# MAGNETIC DETECTORS.

Marconi detectors are of three types—

(1) The one now in service which has a "phonograph" clockwork-speed controlled by centrifugal balls.

(2) The one being introduced. This has an "inker" clockwork-speed controlled by "air beater."

(3) Electro-magnetic type, where the band is hove by friction off an ordinary Morse inker, and an electro-magnet is used to make the field. This type is far the most compact. Two were bought at beginning of year and supplied to "Vernon" and "Duncan."

They were reported on as less sensitive than the other patterns, so no more will be obtained.

*Primary Windings.*

Type (No. 2) has a primary inductance of about 85 micro-henries. This is much too long for B tune, but can be corrected by a capacity of about half a k.cm. placed in series with the aerial.

Type (No. 1) appears to have been issued with all kinds of primary windings; of two supplied to "Vernon" one had an inductance of 20 micro-henries, and the other 70. The former was much the better for B tune unless a condenser was placed in the aerial, when the latter was as good.

*Condenser in Parallel.*

For receiving from Poldhu, the 20-mic. M.D. was improved by a capacity placed in parallel with the winding; whilst the 70-mic. M.D. was but very little improved—if at all.

This is in accord with theory. We believe that with "simple resonance" all detectors can be improved by the addition of capacity in parallel with the primary winding; the good effects increasing up to the "rejector" point (*see* page 41), but that it is only when the inductance on the M.D. is small in comparison with that in the aerial that the effects become marked.

The "tuned shunts" (page 42) will obviate any necessity for this condenser.

*The Magnets.*

Have been replaced (for experiments) by electro-magnets, and signals were just as strong with quite weak magnets as with strong ones. No difference over a large range could be detected.

*The Band.*

It is most important that if this is taken off it be replaced without taking any more turns in it. A nicely twisted-up band seriously reduces the efficiency, and as this was not known until the middle of the year, the M.D.'s now in Service can probably be improved by taking some of the twist out.

"Vernon" finds that the slower the band heaves the better, but Mr. Marconi has stated that for extra long waves (20,000 feet) the band ought to be increased in size and speed.

The band should be kept greased with vaseline, and every care taken of it.

*The Telephones.*

There should be only a minute clearance between poles and diaphragm.

There is far more variation in the efficiency of the telephones than of the M.D.'s.

*"Sharpness" of Signals.*

Can be improved by a condenser in parallel with the telephones. A paper condenser will do and should have a capacity of from 100 to 300 k.cm. according to the requirements of the operator.

*Resistance of Tuners.*

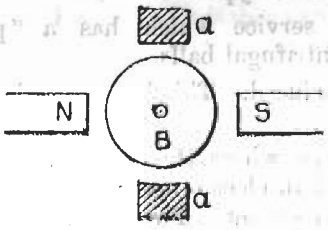
10ω non-inductive (Wheatstone bridge) placed in aerial caused no diminution of strength of signals.

40ω stopped signals.

It is probable from this experiment that the size of the tuners is unnecessarily large.

## WALTER-EWING DETECTOR.

FIG.



B is the end view of a bobbin wound with iron wire in planes parallel to the end view here shown, and slowly revolved in magnetic field NS. The ends of the iron wire on the bobbin B are connected to slip rings whose brushes are connected to aerial and earth, and it is usual to wind the iron wire on non-inductively.

AA is the telephone bobbin enveloping the whole bobbin B. This influences the telephones, and the sounds heard are similar to those on the Marconi detector.

It will be seen that in this detector the aerial current produces an alternating magnetic field at right angles to the axis of the iron wire (instead of co-axially with it as in the Marconi detector), whilst the slowly varying magnetic fields are in both detectors co-axial with the axis of the iron wires.

This difference in principle causes the hysteresis of the iron wires in the Marconi detector to *diminish* on the receipt of a "wave" and to *increase* in the Walter-Ewing pattern.

Professor Ewing and Mr. Walter attribute the result of the change in the hysteresis in their instrument to a change in the permeability "$\mu$" of the iron wires.

We have made the experiment of placing the bobbin AA at right angles to its present position (so as to have no mutual induction with the lines of force due to NS) and have found the strength of signals reduced This would appear to show that the change in $\mu$ is what is measured in this instrument, and the change in hysteresis is what is measured in the Marconi detector.

*Results.*

These have never been so good as with the Marconi detector. Stray signals can be obtained from Culver, but so far none from Portland. The instrument would be far more compact and less delicate than the Marconi detector, and it is expected it can be greatly improved, but it is not at present as efficient as the Marconi pattern.

## JIGGER DESIGN.

An abstract of a report on the "Vernon's" method is given on page 20, and the results with a jigger designed in this way for B tune are given on pages 14 and 46.

The equivalent capacity C of a coherer shown on page 52, was obtained.

As a result of much experimental and theoretical work, both with this method and by practical trials, the following conclusions have been arrived at:—

(1) If the C.P. of secondary (by this term we mean the LS value of the secondary of the jigger with the coherer attached) lies between or near to either of the LS values being received, a good jigger for distance can be made by suitably proportioning the primary winding and outside inductance;

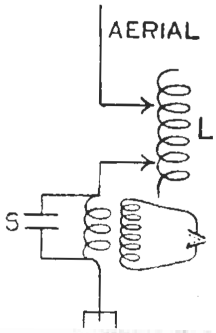
(2) The most critical jiggers (*i.e.*, those least interfered with by undesired waves) are those in which the C.P. value of the secondary is equal, or very nearly equal, to one of the LS values being sent. In this case the best arrangement of primary and outside inductance is to have very few turns on the primary, and the remaining inductance required for resonance placed outside the jigger, where it does *not* influence the secondary.

