RADIATION FROM AERIALS AND TRANSMISSION LOSSES.

Probable explanation of "freak" distances.

During the last twelve months long wave-lengths, increased power and greater ranges, have been more extensively tried and experimented with in the Service. Many peculiar facts have been noted for which there seem to be no rational explanations. "Freak" distances have been very frequent, and have in many cases been noted with perfect regularity. The unexplained and extraordinary ranges that are often obtained at night-time with short waves are no longer of rare occurrence, but can be relied upon under favourable conditions.

With a view to obtaining a rational explanation for these phenomena, and deciding on the directions in which improvements are most likely to be found, the following theoretical work may be of use. It appears to point to the fact that great improvements may be expected in the ranges obtainable with long waves, provided certain losses can be reduced.

Theoretical estimation of radiation.

About twenty years ago Hertz calculated the rate of radiation from a dumb-bell oscillator. These calculations have recently been put in a slightly more convenient form by Professor Flemming, and show that the radiation at any instant from a dumb-bell oscillator, that is, an oscillator consisting of two isolated capacities joined by a straight fine wire of no appreciable capacity, is given by—

$$\frac{2}{15} \cdot \frac{l^2 a^2}{\lambda} \text{ ergs per period,}$$

where l is the distance apart of the capacities, λ the wave-length in cms., and a is the peak current in the connecting wires in ampères.

From this following expression—

$$8 \cdot 13 \, \frac{h^2 a^2}{\lambda} \text{ ergs per period}$$

gives the radiation from a freely oscillating aerial of effective height h feet with a wave-length of λ feet which is greater than the fundamental of the aerial.

Taking an aerial of capacity σ jars, effective height h feet, average wave-length λ feet, reaching a maximum potential of v volts, and assuming this aerial is connected up as the secondary of an oscillator which is accurately tuned to the primary so that the whole energy in the two circuits passes back and fore from one to the other, and therefore spends on the average half the time in the aerial and half in the primary, the radiation will be—

$$191 \, \frac{h^2 \sigma^2 v^2}{\lambda^3} \text{ ergs per period,}$$

and the maximum energy in the aerial will be $\frac{v^2 \sigma}{180}$.

Hence the ratio :—

$$\frac{\text{Energy radiated per period}}{\text{Maximum energy in the aerial}} \text{ is } 34{,}400 \, \frac{h^2 \sigma}{\lambda^3},$$

Call this x.

Working out some examples—

Numerical examples.

(A) A large aerial transmitting a 2,000-foot wave. Assume this aerial is in a ship, then the effective height being the average height of the wire of the aerial above the level of the deck, may be about 100 feet. Take a capacity of two jars, x will then be—

$$34{,}400 \times \frac{100^2 \times 2}{2000^3}, \text{ that is } \cdot 086.$$

(B) The same aerial transmitting a 3,500-foot wave—

x is then $\cdot 016$.

