ADMIRALTY INSTRUCTIONS FOR THE USE OF "A" AND "B" TUNES APPARATUS.—TO SUPPLEMENT THE MARCONI COMPANY INSTRUCTIONS.

Tune "A."

The aerial used is to be *exactly* 180 feet long, measured from the transmitting jigger. Should the gaff not be high enough, the aerial is to be led up to the top of the gaff in the ordinary way (*i.e.*, as vertically as possible consistent with clearness from earthed bodies), and the remainder of the 180 feet of length is to be triced out, like a stay, towards the foremast, or, if this is inconvenient. towards the stern.

It is suggested that the aerial should be double, and of 12 feet spread between the parts. This is principally with a view to getting the longest distances possible, but is by no means essential for the tuning, as a single aerial (provided it be exactly 180 feet long) will suffice.

The Service pattern of aerial wire (or pattern 600) will do as well as the bare wire recommended.

The Company in their Instructions state the aerial may be from 120 to 180 feet long for Tune "A."

This means that between those lengths the antinode of potential with the transmitting jigger supplied will be near enough (after tuning has been effected) to the bottom of the aerial for the sliding receiving condenser to be practically useful in preventing jambing, when placed in usual position in office, viz., in piece of wire leading from aerial to receiver, and inside the latter.

It does not mean that one ship may have an aerial 120 feet long and another ship an aerial 180 feet long.

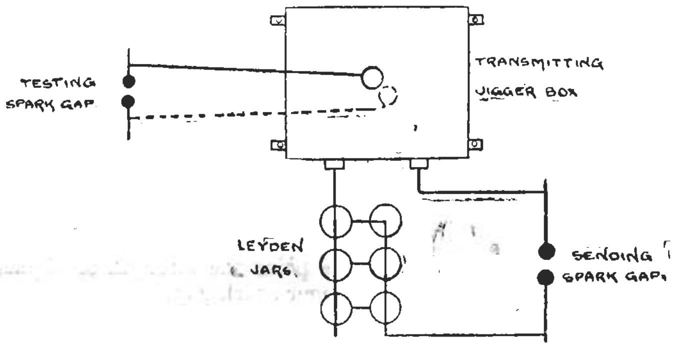
All ships corresponding must have exactly the same lengths of aerial. For the present all ships are to have aerials 180 feet long.

Should it be desired to have another length in addition, then all that is necessary is to fix a length between the limits given (120 and 180 feet) for all ships to have, and to retune the primary circuit to this length. This is a matter for senior officer on station to decide.

There would therefore be no objection to ships tuning up "A" Tune on both 120 and 180 aerials; indeed, it is recommended that both be tried. 180 feet is the best for distance, and it is to be the standard, as it is adopted by the Company, but 120 feet is the best for freedom from jambing.

Fig. 4.

To tune up "A" Tune.



Screw the transmitting jigger ("oscillator") up to the bulkhead, having previously secured a wire to the terminal at back of box (shown dotted), Fig 4. This is the earth terminal, and the terminal in front of box is the aerial terminal. Join up any convenient spark gap (such as that of the spare coil) to the earth and aerial terminals. Place sending spark balls at 1 cm. apart, and pressing the key you ought to get a clear 5 cm.'s spark at the testing spark gap. If you do not get this spark, it shows that the insulation of the secondary of the transmitting jigger is faulty. Supposing this correct, connect the aerial wire to the aerial terminal, and an earth wire to the earth terminal, leaving your testing spark gap and transmitting spark gap connected up as before. Now press the key, and alter the distance between the balls of the testing spark gap until sparks (not brush discharges) occasionally pass and occasionally fail. Then note the distance apart of balls of your testing spark gap. Now alter the length of your primary circuit leads, and again measure the spark obtainable. Continue this process of altering primary circuit leads until you obtain the longest spark possible on the testing spark gap. You have now tuned the transmitting circuit.

Notes on Tuning the Transmitter.

(1.)—If you find the primary circuit leads have to be shortened up as much as possible, and still you have not obtained the maximum, you must reduce capacity by taking off jars.

(2.)—In the "Instructions" it is stated that the aerial and earth are to be disconnected for this experiment. This is wrong; it should be as stated above.