(3) The very best jigger for distance is believed to be that in which the C.P. of secondary is equal to the LS of primary of oscillator at distant end. Roughly, this C.P. is half way between the L.S. values of the two waves emitted by the distant oscillator.

(4) The difference in distance between the very best jigger (3) and a jigger made as in (2) is found to be very small—say 1 per cent.—and as (2) is far more suitable for freedom from interference, this is the pattern which we are

adopting for service. The one used in trials to "Good Hope" and "Drake (page 14) was of this class, and was made as follows:—

FIG. 23.



*Secondary.*

**400 turns 42 SWG D.S.C. and shellacked on a 2·25-inch cylinder.**

This has a C.P. value equal to the shorter of the two B tune waves.

*Primary.*

3½ turns of 30 SWG on 2-inch cylinder.

*Tuner L.*

This is adjusted practically. About 20 micro-henries are required.

*Capacity S.*

This was one jar in the actual trials. The "tuned shunts" which have since been invented are really more suitable.

This jigger, besides being practically as good for distance as anything we have tried, is far the best we have used for freedom from other tunes. The results on page 46 are with this jigger.

### CHOKING COILS IN MARCONI BOX.

The choking coils in the coherer circuit of the Marconi receiver box appear to be o no practical use. It is very difficult to so adjust the instruments that any difference at all can be detected between signals received with or without the chokers in the circuit.

For this reason the introduction of chokers to the Service box is not contemplated.

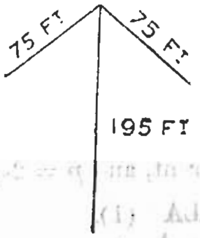
### COMBINED AUTUMN MANŒUVRES.

In anticipation of the combined Naval and Military Manœuvres, experiments for the purpose of establishing communication on the systems of Wireless Telegraphy employed by the Navy and Army were carried out in August 1904.

Satisfactory communication was established between "Vernon" and the military station at Aldershot.

The aerial used in the "Hector" is shown in Fig. 24.

FIG. 24.



**The jigger used in "Hector," found by trial, consisted of a primary of six turns of No. 25 S.W.G. wire on a 2¾-inch diameter, and a secondary of 300 turns of No. 42 S.W.G. on a 3-inch diameter.**

**Strong signals were obtained in "Hector" on a magnetic detector when a capacity of about 1·2 jars was placed n the aerial in series with the magnetic detector.**

By measurement the self-induction and capacity of the aerial in "Hector" were 65 mics. and ·53 jars respectively.

The LS of wave length sent by Aldershot was about 50.

Signals were transmitted by "Plain" at each end, with inductance at the base of the aerial so as to bring them into tune.

The "Good Hope," which was lying at Spithead, fitted up an aerial precisely similar to that in "Hector." The self-induction and capacity of the aerial was, by measurement, found to be the same as that of "Hector" aerial. The receiving gear was transferred from "Hector" to "Good Hope."

Two days were spent in "Good Hope" trying to establish communication with Aldershot, with no success.

The "Hector" was receiving the messages both from Aldershot and "Good Hope," and was in communication with both of them.

During the manœuvres "Good Hope" never established satisfactory communication with the military system at more than a few miles.

The only difference between "Good Hope" and "Hector" was that the former's aerial wire was almost surrounded by metal stays, the roof part of the aerial being quite close to the triatic stay, and it is supposed that the failure of the "Good Hope" must be entirely ascribed to the screening effect of these stays.

For details of apparatus used at Aldershot *see* page 25.

## TUNED SHUNTS.

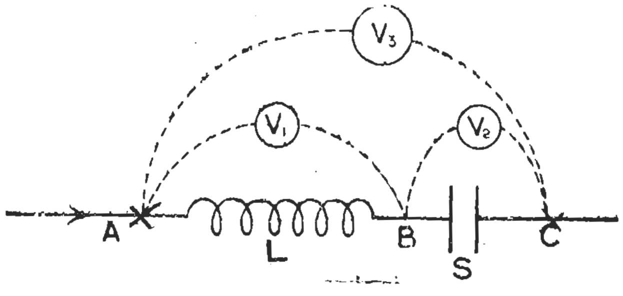
### *General Principles.*

It can be shown that two phenomena, well known in the theory of ordinary alternating currents, should to some extent be practically useful in Wireless Telegraphy.

They may be briefly explained as follows:—

I. If an alternating current is passed through this circuit ABC—

FIG. 25.



containing a self-inductance and a capacity, then the voltmeter $V_3$ will always show the *difference* between the readings of the voltmeters $V_1$ and $V_2$; and by making the values of $V_1$ and $V_2$ equal, $V_3$ will show *nothing;* that is there will be no D.P. between A and C.

*Mathematics.*

If A is the R.M.S. value of current, and $p = 2\pi$ times the frequency—

$$V_1 = pLA \quad (1).$$

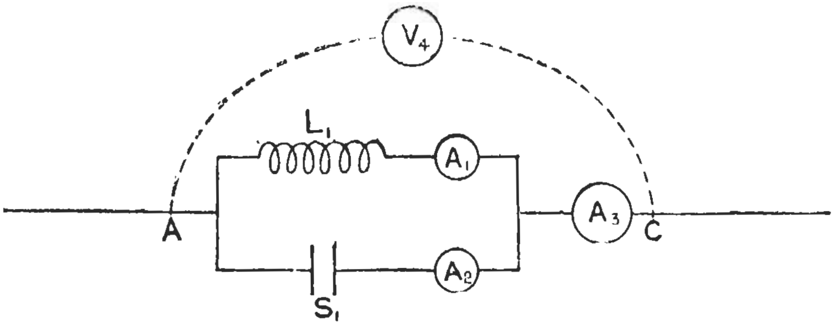
$$V_2 = -\frac{A}{pS} \quad (2).$$

$$V_3 = V_1 + V_2 = A\left(pL - \frac{1}{pS}\right) \quad (3).$$

$$= 0 \text{ when } pL = \frac{1}{pS} \quad (4).$$

II. If an alternating current is passed through this circuit AC,

FIG. 26.



the ammeter $A_3$ will show the *difference* between the readings of $A_1$ and $A_2$, consequently when $A_1 = A_2$, $A_3$ will be showing that no current is passing *through* the system, though large currents may perhaps be flowing *in* it.