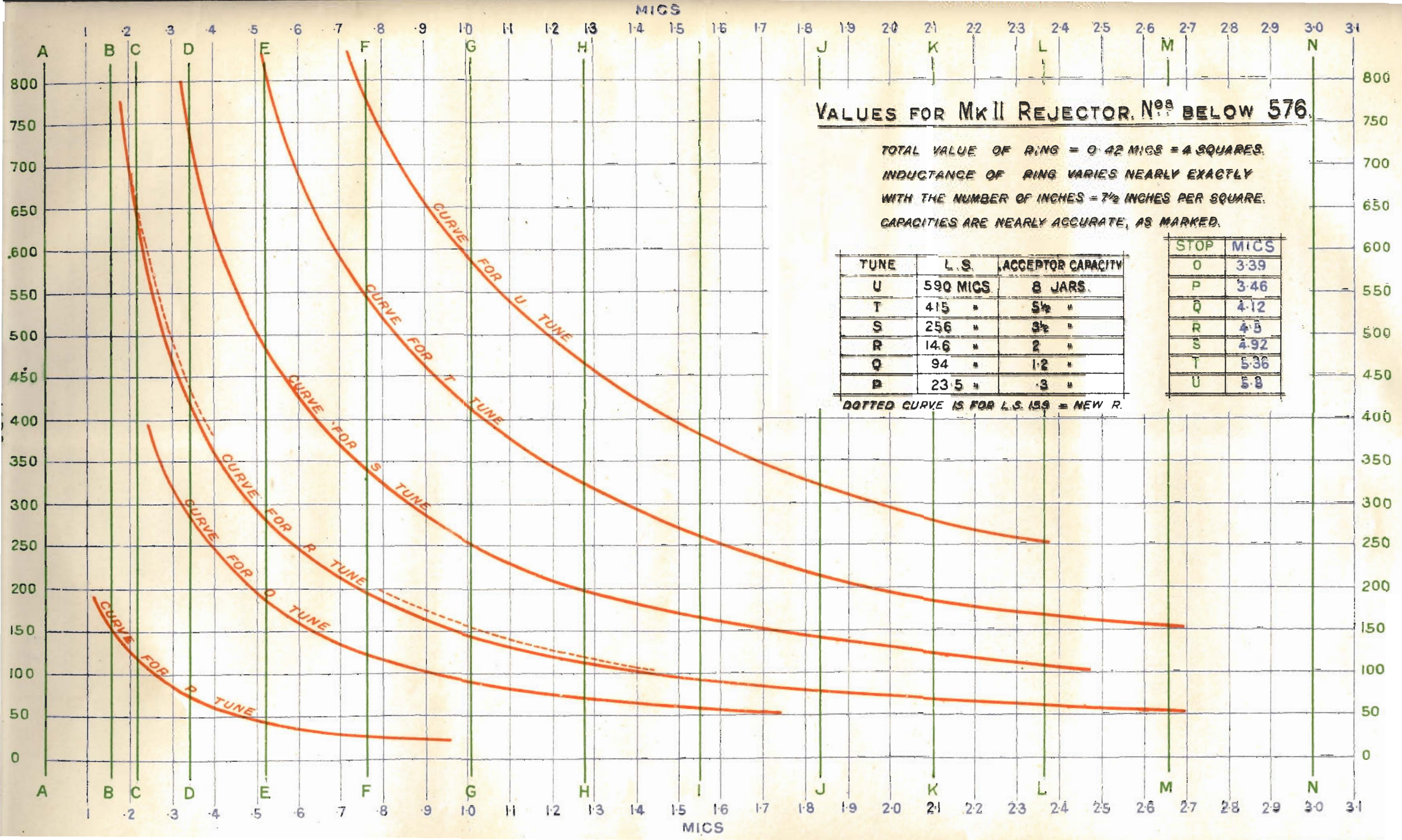
VALUES FOR Mk II REJECTOR. Nos BELOW 576.

TOTAL VALUE OF RING = 0·42 MICS = 4 SQUARES.
INDUCTANCE OF RING VARIES NEARLY EXACTLY WITH THE NUMBER OF INCHES = 7½ INCHES PER SQUARE.
CAPACITIES ARE NEARLY ACCURATE, AS MARKED.

TUNE	L. S.	ACCEPTOR CAPACITY
U	590 MICS	8 JARS.
T	415 "	5½ "
S	256 "	3½ "
R	14.6 "	2 "
Q	94 "	1·2 "
P	23·5 "	·3 "

DOTTED CURVE IS FOR L.S. 159 = NEW R.

STOP	MICS
O	3·39
P	3·46
Q	4·12
R	4·5
S	4·92
T	5·36
U	5·8



(C) The same aerial transmitting a 5,500-foot wave—
x is then ·0041.

Hence a large ship's aerial will radiate each period 8·5 per cent. of the total energy it contains if using a 2,000-foot wave, 1·6 per cent. with a 3,500-foot wave, but only 0·4 per cent. if using a 5,500-foot wave.

Estimated efficiency of radiation.

If the whole oscillating transmitting circuit is fairly persistent, and loses in every period in resistance, brushing, &c., about 10 per cent. of the energy it contains, then with the 2,000 foot wave energy disappears at the rate of 18½ per cent. each period, of which 8·5 per cent. is radiated and 10 per cent. lost.