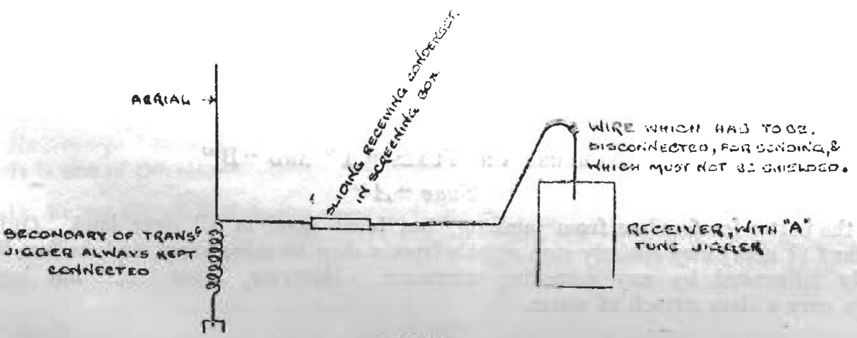
(3.)—Be very careful not to alter the adjustments of sending coil or sending spark gap during the experiments.

(4.)—Plot results on squared paper.
It gives you a clearer maximum, prevents you making mistakes, and saves time.

(5.)—For all leads, use thick wire.

Fig. 5.

To Receive on Tune "A."



Connect up as shown in Fig. 5.

Now make your final adjustments by getting a ship similarly rigged for receiving and slightly altering the primary leads until the receiving ship gets strongest signals.

The ways of altering the strength of signals are by altering sending spark, the receiving sliding condenser, and, of course, the distance between the ships.

Position of Sliding Condenser.

The sliding condenser ought to be placed at an antinode of potential. If it is so placed, then the capacity can be greatly decreased without affecting the signals received from a transmitter of correct tune, and the smaller the capacity the more is any wrong tune (which does not give the antinode at this point) "blocked out."

Now, when you "tune" your transmitting jigger up, what you really do is to discover the the best self-induction and capacity in primary circuit to get the antinode of potential (as measured by the testing spark gap) at the aerial wire terminal of the transmitting jigger.

Also when you are sending with the antinode at this point, the "wave" hitting a similar tuned aerial will re-develop an antinode at the same point in receiver.

At or near the aerial wire terminal of transmitting jigger is therefore the correct place for the receiving sliding condenser.

Here, however, it is apt to be punctured by the sending spark, consequently it is to be placed INSIDE the receiving box, and not outside as shown in figure above, and the shorter the lead from aerial to box the better.

NOTE.—The lead-cased wire to receiver must be removed and some unshielded wire substituted. Apparatus for doing this conveniently will shortly be issued, meanwhile ships must improvise their own arrangements.

The Spark for Tune "A."

The "Company" states that, as a rule, ships 30 miles apart should get good signals with 3 mms. spark at sender, and sliding condenser at receiver nearly drawn out of tube. The sending spark should never exceed 14 mms., as beyond this point the strength of signals *diminish*. This is due to the extra resistance introduced by the longer spark gap.

TUNE "B."

The aerial is exactly the same as for Tune "A."

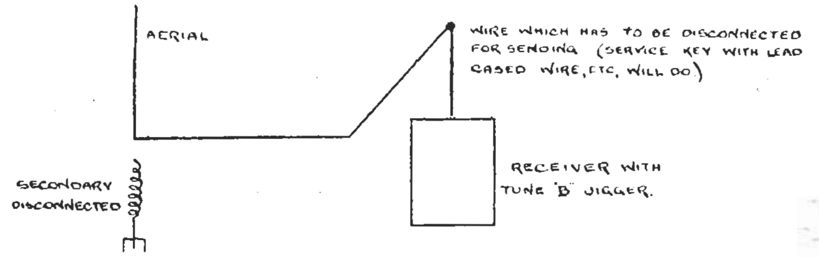
The transmitting jigger is rigged up in the same way as for Tune "A," but a straight filament incandescent lamp, hot wire voltmeter, or thermal junction is placed in series with the aerial (between aerial and aerial terminal on transmitting jigger), and capacity or self-induction of primary circuit altered till a maximum current is obtained.

The capacity or self-induction should now usually be slightly increased, as you want the node of potential or, in other words, the antinode of current *in* the jigger, whereas you measure it from the outside.

The final adjustments should be made as for Tune "A" (*i.e.*, from distant ship).

FIG. 6.

To receive Tune "B."



Connect up as shown in Fig. 6.

In this case (Tune "B") the lead-cased wire to box does no harm.

Spark for Tune "B."

The spark can be increased up to 2 or 3 cms., with advantage in distance, but our coils will not give as much as even 1 cm.

REMARKS ON TUNES "A" AND "B."

Tune "A"

Is much the better for freedom from jambing, but is no good at all over land. Quite a small strip of land ($\frac{1}{2}$ mile) may entirely stop signals from a ship 10 miles away, and, in fact, Tune "A" is greatly influenced by any screening whatever. However, Tune "A" has been worked 200 miles over a clear stretch of water.

Tune "B"

Gets jammed easily, but goes greater distances than "A," and is little affected by land or screening.