*Mathematics.*

If $V_4$ is the DP across AC—

$$V_4 = pL_1 A_1 \quad (1a).$$

$$= -\frac{A_2}{pS_1} \quad (2a).$$

$$\text{or } A_3 = A_1 + A_2 = V_4\left(\frac{1}{pL_1} - pS_1\right) \quad (3a).$$

$$= 0 \text{ when } pS_1 = \frac{1}{pL_1} \quad (4a).$$

Now, suppose we have an alternator feeding some circuit, and that one of the wires be cut, and a circuit like ABC (of I. above) be introduced, then for a *particular frequency* [given by equation (4)] there will be no voltage across from A to C, and since there is no drop of voltage, no energy is consumed, and the current therefore remains what it originally was, in other words, the introduction of ABC into the circuit has effected no alteration to it. A circuit like this, consisting of a combination of an inductance and capacity in series, is termed an "acceptor" because for a *particular frequency* it does not hinder the flow of current, but "accepts" it.

Again, suppose instead of introducing the "acceptor" we had introduced a circuit (like II.) of an inductance and capacity in parallel, then for the right frequency no main current ($A_3$) will flow at all, hence there will be no drop of voltage in the alternator mains, but the whole voltage of the alternator will be across this circuit. This arrangement is termed a "rejector."

We have in the above examples neglected resistance.

The effect of resistance is that in the acceptor $V_3$ will never become actual zero, but it will be a minimum when $pL = \frac{1}{pS}$, and under this condition $V_3$ will be equal to the current × resistance, that is to the simple ohmic drop of voltage.

Similarly in the rejector the minimum value of $A_3$ will be $= V_4 \frac{RS}{L}$, that is, it will be proportional to the resistance, which it is therefore important to keep low.

Resistance does not matter when the circuits are out of tune, because the E.M.F.'s of inductance and capacity swamp the resistance E.M.F., but when the circuit has been "tuned," *i.e.*, when—

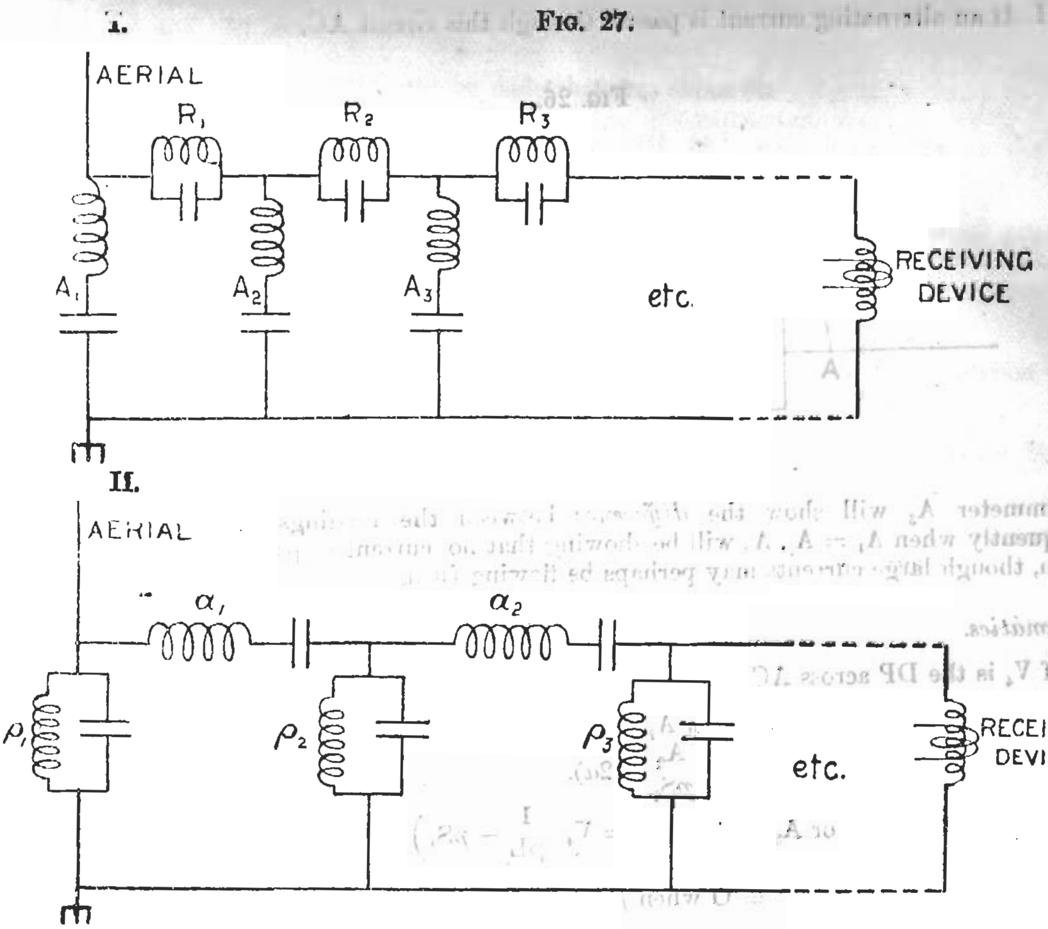
$$pL = \frac{1}{pS}$$

then the resistance is *the* factor operative in preventing $V_3$ or $A_3$ from becoming absolute zero.