As the whole energy given to the aerial is used up in this same proportion, it means that—

$$\frac{8·5}{18·5} \text{ or } 46 \text{ per cent.}$$

of the total energy is radiated.

With the 5,500-foot wave energy is dissipated at the rate of 10·4 per cent. per period, of which 0·4 per cent. is usefully radiated. So that $\frac{0·4}{10·4}$ or 3·9 per cent. of the total energy is radiated. With the 3,500-foot wave 13·8 per cent. of the energy is radiated.

This means that a fairly efficient oscillating circuit with a large aerial, when radiating a 2,000-foot wave, is more than 10 times as efficient as it is when radiating a 5,500-foot wave, and more than 3 times as efficient as when using a 3,500-foot wave.

Travelling losses.

This very great superiority of the short wave in getting radiated is largely counterbalanced by the rapidity with which it is absorbed and lost during its passage between the two signalling stations. This loss must depend on the state of the ether between the two stations, as it is so very different during the day and at night; it must therefore be variable. Also, as suggested in A.R., 1904, it must reduce the strength of signals in such a manner that the loss is much greater in proportion for long distances than for short.

As S tune, of which only 14 per cent is radiated, carries as far, or further, by day than Q tune, of which 46 per cent. is radiated, it shows that the loss while travelling during day for Q tune must be much greater than for S tune, which would by analogy be much greater than for U tune. It follows that this travelling loss must be very great for Q tune.

When, due to favourable conditions, this variable travelling loss is greatly reduced, it would be greatly to the advantage of the shorter wave, which would therefore carry very much further than usual, with the resulting freak distances.

If longer waves could only be more efficiently radiated, as this travelling loss has far less effect on them, they ought to carry further than the shorter waves during the day, and through unfavourable atmospheric conditions.

This greater efficiency of radiation can be obtained if the losses in the transmitting circuits can be reduced.

Thus, if these losses are very much reduced, to, say, 2 per cent. per period—

81 per cent. of the 2,000 foot wave will be radiated,
41 „ „ 3,500 „ „ „ and
17 „ „ 5,500 „ „ „

which means the strength of the 2,000-foot wave is nearly doubled, the strength of the 3,500-foot wave is tripled, and the strength of the 5,500-foot wave is more than quadrupled.

Hence with improved transmitting circuits a much better range may be expected with long waves, and these may be expected to carry further by day, and under unfavourable atmospheric conditions, than shorter wave-lengths. Also as these longer waves are less affected by the variable atmospheric conditions, they may be expected to be more reliable than the shorter waves.

In addition to the transmission and travelling losses, here considered, the relative strengths of signals of different wave-lengths depends on the relative collecting power of the receiving aerial and on the relative efficiency of the receiving instruments for waves of different lengths.

Methods of Transmitting Short Waves from Long Aerials.

Uses of short waves.

As short waves are used for special purposes, it is often necessary to be able to send them. A separate aerial can be used for this purpose, but its use is open to serious objections, and is liable to interfere with ordinary work.

Methods of transmitting short waves.

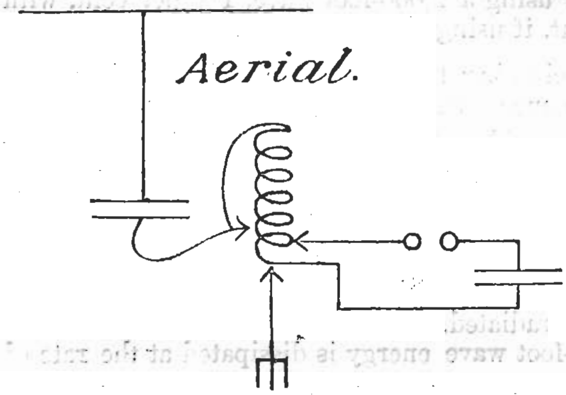
A far better plan is to send the short wave from the ordinary large aerial. There are two methods of doing this:—

Method 1.

The first method is suitable only for waves slightly shorter than the fundamental of the aerial.

The circuit is as shown in Fig. (*a*).

FIG. (*a*).