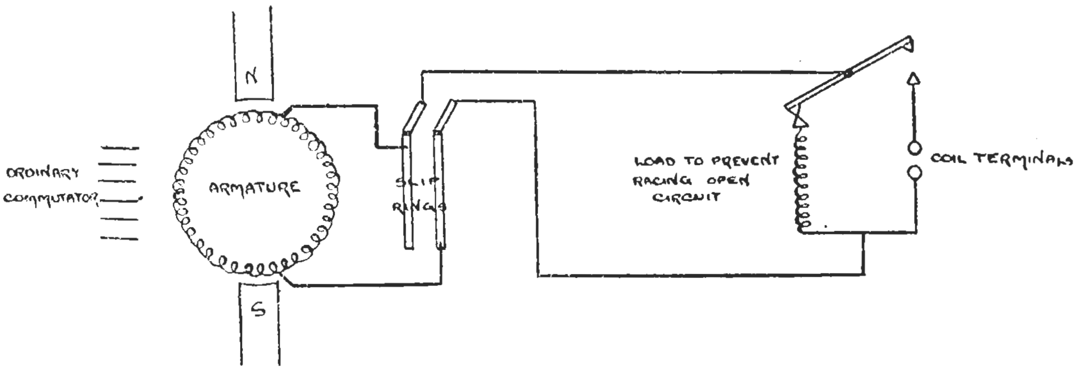
To increase spark on Tune "B," the Company join up two or more coils, both primaries and secondaries in series.

They add 16 volts additional per extra coil added, and increase capacity at the break proportionally to the number of coils used.

They also work their coils off the light mains, adding a series resistance of about 5 ohms in primary circuit.

They also state that coils can be very satisfactorily worked off alternating current provided by fitting slip rings to any motor available.

FIG. 7.



The *speed* of the motor must be regulated so as to give the maximum spark possible with the condensers actually in use. For Tune "B" disposition about 2,000 r.p.m. are required for a 2-pole motor, the frequency of motor and frequency of secondary of coil and condenser being then in resonance.

The "Good Hope" is trying this arrangement on a fan motor.

An 80-volt motor will do, but the Company prefer 150 volts.

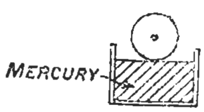
The coils can be worked up to 1 K.W. without damage.

Additional details will be given when further experience has been gained; and ships are to give full particulars (in the reports called for) of any particular difficulties experienced.

INSTRUMENTS UNDER TRIAL.

Lodge, Muirhead & Co. Automatic sender, p. 120.

Coherer.



A steel wheel ($\frac{1}{4}$ inch diameter) is kept revolving, and barely touching some mercury, contact with it is prevented by a film of oil on the wheel.

The electrostatical strains of the received P.D. break down the insulation of this film, which re-establishes itself on their cessation.

A potentimeter is used to reduce the voltage, working voltage usually ·2 volt.

Results.—At times have been excellent, getting beautifully clear signals from Portland: but so far the coherer sometimes fails entirely in an unaccountable manner.