Another thing which has been assumed is that the alternating current lasts through sufficient cycles (say ten) to enable a steady state to be reached. This of course is the case with an alternator, but is only partially true for a Wireless wave, becoming less and less true as the wave makes fewer and fewer swings.

Now to practically apply these circuits to Wireless, two general methods are possible:—

FIG. 27.



In I. we adjust $A_1$, $A_2$, &c. as acceptors
$R_1$, $R_2$, &c. as rejectors
to the *enemy's* wave; consequently the enemy's wave has a much smaller inclination to reach the receiver than has your friend's wave, because the shunts, &c., are tuned to cut the enemy's wave down.

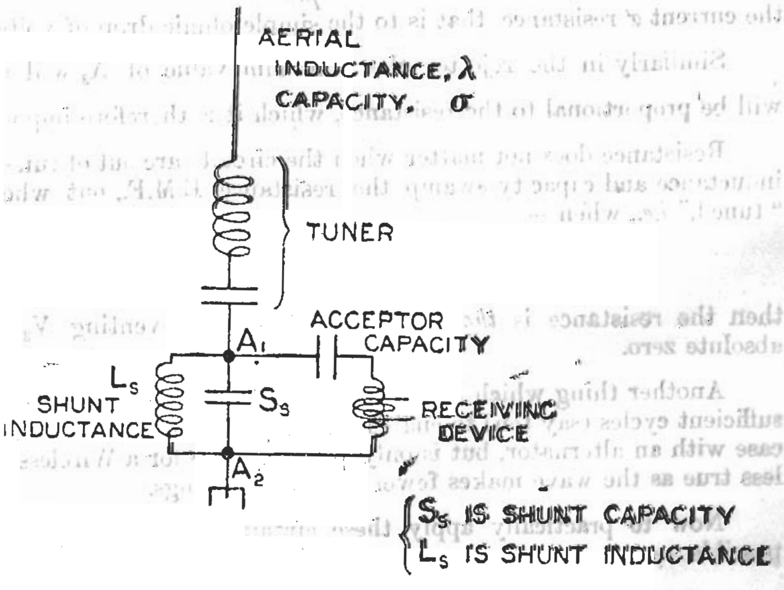
In II. we adjust everything to our friend's wave, which therefore loses but little sensitiveness, because the shunts, &c., are adjusted so as *not* to cut the friendly wave down; whilst the enemy's wave suffers much greater diminution, because the shunts are not so adjusted.

In all cases what is required, of course, is to make the ratio of the strength of friendly wave received as great as possible in comparison with the strength of enemy's wave; and it is quite possible that I. is superior to II. for this purpose; or possibly a combination of the two might be the best; but for practical use in war it is felt that II. is the only feasible form to adopt. When we are trying to cut out an enemy's wave we do not know what his wave length is, and it is impracticable to go fumbling with the shunts in I. at the last moment; also one of our worst "enemies" viz. — "atmospheric" consisting probably of many different wave lengths, cannot be adjusted to.

On the other hand, II. is a method of adjusting to one's friend wave; this can be well known, and the adjustments once properly made will remain, so that when practical signalling is to be carried out, nothing has to be touched.

For commercial purposes, and for blocking out of one of our own, but different, tunes, I. can be used. We have not yet gone in for this, however, and have confined our attention so far to the simplest case of II. viz. :—

FIG. 28.



which it is anticipated will be introduced throughout the Service in a practical form shortly.

**Now to adjust this circuit:—**

(1) The acceptor branch, consisting of the inductance of the receiver $L_A$ and the capacity $S_A$, must be adjusted so that minimum voltage is required for working a given current through.

Therefore $L_A \times S_A =$ LS of wave received.

(2) As the acceptor accepts the wave, the aerial must be in tune just as if the acceptor were not there; that is, as if the point $A_1$ were earthed. The "tuner" must be altered so as to bring this about, which occurs when—

$$(\lambda + L_T) \frac{1}{\frac{1}{\sigma} + \frac{1}{S_T}} = \text{LS of wave received.}$$

NOTE.—*Both* a capacity $S_T$ and an inductance $L_T$ are not required; either one or the other is sufficient. When the wave is longer than the fundamental ($\lambda\sigma$) of the aerial in use inductance is required and no capacity, so making $S_T = \infty$.

Our equation becomes

$$\text{LS received} = (\lambda + L_T) \frac{1}{\frac{1}{\sigma} + 0} = (\lambda + L_T)\,\sigma$$

whilst for short waves the capacity is required, and the inductance $L_T$ is made zero. (*See* also page 31, on examples of tuning aerials by simple resonance.)

(3) The rejector must be adjusted to reject the desired wave—that is:—

$$L_S \times S_S = \text{LS recd.}$$

*Practical Example.*

Continuing first example given on page 31, receiving wave from Poldhu.

First, the inductance required in aerial being $\frac{950}{1{\cdot}18} = 805$ mic., we do not now have to subtract the inductance of the magnetic detector, because the acceptor capacity has wiped this out, and practically the earth is now at $A_1$, hence—

$$\begin{aligned} L_T &= 805 - \lambda \\ &= 805 - 85 \\ &= 720 \text{ mic.} \end{aligned}$$

Next, to find the acceptor capacity we have—

$$\text{Acceptor capacity} = \frac{950}{\text{inductance M.D.}} = \frac{950}{80} = 11{\cdot}9 \text{ jars,}$$

and the rejector has similarly to be adjusted so that

$$L_S \times S_S = 950;$$

And if $S_S$ is big, say, 1,000 jars (and, therefore, $L_S$ small), the tuning will be critical, the enemy's wave or atmospheric much reduced, and the friendly wave weakened; whilst if $S_S$ is not very big, say, 100 jars, the friendly wave will not be perceptibly weakened, whilst the enemy may perhaps be sufficiently cut out.