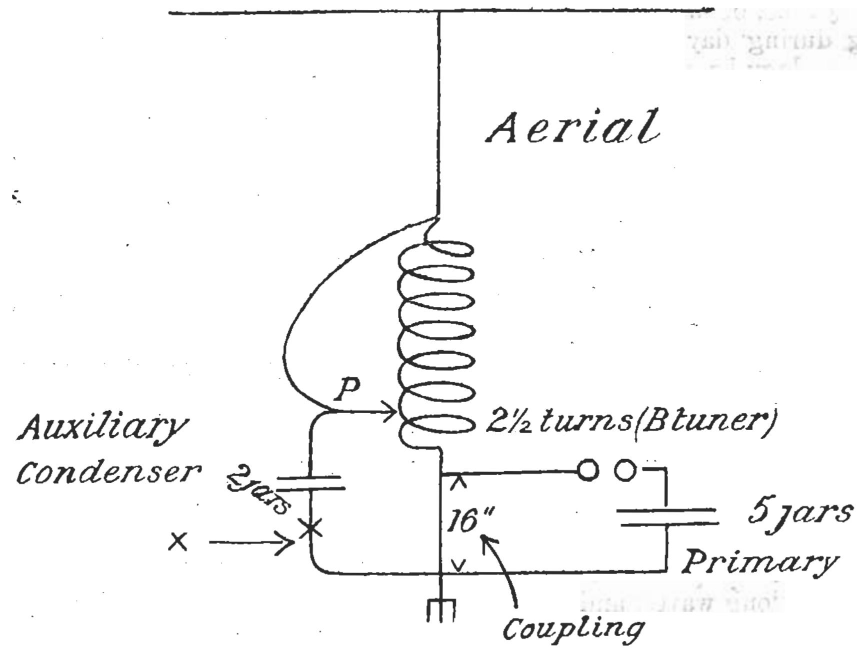
A condenser is placed in series with the aerial to reduce its natural wave-length, the ordinary oscillator is used for tuning. The condenser should be kept as large as possible, only just sufficient oscillator being used to get the necessary coupling. This circuit is tuned in the ordinary way.

Method II.

The second circuit is suitable for wave-lengths considerably shorter than the fundamental wave-length of the aerial, but longer than the first harmonic of the aerial. The extra condenser is added where it will increase the length of the first harmonic, and bring it up to the desired length.

The circuit is shown in Fig (*b*), the values opposite the condensers, &c., give those that were found to give good results when sending a 700-foot wave from the "Vernon," with a C tune aerial having a capacity of 1·5 jars.

FIG. (*b*).



Tuning.

There are two methods of tuning this circuit. The first method is the simpler, and is as follows:—Put in an auxiliary condenser of from 1 to 3 jars. Disconnect the primary jars and insert a temporary spark gap at X. Use this spark gap and tune up, varying the point P until the circuit is in tune with the wave required.

There will be two waves widely separated; the shorter one is the one that will be used.

Then disconnect the aerial and the auxiliary condenser and tune up the primary to the wave-length required.

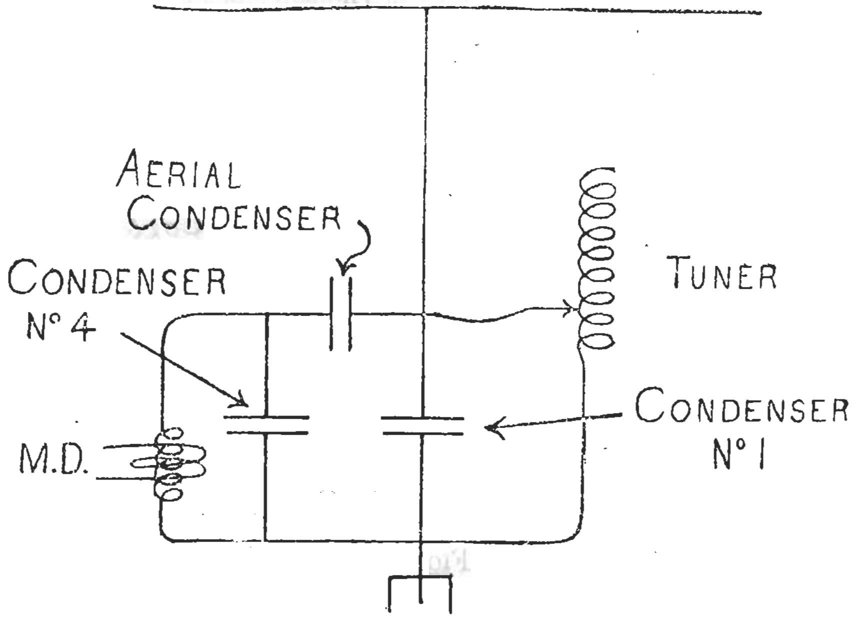
Join up all circuits again, short circuiting the spark gap at X, and check the waves with the wavemeter, varying the coupling if necessary. Three waves will be found, two short ones fairly near together, which are the waves being used, and one much longer wave which is very feeble.