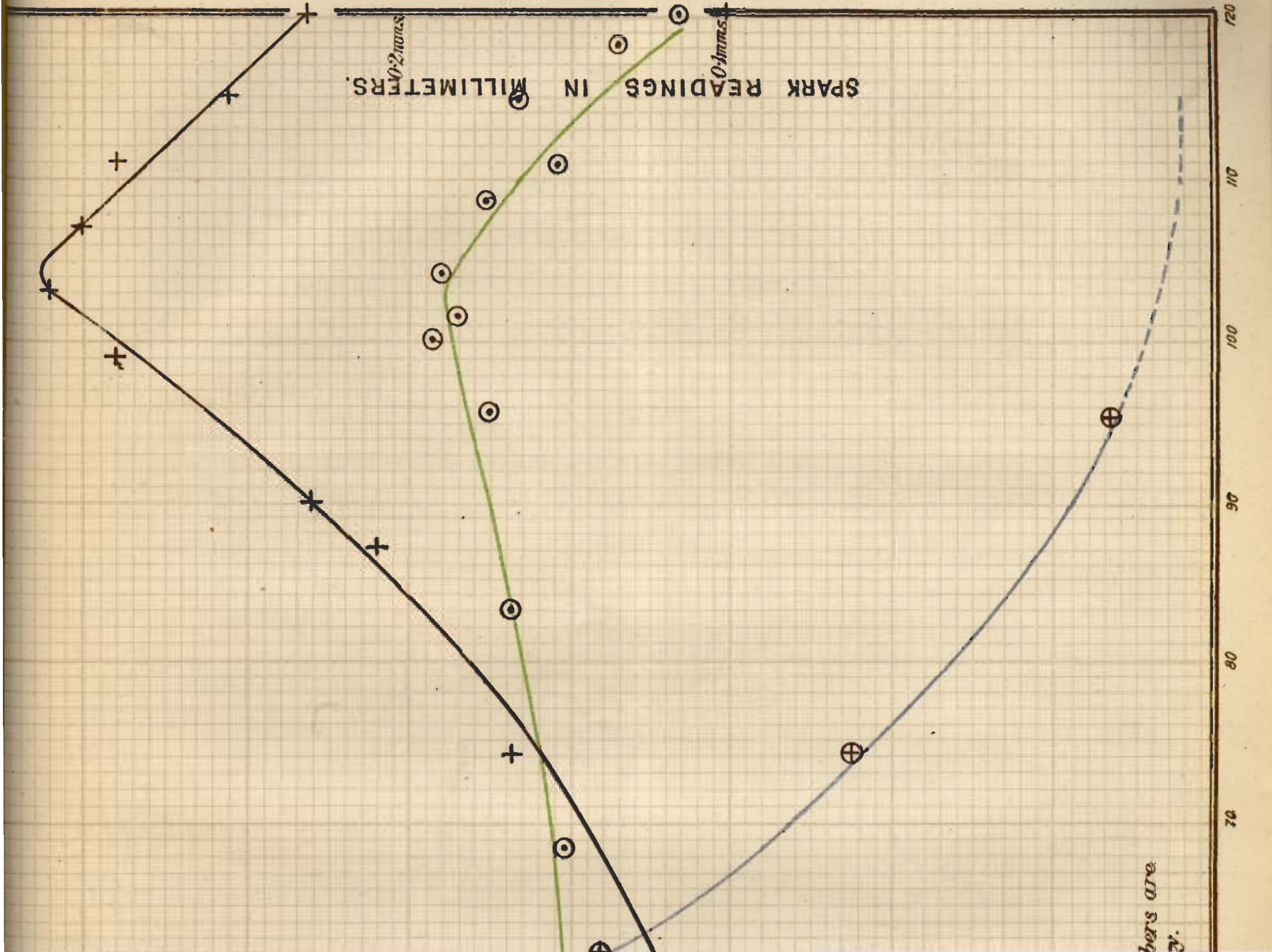
It has been suggested that the siphon-recorder they habitually use in conjunction with this coherer is much more suitable, and Messrs. Muirhead are going to try one here.

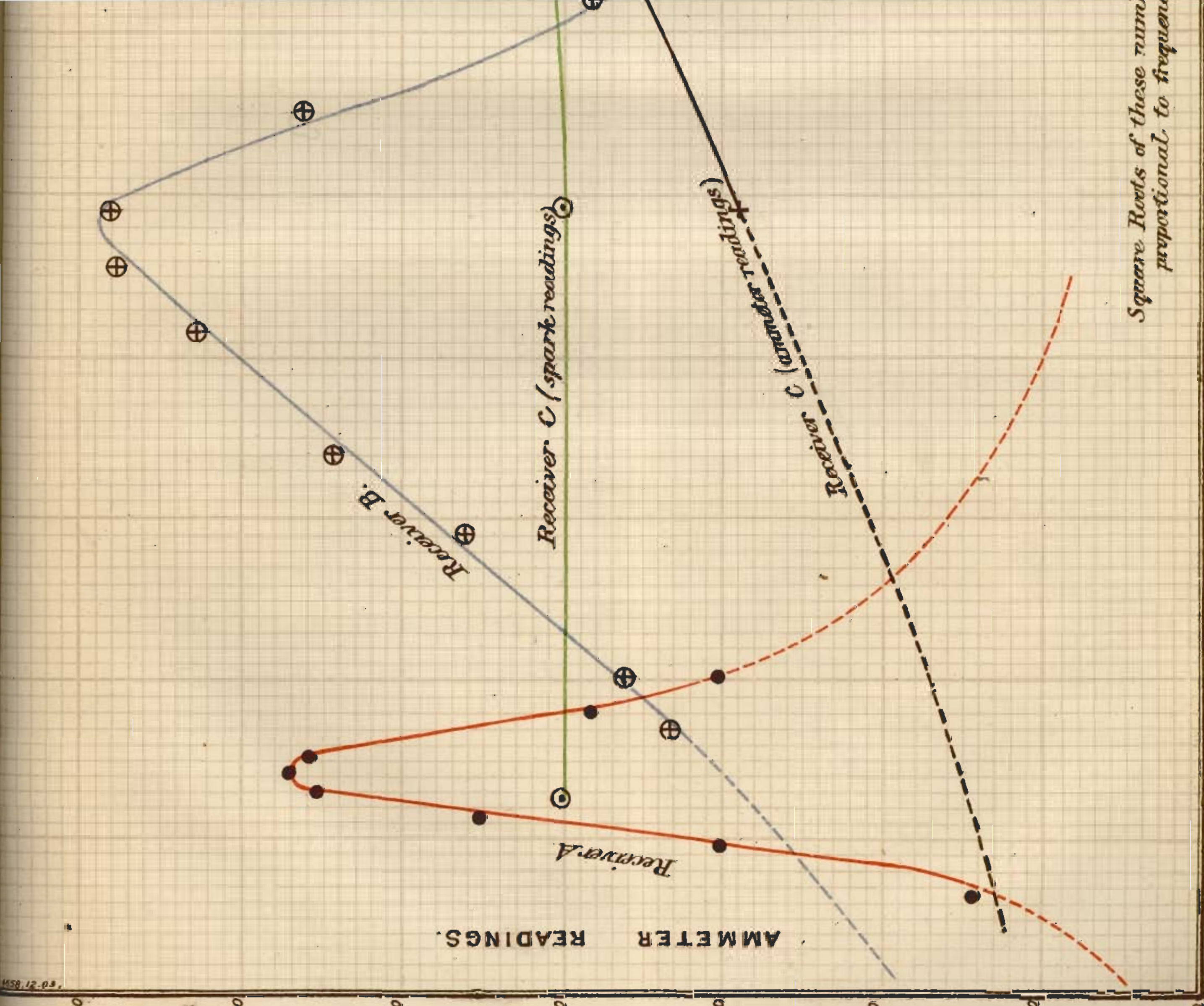
They cannot be introduced into the Service in their present form.