NOTE.—Practical directions for these shunts cannot be issued until the instruments are manufactured in their practical form; but if it is desired to try these methods at once, the following must be attended to or failure will *inevitably* result:—

(1) The circuit must be joined up *exactly* as shown; particularly, all the circuits *must* come to the points $A_1$ and $A_2$, which are intended to represent the terminals of the shunt capacity $S_S$, and no earth connection can be allowed on the receiver, but only at the point $A_2$ as shown.

(2) The capacities must have as little "hysteresis" losses as possible (*see* page 56), and the resistance of everything must be cut down so as not to get resistance losses. For the acceptor capacity the tune B jars are useful; whilst for the shunt capacity mica is much best, but the paper used in Newton's coil condensers is not bad.

(3) There must be minimum self-induction between $A_1$ and $A_2$ through the shunt condenser. In the Marconi long-distance receiving condensers there is considerable self-induction between the terminals $A_1$ and $A_2$ and the actual plates of the condenser. This seriously reduces the efficiency; whilst if, in order to try the effect of a shunt condenser "practically," we take two ordinary leads from the terminals of same condenser and apply the condenser in this manner as a shunt, the chances are that *signals will entirely stop.*

*Results obtained*:—

Provided the proper arrangements are adopted, there is no doubt these shunts make a great difference in the possibilities of tuning. So far only crude and imperfect apparatus has been used, but the following results have been obtained:—

(1) Receiving a long wave from "Boscawen" at Portland. Interference from B tune—

*Without Shunts.*—Culver (14 miles distant) interferes with 3 mm. on B tune.

*With Shunts.*—Culver is shut off, and 3 mm. B tune from *one* mile continues to be entirely shut off. Remove the shunts and the interference comes in; re-insert the shunts and the interference *absolutely* stops.

(2) Receiving B tune from "Boscawen" (3·5 mm.). Interference from A tune at Horsea Island (about one mile distance)—

*Without Shunts.*—The *minutest* A tune sparks hopelessly fog the tape.

*With Shunts.*—The tape continues to receive clear signals until the A tune spark exceeds 6 mm. (after which interference commences).

These results show that the shunts successfully tend to shut out wave lengths longer or shorter than the wave length adjusted to, and it would appear that they made the circuits from 10 to 20 times freer from interference.

That is, if an enemy could with the present Service gear interfere at, say, 20 miles, then when our shunts had been inserted he would *not* interfere until he came within 1 to 2 miles distance.

This assumes the enemy is using some moderately persistent wave like A or B tunes, and it is believed most foreign nations now use such waves.

If, instead, a sharp blow, like ordinary plain aerial is used, the shunts are not quite so useful. Some rough experiments indicate the improvement is then only, say, 5 to 10 times, that is, that the enemy in above example would commence to interfere at from 2 to 4 miles distance.

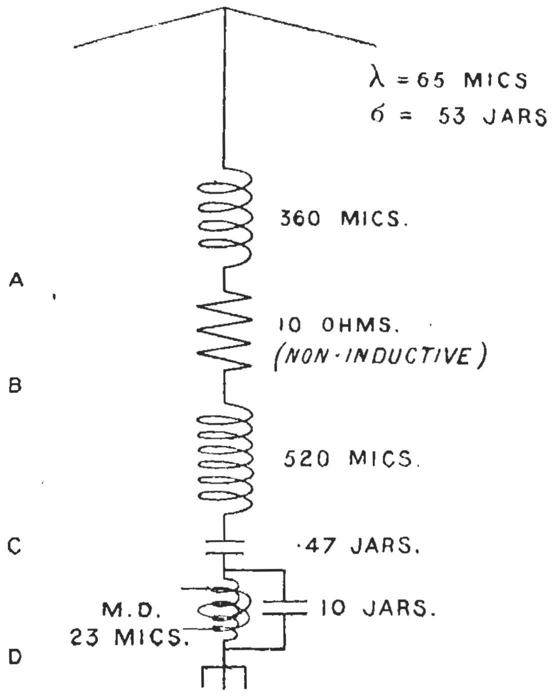
Lastly, if the enemy is using a wave length very near to our own, then of course he will interfere to very nearly the maximum distance. The shunts will then be of very little use, and the only chance of getting signals through will be by experiments such as are now used in manœuvres, &c. between our own ships all fitted with the same tunes.

The following figs. show a few of the results obtained when receiving a long wave from Portland.

The wave from Portland had an LS value of 240 of our units.

The receiving aerial in "Hector" was shown in Fig. 28.

FIG. 29.



The above combination gave the strongest signals when using an "acceptor'

Wave being received = 240:—

(1) Resonance down to A—
(65 + 360) ·53 = 226.

(2) Resistance between A and B, 10 ohms—
No difference.

(3) Acceptor between B and C—
520 × ·47 = 244.

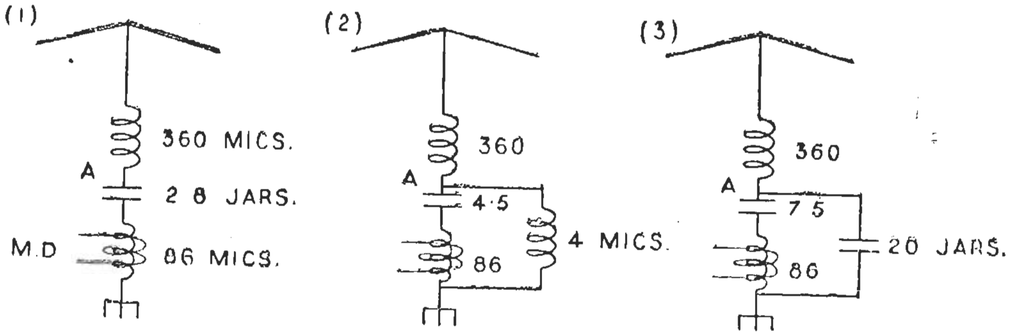
(4) Rejector between C and D—
23 × 10 = 230.