The second method of tuning consists of first tuning the primary, then connecting up the whole circuit and measuring the two short waves, shifting the point P to different positions, and plotting curves giving these two waves for different positions of the P. The position of the P for which the two short waves are nearest together is the correct one for tune.

The second method is the better one for sending the destroyer's wave-length from a cruiser or scout. It is also probably the better way of sending a 1,000-foot wave from a ship with a very large aerial, but the first method is probably better for sending this wave-length from a small or medium sized aerial. Relative values of the two methods.

Connections similar to those used on the second method are probably good for a ship with a large aerial when receiving a destroyer's wave. The circuit is shown in Fig. (c). The aerial condenser should be put at about $\frac{1}{10}$ a jar, the tuner and condenser No. 4 tuned up. Receiving short waves.

FIG. (c).



Sharper tuning can be obtained by using smaller values of the aerial condenser, or larger values of condenser No. 1. As condenser No. 1 is increased the tuner will require decreasing.

This circuit has the disadvantage of completely disturbing all the receiving instrument connections, and should only be used in special cases where it is absolutely certain that ordinary reception will not be required for some time.

PROPOSED SHORT DISTANCE W.T.

The subject of short distance W.T. is one that is attracting a good deal of attention at the present moment. It must be divided up into two distinct portions, *e.g.*, that dealing with the means of limiting at will the range of a large power installation, such as Service Mark II., to comparatively short distances, say, 50 miles, and that dealing with an additional installation suitable for distances of a few miles. Definition of short distance W.T.

It is proposed to limit this section to discussing the latter portion.

A general consensus of opinion points to the desirability of designing some sort of apparatus capable of working over a range of about 5 miles, which would be available, if necessary, to take the place of visual signalling by day or night, and which could be employed as a means by which to manœuvre the fleet. To be of any real use, this system must be capable of working independently of the main W.T. installation of the ship without interference to it, or from it. Uses of short distance W.T.

The present systems of short distance W.T. as described on pages 18 and 19, Addenda, A.R. Torpedo School, 1906, in this respect fall short of practicable application, as they preclude the use of the main installation during the time that they are themselves being used.

Experiments are being carried out by the "Vernon" from which to design a set which will fulfil the requirements mentioned above; and although these experiments are still undeveloped, the results already obtained point to the possibility of doing this. "Vernon" experiments.

"Vernon" short distance set.

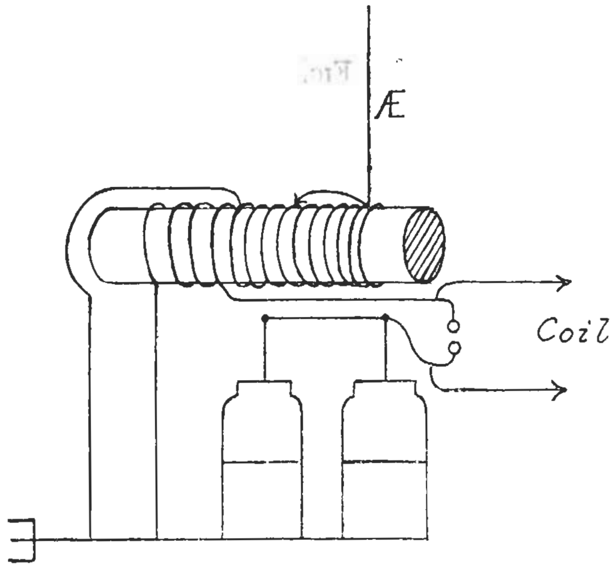
Experiments are being conducted between the "Vernon" and Horsea Island. The transmitting instruments at either end are similar, and consist of an aerial 36 feet long, made up of two parts of 14-gauge copper wire.

