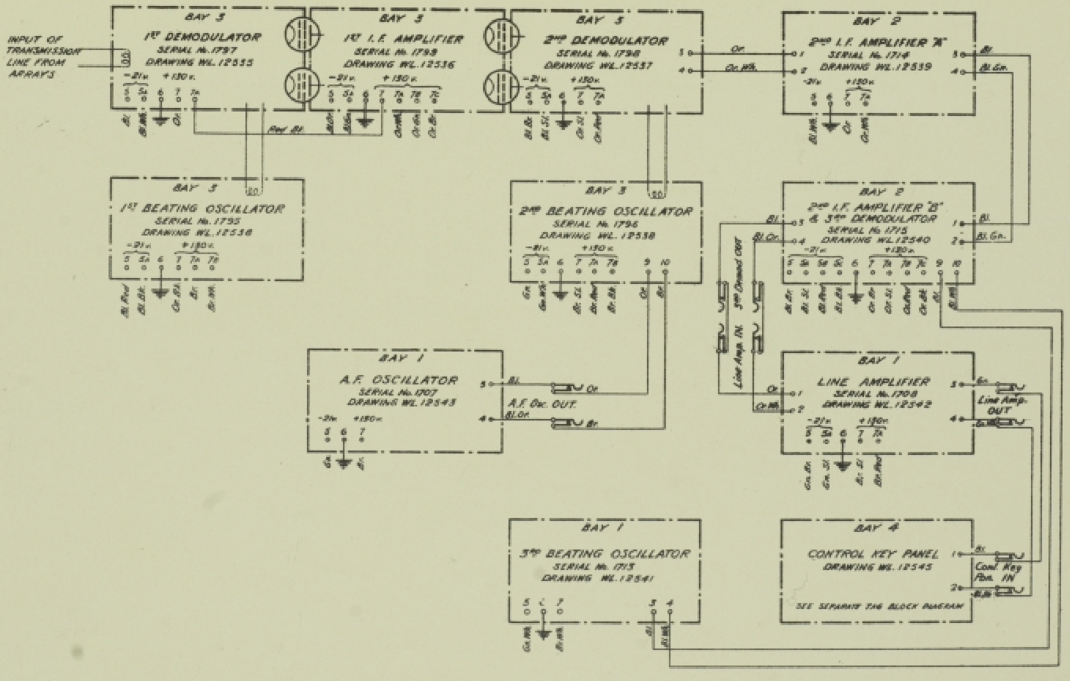
OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.			
DRAWING WL. 12542			SUFFIX
Specification			
Scale:- except where otherwise stated			
Drawn by	Checked by	App'd by	Date 17.4.34
Particulars of Amendment	Date	Initials	





A.F OSCILLATOR.
SERIAL No. 1707
VT. 75
100,000 Ω
0·1 μF
0·5 H
20 Ω
0·118 H
·09 μF
·05 μF
·06 μF
KEY 212
1 μF
50,000 Ω
5,000 Ω
VT. 75
RD. 299
·005 μF
3 Bl.
4 Bl. Or
0·2 H
6 Ω
0·8 α
1+1 μF
B. 1.
1+1 μF
KEY 68
50 Ω
Gn.
Br.
Bare Wire
OFFICE OF THE ENGINEER-IN-CHIEF G.P.O.
DRAWING WL. 12543
Specification
Scale- except where otherwise stated
Drawn by
Checked by
App'd by
Date
Particulars of Amendment
Date
Initials
SUFFIX

WL.12562



DRAWING No. WL.12562

S.W. RECEIVER No. 24.

BLOCK SCHEMATIC DIAGRAM.

DRAWN	APPROVED	DATE
		4-6-34