The following figs. show some results obtained leading up to the "tuned shunts" in the final fig.

The object of this set of experiments was to find the best self-induction and capacity to use in the aerial so as to get the shunt capacity as large as possible and the shunt self-induction as small as possible without losing the signals; the system would then be in its best arrangement for cutting out waves longer or shorter than the one being received.

The receiving aerial is the same as before, and the LS value being received was again 240.

FIG. 30.



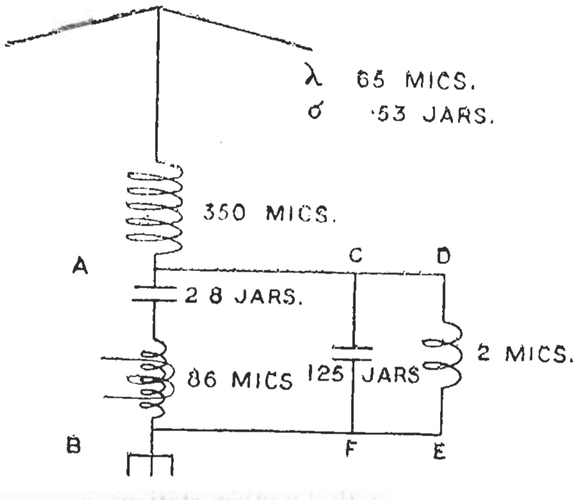
In each fig. the aerial was in resonance down to A.

Fig. (1).—Acceptor introduced—

2·8 × 86 = 244 units.

Figs. (2) and (3).—Show the alteration that was made in the acceptor capacity so as to still read signals; with fig. (2), the shunt self-induction as small as possible; and fig. (3), the shunt capacity as large as possible.

FIG. 31.



The above fig. shows the result that was eventually arrived at, clear signals being received from Portland with the shunt capacity as high as 125 jars, and the shunt self-induction as low as 2 mics.

"Horsea," a mile away, signalling with best spark on "B" or "Plain" on 180-feet aerial was completely blocked out.

All leads to and in the "tuned shunts" circuit must be as short as possible.

**Above circuit :—**

(1) **Resonance down to A—**

(65 + 350) ·53 = **220 units.**

(2) Acceptor from A to B—

2·8 × 86 = 240.

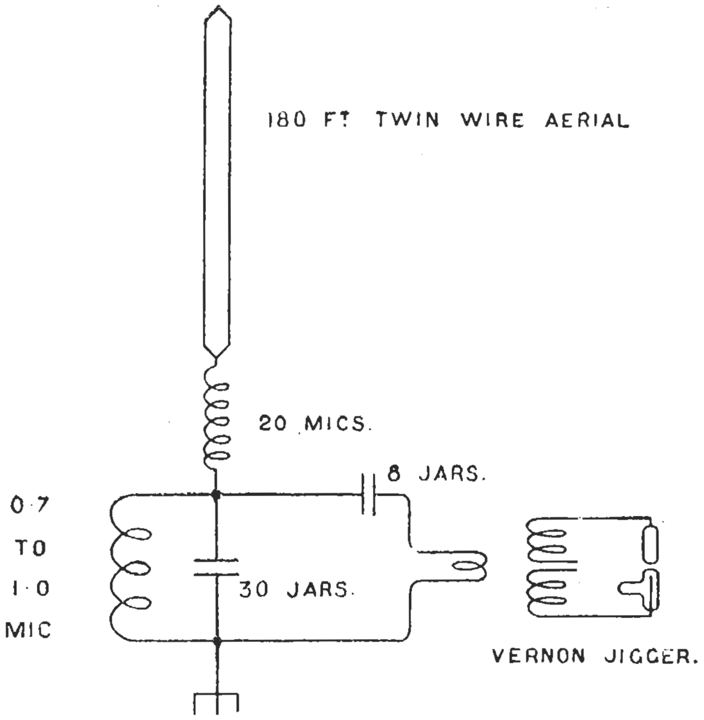
(3) Shunt CDEF, rejector—

125 × 2 = 250.

Wave being received about 240.

The following fig. shows the arrangement used with "B" tune, receiving on the coherer :—

Fig. 32.



It is almost as sensitive as the ordinary arrangement for receiving "B" tune, giving good signals from Portland, 55 miles distant, with the coherer turned up horizontal, a 3·5-mm. spark being used. At the same time tune "A" from Horsea Island, one mile away, did not cause much interference when a 6-mm. spark was used, and none if the spark was less than 4 mm.

If an ordinary "B" tune jigger is used in place of the "Vernon" jigger, the acceptor capacity of 8 jars must be short-circuited, but the results when obtained are not as good.

## Methods of Measuring Wave Lengths.

### (a.) *From Distant Ship.*

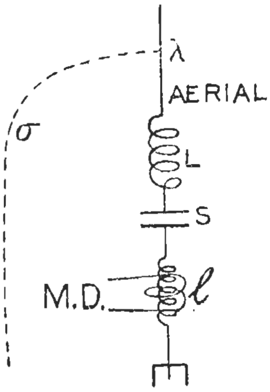
Several methods have been successfully used, and the best one to employ in any particular case will depend on the time and gear available and the accuracy desired. There are two principal methods, the first using a coherer and inker, the second using a magnetic detector.

When using a coherer there are many practical difficulties, and considerable time is necessary. It is impossible to measure the wave length of signals that are not fairly continuous, or that are interfered with by other stations using wave lengths differing from that to be measured by less than about 50 per cent. Under the most favourable conditions the experiment is a difficult one to carry out.