The primary of the oscillator consists of two Leyden jars and three turns of Pattern 611 wound on ebonite former $2\frac{1}{2}$ inches in diameter. The secondary is of Pattern 733 wound on the same former, the turns of the primary butting close up to the last turn of the secondary.

The necessary power is obtained from a single coil, using hammer make-and-break.

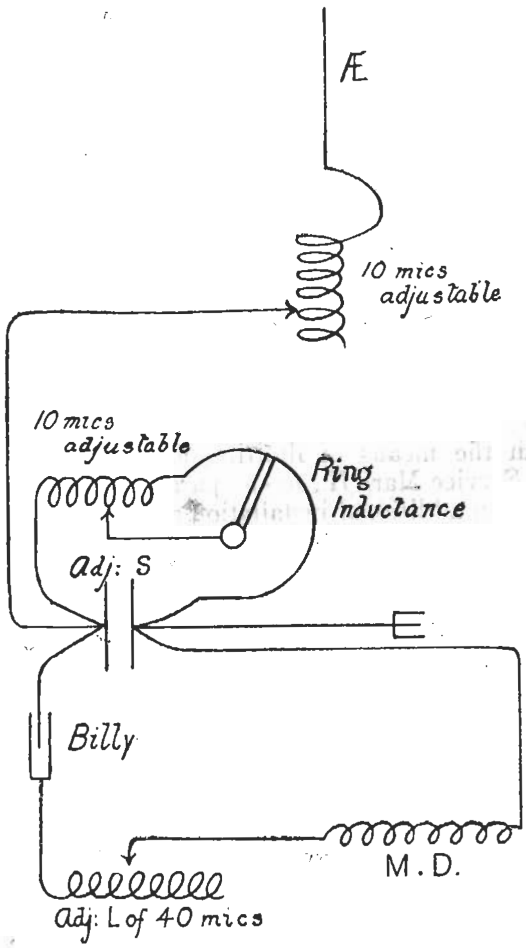
Both the primary and secondary of the oscillator are tuned to an L.S. of 3·75, corresponding to a wave-length of 400 feet.

FIG. (*a*).



TRANSMITTING CIRCUIT.

FIG. (*b*).



"VERNON" RECEIVING CIRCUIT.

The billy condensers are made up of one 12-bore and one 16-bore "Grouse" cartridge cases, and seem very suitable.

The receiving gear at Horsea is identical to that shown on page 19, A.R., 1906, but in the "Vernon" this has been modified by the addition of a rejector with small capacities adjustable from ·25 to 16 jars.

The aerial in the "Vernon" is triced up immediately below the large power aerial, and it has been found possible to adjust the small aerial to a 400-foot wave at the same time cutting out the Service Mark II. when sending R and T wave-lengths on big Æ with a 2 per cent. coupling. With an 8 per cent. coupling it is impossible to cut them out.

When sending on the small aerial, signals on R, S, T, and U can easily be read on the big Æ by inserting the red plug and plugging up more than 200 jars.

Short distance W.T. may be of great use for purposes of harbour defence. Harbour defence.

During some recent experiments on the defence of Portsmouth, the "Vernon" was ordered to erect a short distance at Culver Cliff to work in conjunction with the long distance station already there, for the purpose of giving instructions, and receiving reports from the patrol vessels and submarines of which the "Niger" was the connecting vessel.

The "Niger" was accordingly tuned up to transmit and receive a 700-foot wave, which was the wave-length decided upon for the short distance station at Culver.
Figure (*c*) shows the circuit employed ashore.