Localizing Apparatus designed by the firm is not yet ready for trial.

A "Radioscope" invented by Colonel Hozier and Mr. S. G. Brown has been tried with poor results. It is one of the electrolytic-no-tapper forms.

The De Forest Co. of U.S.A. use some such device.

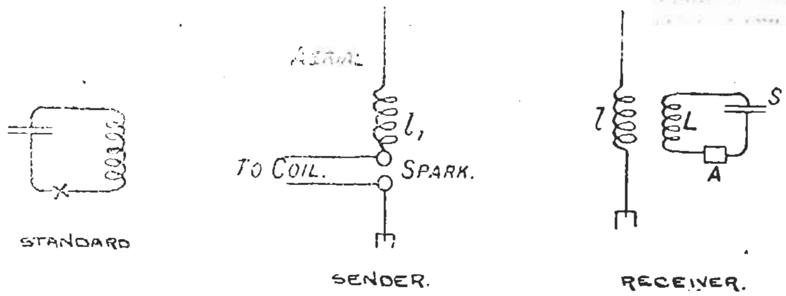

SPARK READINGS IN MILLIMETERS.
0·2mms.
0·1mms.
120
110
100
90
80
70



To face page 104.

TUNING.

The curves shown in Plate III. are a sample of the way the subject has been attacked. They are obtained as follows :—



A sending aerial is arranged one side of the deck and its frequency is altered by varying the turns l_1.

A standard circuit placed near it (but far enough away not to have enough mutual induction with l_1 to affect the period, *see* theory) determines the frequency. The receiving aerial is placed the other side of the deck and has an ammeter at A, whose deflections are observed. The receiving aerial is first tuned (by altering the turns l and L) until the ammeter shows a maximum for some given frequency, and then the sending frequency is altered and the new ammeter readings taken :—

——	l.	L.	S.	Adjusted to a frequency of
Receiver A -	2 turns	6 turns	cm. 2,300	1·39 10^6
„ B -	5 „	15 „	2,300	·70 10^6
„ C -	7 „	30 „	2,300	·48 10^6

The abscissæ of the curves are the values of the "L S" (each in "centimetres") of the standard, and are therefore proportional to the square of the frequency.

Curve A has a max. for an abscissæ of 12 10^6
„ B „ „ „ 48 10^6
„ C (ammeter) „ „ 104 10^6
„ C (spark) „ „ 104 10^6

} And these agree very closely with the frequency originally adjusted to.

Curve C was done twice. In the second case the value of the spark at the condenser terminals was measured by a micrometer.

It will be seen that with :—

Frequency.	A receives	B receives	C receives on ammeter	C receives on spark
1·39	58	30	15	·15 mm.
·7	5 (say)	68	27	·15 „
·48	Practically zero	4	72	·11 „

CONCLUSIONS.

Tuning is thoroughly efficient for mean-value recorders such as the ammeter used.

Tuning is very inefficient for maximum-value recorders such as the spark-gap used.

The theory of this, of course, is that a mean-value recorder takes into account the mean value of the whole train of waves, and it is only after the first few oscillations have taken place that the receiver feels the good effects of being in tune; whereas the maximum value of the initial oscillation, *which is always necessarily the biggest*, is nearly as big whether the receiver is in or out of tune.