With the magnetic detector most of the difficulties and limitations disappear. If the induction of the primary winding on the magnetic detector is known, and the capacity and induction of the aerial have been measured beforehand (*see* p. 50), a strange wave can be measured by the following method, with but little gear and in a few minutes :—

First method, using simple resonance. (*See* Fig. 33.)

FIG. 33.



To use this method it is necessary to know, $l$ the induction of the magnetic detector, $\lambda$ the induction of the aerial, and $\sigma$ the capacity of the aerial, and to have an adjustable capacity S or an adjustable induction L; if neither of these are available a drum wound with bare wire could be used as a variable induction, the number of turns being varied and its induction calculated. (*See* page 34.)

After connecting up, L or S is adjusted until the signals to be examined are of maximum strength in the telephones attached to the detector, showing that the system is in resonance with the wave being received.

The induction of the system is—

$$(\lambda + L + l)$$

and the capacity—

$$\frac{\sigma S}{\sigma + S}$$

therefore the "LS value" is—

$$(\lambda + L + l) \frac{\sigma S}{\sigma + S}.$$

Having the LS value, the wave length can be deduced (*see* page 31), and is—

$$206 \sqrt{(\lambda + L + l) \frac{\sigma S}{\sigma + S}} \text{ feet.}$$

The induction being in micro-henries and capacity in k.cm.

We see from this expression that if either L or S is decreased the L S value of the receiving circuit is decreased; but that whilst it may be decreased indefinitely by the reduction of S (becoming zero when S is zero) it can only be reduced to—

$$(\lambda + l) \frac{\sigma S}{\sigma + S},$$

when L is zero.

Suppose, then, in a practical case we find that by reducing L, signals increase in strength; becoming strongest with L = zero; it is evident our tune is still too long; reduce S therefore by putting in another capacity in series with the aerial; and *continue* reducing capacity until resonance is obtainable on L.

Similarly, if L is becoming inconveniently large, the tune may be increased by increasing S up to its largest value, viz., ∞ (*i.e.*, remove S out of the circuit altogether), in which case the formula becomes—

$$(\lambda + L + l)\,\sigma$$

and now the remainder of the tuning *must* be done by increasing L until resonance has been obtained.

This, being a maximum sound method, can be used when stations other than the one of which the wave length is required are working, even if the signals are weak.

In this and any other method, when signals are strong, the sharpness of the tuning is much increased by putting an induction, the smaller the better, in parallel with the primary winding of the magnetic detector, but this will make the signals weaker, and if the induction is very small, less than 5 micro-henries, very much weaker.

If $l^1$ is the induction put in parallel with the detector and $l$ that of the detector, the resulting induction will be—

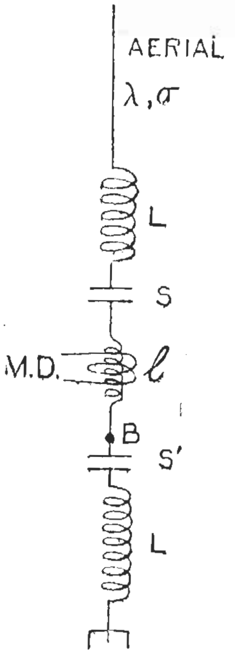
$$\frac{l\, l^1}{l + l^1},$$

and this must be put in place of $l$ in the formula for the LS value.

In the newer detectors now being supplied $l$ is about 80 or 90 micro-henries, and if $l^1$ is taken at 10, tuning will be sharp, and an error in the value of $l$ will make practically no difference to the final L S value. This method of simple resonance is very useful, but it requires an accurate knowledge of $\sigma$, $\lambda$, and $l$.

*The Acceptor Method.*—This method is an extension of the above, has all its advantages, and does not require $\sigma$ $\lambda$ or $l$ to be known; in addition, it is more accurate, but takes a little longer to carry out, and requires more apparatus (*see* Fig. 34).

FIG. 34.



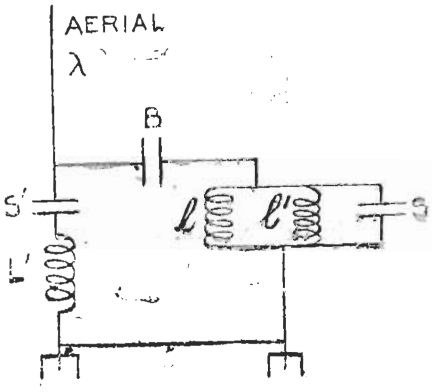
The system is first earthed at B, and resonance obtained by varying L or S as in simple resonance. B is then disconnected from earth and $S^1$ and $L^1$ introduced as in Fig. 34. Either $L^1$ or $S^1$ must be adjustable, and be adjusted to give maximum sound in the detector telephones, showing that the system is again in resonance with the wave being received; while this second adjustment is being made nothing above the point B must be altered. The whole system is now in resonance, and it is in resonance when it is earthed at B, so that $L^1$ $S^1$ must form an acceptor (*see* page 40). Hence the L S value of the wave is $L^1 S^1$ and ∴ its wave length $206 \sqrt{L^1 S^1}$ feet. To use this method successfully the value of $S^1$ should be as small, and that of $L^1$ as great, as possible; in any case $L^1$ should be as great as $(\lambda + L + l)$, otherwise a small error in the tuning up for simple resonance may make a large error in the final result, the smaller the value of $S^1$ and the larger that of $L^1$, the sharper will be the tuning and the more accurate the result. At the same time the signals will be weaker, and in extreme cases the tuning will be so sharp that the resonance point may be missed. If great accuracy is required it is a good thing to try several acceptors, each one with a smaller capacity than the last, until with the last one signals are only just audible.