The aerial used was 60 feet in length, but when erected at Culver it was found to intefere with Culver Cliff Station, so it was removed to the Coast Guard Station at Sandown, where it worked uninterruptedly, without interference to or from Culver.
The earth consisted of about 40 yards of wire netting laid flat on the ground round the foot of the aerial.

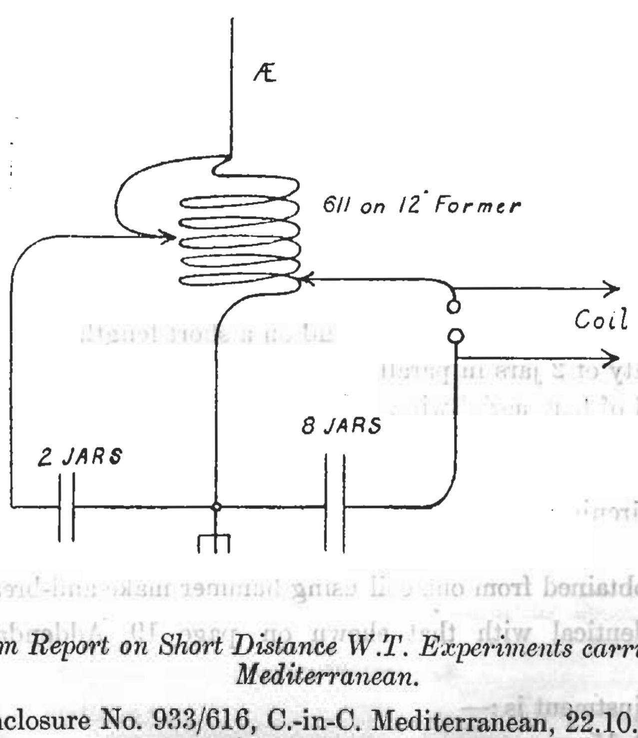
Signals between "Niger" at Portsmouth and Sandown were strength 6.

The power was obtained from one coil using two 5-cell accumulators..

The reciving instruments at either end consisted of a tuner, two No. 3 condensers, and M.D.

In the transmitting circuit it will be seen that the Æ was lengthened by adding a capacity of 2 jars at the foot, not by adding inductance.

FIG. (*c*).



Extract from Report on Short Distance W.T. Experiments carried out in the Mediterranean.

(Enclosure No. 933/616, C.-in-C. Mediterranean, 22.10.07.)

The battleships of the Mediterranean Fleet were fitted with a short distance installation, and "communication by this means, including manœuvring signals, has, during the recent summer cruise, been successfully carried out at night between ships steaming in close order and without lights."

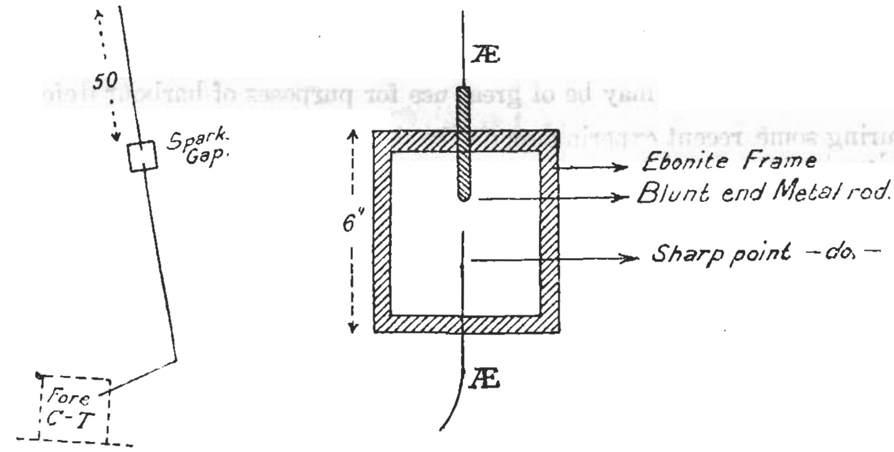
Installation.

The installation was fitted in the fore conning tower, precautions being taken to screen the induction coil so as not to affect the compass.

Aerial.

The aerial consisted of 110 feet of ordinary bare aerial wire, broken at a point 50 feet from the top and a spark gap inserted (*see* Fig (*a*)), which was usually adjusted to 4–6 mms.