Now, unfortunately, it is certain that a coherer is only acted on by the maximum value of received P.D., consequently it is to be expected that tuning will have little effect on it, and so it is found in practice, in the Marconi-tuned receivers, leaving out of account the sliding receiving condenser method of tuning, which belongs to quite a different category of "tuning" arrangements, the change of effect by altering the number of turns on jigger is quite small, and within limits is only observable at long ranges.

As soon, however, as we get hold of a mean-value recorder we shall enormously enhance the value of tuning. There are such. Professor Fessenden has one, consisting of a loop of platinum wire of extreme tenuity, which gets heated by the passage of the current and affects a telephone in circuit, and with it distances of 60 miles have been obtained. Again, there are several electrolytic coherers, which may possibly be mean-value recorders; and, lastly, there is Marconi's magnetic-detector. The last-named, however, is almost certainly a maximum-value recorder, and, if so, only superior to the coherer in that its capacity is not altering continually.

NOTE.—The spark curve for receiver C is the only one that has been obtained, and *requires confirming*. (The current curves have been done many times, and are absolutely reliable.)

Though not shown on the curve, due to lack of space, the curve falls rapidly *beyond* the point where the maximum is. If this turns out correct it modifies the conclusions with reference to spark gaps (or coherers) to :—

Tuning is very inefficient for coherers until the frequency set for has been *exceeded*.

This would therefore show that *some* tuning was possible; that is to say, that if we have two receivers, a long frequency one (say a jigger adjusted to Poldhu) and a short frequency one (say the Service jigger), then the Service frequency would affect both Service and Poldhu, the Poldhu frequency would only affect Poldhu, and this seems to be partly borne out in practice.

If correct, then, it is to be expected that a suitable jigger for receiving *all* frequencies fairly well would be one of a great number of turns, that is to say, assuming a coherer is used; if a mean value recorder were used, the tunes would have to be right for the frequency sent.

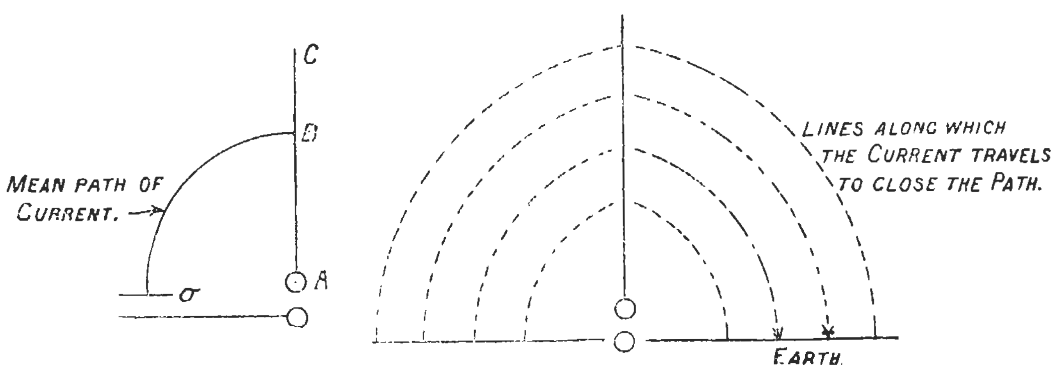
THEORY.

The natural frequency of an aerial wire being sparked into direct is :—

$$\text{Frequency} = \frac{1}{4\sqrt{LS}}.$$

("4" not "2π.")

The reason why Kelvin's formulæ is quite inapplicable is because the whole of the aerial wire is acting as a condenser :—



Consequently if we wish to apply Kelvin's formula we must use some length A B to calculate the self-induction from; the point being the point at which the capacity σ of the whole aerial wire may be supposed to act, and theory shows :—

$$AB = \cdot 406 \text{ of } AC.$$

Therefore, if we stick to Kelvin's formula, instead of calculating L for the whole aerial, we must calculate it for a length = ·406 of whole aerial. Experiment shows that this is absolutely correct.

$$\text{Now wave length} = \frac{3 \cdot 10^{10}.}{\text{frequency.}}$$

$$= 3 \cdot 10^{10} \times 4\sqrt{LS}.$$

And if we apply the formulæ for L and S for single aerials we find—

$$3 \cdot 10^{10} \sqrt{LS} = \text{length of aerial.}$$

Consequently the wave length of a single part aerial is equal to four times its length.

But we also find that the wave length of *all* aerials we have yet used (up to four-part aerials) is always equal to four times the length of one of the parts.

The meaning of this of course is that as the parts increase, L increases and S diminishes, and both go at the same rate (so that L S remains constant).