When using this method care must be taken that at each adjustment the system is tuned up to the same wave, not to a different harmonic. Thus with tune "B" clearly results will be worthless if, when the first adjustment of simple resonance is made, the system is tuned up to the 31 L S of the tune (*i.e.*, the 1,150-ft. harmonic), and afterwards, when the acceptor is inserted, the system is tuned to the 58 L S (*i.e.*, the 1,570-ft. harmonic). This can be safe-guarded against by working out the wave length from the simple resonance result, (if $\lambda$ $\sigma$ and $l$ are not known, approximate values must be taken), and seeing that it is approximately the same as that given by the acceptor.

The above methods are unsuitable for measuring waves less than four times the length of the aerial, but are very convenient for waves longer than this. The best method of measuring a short wave is to use one of the above methods with a short aerial, thus an aerial of 70 or 80 feet would be suitable for examining tune "A."

The following electro-static method may be useful (*see* Fig. 35).

FIG. 35.



The magnetic detector $l$ is shunted with an induction $l^1$ and the variable capacity S placed across. B is a billi condenser as used in tune "A." $L^1$ and $S^1$ are not necessary, but when used and adjusted will increase the strength of signals. S is adjusted for maximum sound, B being pulled out as far as possible; pulling out B will weaken the signals.

When in resonance the L S value of the wave is—

$$\frac{l\,l^1}{l + l^1}(S + B).$$

The capacity B of the billi condenser is proportional to the length of the active paraffin paper and has a maximum of about 0·1 jars when the sliding part of the billi condenser is pushed home.

The wires connecting $l$, $l^1$ and S must be very short. This method requires strong signals for good results, and is only reliable when B can be pulled out nearly the whole way.

### *Tuned Shunts Method.*

This is a reliable and accurate method provided certain precautions are taken (*see* page 43). It consists of taking the L S values of different parts of the circuit used in the tuned shunt method of receiving (*see* pages 40 to 46).

In Fig. 28, when the circuit has been adjusted, the L S value of the wave received will be—

$$= (\lambda + L_T)\,\frac{\sigma\,S_T}{\sigma + S_T} = L_S\,S_S = L_A\,S_A.$$

These three values should agree and act as a check on one another; *if they do not agree, the result is unreliable.* The first contains the (possibly) unknown $\lambda$ and $\sigma$ of the aerial. The second must be corrected carefully for the induction of connecting wires, and the third will give accurate values if the magnetic detector is shunted as described above.

The above methods give the best and most consistent results. Several other methods have been tried, and it is found that minimum sound methods, that is, methods in which strong signals are choked down to give minimum sound by adjusting apparatus, are very unreliable, especially for tuned waves consisting of two or more component waves.

### (b) *In own Ship.*

Intimately connected with the measurement of a wave length from a distance is the measurement of the wave length that is being transmitted by one's own ship, and the capacity and induction of the aerial that is being used.

A good way of measuring the wave length of the wave transmitted by a station is that making use of the potential difference between two points on the earth wire to influence a tuned circuit. (*See* Fig. 36.)

FIG. 36.

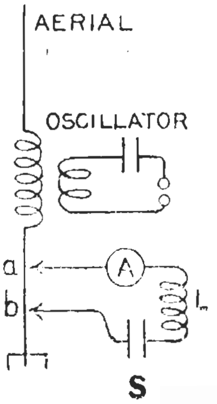
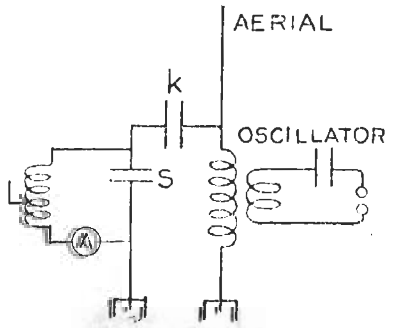


FIG. 37.



The tuned circuit consists of the induction L, the capacity S, one of which must be variable, and an ammeter A (the hot wire voltmeter supplied for tuning up "B" tune is a suitable instrument).

A good steady spark is essential; and it is found well to use an Isenthal interrupter with a steadying resistance of a few ohms in series with the coil primary.

The key is pressed and L or S varied until A gives a maximum reading, showing that the tuned circuit is in resonance with the transmitted wave, the L S value is then (L + $x$) S from which the wave length can be found. Where $x$ is the induction of the wires used as connections, if they are as short as possible, and L and S compact, $x$ will be probably about 1·0 to 1·5 micro-henries.

The points $a$ and $b$ would be about 2 or 3 inches apart, this would give fairly sharp tuning, but probably only a small reading on the ammeter. If this reading is too small to work with, it can be made much greater by cutting the earth wire between $a$ and $b$ and inserting a small coil of wire in series with the aerial and in parallel with the tuned circuit. This coil might be two turns of pattern 611 of 3 inches diameter. Its introduction would be equivalent to adding 2 or 3 feet to the length of the aerial, taking away from the accuracy of the result. The correction $x$ would have to be increased to 2 or 2·5 micro-henries.

Instead of using the variation of potential on the earth wire due to the current flowing along it, it is sometimes better, with tune "A" for instance, to make use of the potential difference between the foot of the aerial and earth. (*See* Fig. 37.)

The tuned circuit is here influenced through a very small capacity $k$, consisting of two metal plates, say 4 inches square, separated by half an inch air space, one plate being connected to the foot of the aerial, and the other to one side of the condenser S. The other side of S is earthed, as in the figure. The tuned circuit is then adjusted until A shows a maximum reading, and the L S value arrived at as before.

Another method is to influence a coil of fine wire (a jigger secondary) with a small capacity attached, and adjusted to give a maximum spark between one end of the coil and a small insulated rod, as when tuning up "A" tune.