FIG. (*a*).

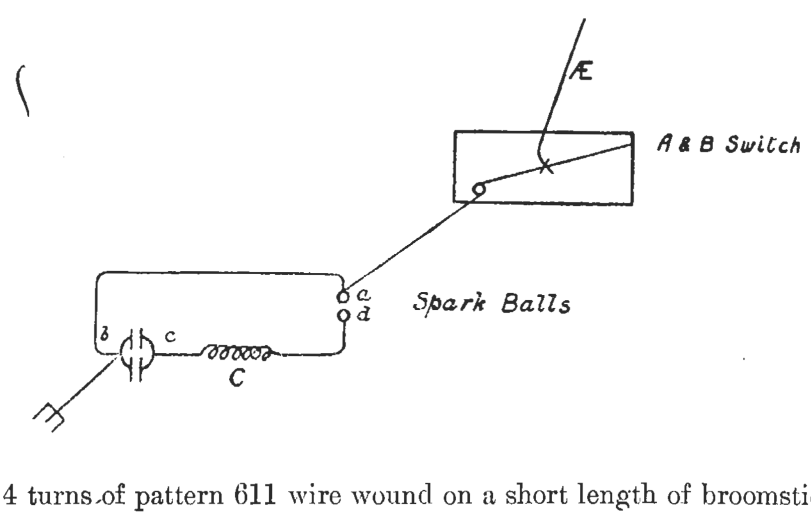


Oscillator.

The lower end of the aerial was brought down to the conning tower, care being taken to keep it well clear of stays, &c.

The oscillator was made up as follows :—

FIG. (*b*).



C is 4 turns of pattern 611 wire wound on a short length of broomstick.

s is a capacity of 2 jars in parallel.

a b is 1 yard of bare aerial wire.

Total length of pattern 611 wire connecting C to *e* and *d* is $1\frac{1}{2}$ feet.

The above circuit is in tune with the aerial, the natural wave-length of which is about 500 feet.

Receiving circuits.

Power was obtained from one coil using hammer make-and-break.

This is indentical with that shown on page 19, Addenda, A.R. Torpedo School, 1906.

The best adjustment is :—

Tuner. A 15a.

Billi. About $\frac{1}{2}$ out.

The tuner may be replaced, if necessary, by winding several turns of Pattern 611 wire on a short piece of broomstick. About 15 turns has an inductance roughly equivalent to A 15a on the tuner.

It was found possible to reduce interference by using less inductance, and, if necessary, re-adjusting the billi. **Interference.**

"As a result of these experiments it has been established that a short distance W.T. installation, separate from the Service installation, is useful for communicating between ships in close order under the following simultaneous conditions :— **Results.**

"(*a*) When visual signalling is impracticable or undesirable.

"(*b*) When it is essential that the communication be not "blocked" by outlying ships, hostile or friendly, or by atmospheric disturbances.

"(*c*) When it is necessary to maintain wireless touch with distant ships.

"With regard to the technical results obtained, it has been found that sending with maximum power on the Service installation in a ship interferes with short distance W.T. reception in the same ship, and *vice versâ*, but that other ships of the Fleet sending on their Service installations do not interfere with this short distance W.T. reception, and similarly short distance W.T. sending does not interfere with long distance reception in other ships, however close.

"That is to say, the mutual interference of the short distance and long distance W.T. is localised in one ship, and is, therefore, easily controlled."

"The wave-length used has been 500 feet, and the receiving aerial was at first tried about 50 feet high, but as signals were sometimes weak, this height has been increased to about 100 feet by short-circuiting the aerial spark gap, and it has been with this latter arrangement that the above results were obtained." **Receiving aerial.**

"The short distance W.T. installation was placed in the fore conning tower so that the Captain on the bridge should be in direct communication with the short distance W.T. office, which is also in a most convenient position for rigging the aerial wire well clear of the long distance aerial." **Position.**

It would appear that at no time was the short distance reception interfered with by atmospherics, even when reception on the long distance aerial was being most hampered by them. **Atmospherics.**