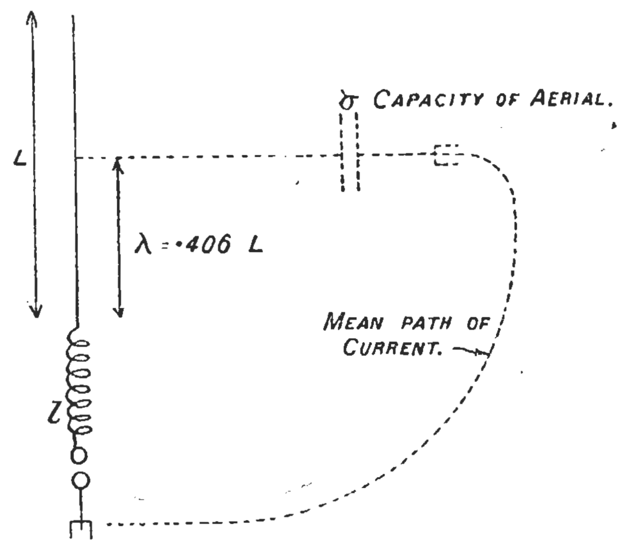
Whether, however, this can be pushed as far as the Poldhu aerials we do not know. At any rate it holds for all ordinary aerials.

This then is much the simplest way of getting the frequency of a plain aerial. Simply multiply its length by four, and you have the wave length.

Now to find the frequency of an aerial with self-induction (say) at its foot the simplest way is as follows:—

Calculate L of the aerial by usual formulae.

Multiply this by ·406. (Call the result λ.)



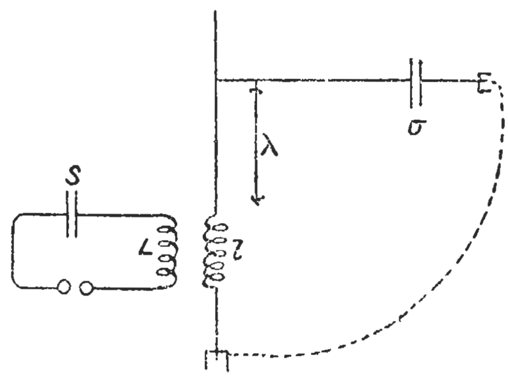
Then if a self-induction " l" is placed at the bottom of the aerial the frequency can be obtained by Kelvin's formula, *i.e.* :—

$$\text{frequency} = \frac{48 \cdot 10^8}{\sqrt{(l + \lambda)\,\sigma}},$$

where σ is the capacity of the aerial.

All this is verified by experiment.

Lastly, to obtain the frequency of an aerial influenced by an oscillator, a theory I have obtained



shows that the frequency is given by the formula (where $p = 2\pi \times$ frequency)—

$$(1 - LS\,p^2)\,(1 - \overline{\lambda + l}\,\sigma\,p^2) = M^2 S \sigma p^4,$$

which in the case of small magnetic leakage (nearly correct in practice) reduces to :—

$$L\,\lambda\,S\sigma\,p^4 - (LS + \overline{\lambda + l}\,\sigma)\,p^2 + 1 = 0.$$

This equation is rather unhandy, but an examination of it reveals the following curious facts :—

(1.) There are always two answers; always two frequencies in the circuits—one is in the L S circuit, the other in the $(\lambda + l)\,\sigma$ circuit.

(2.) These two frequencies can *never* be equal.

(3.) Neither can *ever* be equal to the natural frequency of the aerial wire.

(4.) The 2 frequencies became more nearly equal as λ or σ diminish.

Consequently tuning up an oscillator must consist in making one of the frequencies some multiple of the other. In practice we have found that when one frequency is either twice or three times the other frequency, the oscillator is at its best. Exactly the same conclusions apply to the receiving circuit.

Lastly, all these results only hold for frequencies equal to or below the fundamental.

Thus "Tune B" answers to above.
"Tune A" does not.

The reason in the latter case is this: The aerial having a half wave in it, means that the lines of current, instead of closing on to the earth, are partly closing on to the other parts of the same aerial—so much so that in a perfect Tune A disposition (not realised in practice) an earth connection would not appear to be necessary.

Therefore the frequency is more nearly given by the value of L S—due to fall in value of σ (*see* (4)). Tune A therefore alters little whether the aerial or earth is connected or not. Tune B alters enormously if either is removed. I am not here talking of the *efficiency* of either arrangement; only of the alteration of *frequency* when the aerial or earth is, or is not, connected.

Notes on Theory.—An ammeter-method of measuring is much the most convenient and accurate, but must be used with great discrimination.

Thus it would be suicidal to use it for Tune A. There a *minimum* of current is wanted, not a maximum.

Again, owing to the current changing along the wires which have capacity, an ammeter reading *may* go up owing to the antinode of current shifting about in the wire, instead of its being the actual numerical value of the current which is ascending. In most of the cases in which the ammeter can be used this, however, does not come in.

Then, since the ammeter reads the time mean value of the square root of the mean of the squares of the instantaneous currents, the reading may go up because the *persistency* of the currents is greater (less damping) or else because the frequency of the hammer or Isenthal make-and-break gets greater.

Lastly, the reading might go up because there was *less* radiating power. The ammeter measures the currents in the circuit, and the more they *leave* the wire, the less do they affect the ammeter.

In no case, of course, can the last come in in a *receiving circuit*, and it has never been noticed in a sending circuit either so far, that is to say, an oscillator tuned below the fundamental or to the fundamental or odd harmonics has never yet been noticed in which an increasing ammeter reading did not indicate an increase of radiation.

It is found that an aerial wire will give out waves whose lengths are any multiple or sub-multiple of the length. The standing features are :—

There is always an antinode of potential at the top.
There is either a node (as in Tune B) or antinode (Tune A) of potential at the bottom.

Calling wave length=4 length of wire=the fundamental vibration; then the node is at the bottom for—

All frequencies below the fundamental.
For all odd harmonics of the fundamental.

And there is an antinode at the base for—
All even harmonics of the fundamental.

A receiving aerial reproduces the standing wave of the sender.

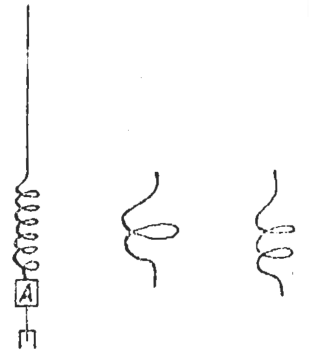
Condensers can always be placed at the nodes of current, and have much less hindering power there than elsewhere, but theory indicates that *some* current always gets through, so that the standing wave is of the form (of current) where the dotted curve is the theoretical result and the full line curve the actual thing realised.

AERIAL A.C. UTILIZING THE FOURTH HARMONIC OF THE FUNDAMENTAL.

Self-Induction **cannot be considered a fixed quantity assignable to a circuit under all circumstances. The self-induction of any circuit is the measure of the back E.M.F. in that circuit per unit of rate of change of the current in it. A current cannot have a rate of change if its value is**

always zero; consequently a self-induction placed at the top of an aerial wire will never develop a back E.M.F., whilst at the bottom of the aerial it will in general do so, its "self-induction," therefore, has no very precise meaning for some purposes.

For all that, for all ordinary vibrations (where the current is a maximum at the bottom) it is found by experiment that "self-induction" is the most important factor, *e.g.*:—

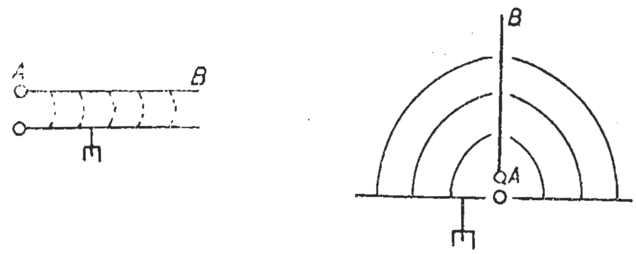


An aerial subjected to a given frequency was tuned so as to develop a maximum current in the ammeter in the following three ways:—

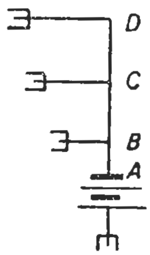
Patt. 611 on a 16-inch drum,
,, 611 ,, 10-inch drum,
42 SWG ,, 2·25-inch drum,

and in these three widely different cases it was found that the *self-induction* (not the *length* of wire or anything of that sort) was the same in all of them.

Reason for current having different values in different parts of a circuit is always due to capacity between parts of the same circuit, thus an ordinary aerial A B is simply the case of a



condenser (which has also self-induction) in which the current is flowing between the plates, and the reason why the current is greatest at the bottom is the same as for a line of observation mines,



where the current gradually falls off as it gets to the top, due to continual slight short-circuits.

The reason why the E.M.F. of the aerial is greatest at the top is much harder to explain without abstruse mathematics, but lies in the fact that Ls and Ss develop back E.M.F.'s which are opposed to the main battery and *also opposed to each other.*

Since the current is greatest at the base of the aerial, and it is the currents (probably) which develop the most injurious effects in the surroundings, it is the bottom of the aerial which must be kept as unshielded as possible.

The current in a plain aerial falls off according to a sine curve. The E.M.F. rises in the same way, that is, as the cosine if measured from the same origin.