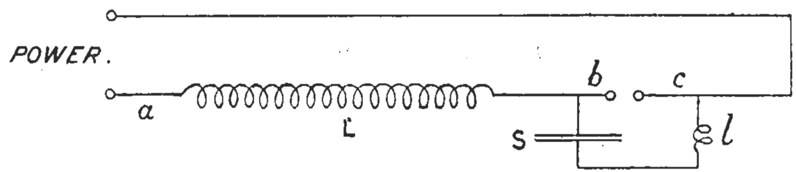
Alternating Current as a source of Power for Wireless Purposes.

Alternating currents in wireless telegraphy.

The chief points connected with the use of alternating current as a means of charging the transmitting condensers are briefly stated in A.R. 1904, page 59 of Appendix.

Good results can be obtained by using the acceptor method and taking advantage of resonance effects.

FIG. 21.



Choking coil.

S in Fig. 21 represents the transmitting condenser to be charged, *l* the primary of the oscillator, and *b* and *c* the ends of the spark-gap. A self-induction L is placed in series with the circuit, which is connected to a suitable source of alternating current.

Consider first what happens before a spark is formed between *b* and *c*. The induction *l* is, in all practical cases, less than one one-millionth part of L, and can be neglected. L is so chosen that L and S form an acceptor for the applied alternating current; then with this current, as explained in A.R. 1904, page 40, the back e.m.f. across L and the back e.m.f. across S, will be equal and opposite and cancel one another, and the current through the circuit will be governed simply by the resistance of L. If this resistance is small the current will be large, and the condenser therefore charged to a high potential. Thus if the circuit is properly arranged an alternating current of fair voltage applied to the circuit will cause S to be charged to a considerably greater voltage.

When, due to the voltage across S, a spark passes and short-circuits the spark-gap *b c*, the back e.m.f. due to L will no longer be cancelled by that due to S, and it will choke down the current taken from the power supply to a small value. As soon as the spark has ceased to short-circuit the gap the back e.m.f. of the condenser S will again come into play, cancelling that due to L, the current will again increase, and S be charged up to give the next spark.

Thus this circuit will readily accept power when it is required to charge the condenser, will choke down the current when the spark is short-circuiting the gap, and will give a higher voltage across the condenser than is applied to the circuit.

If the power were applied directly, without a choking coil, when a spark short-circuited the gap, it would short-circuit the source of power. An alternating arc would form between the spark balls, they would be burnt up, and the gear supplying the power would be severely strained.

Returning to the acceptor arrangement. When the power is applied the condenser S is not at once charged, but the current taken grows steadily. The way in which the P.D. across the condenser grows is shown in Fig. 22.

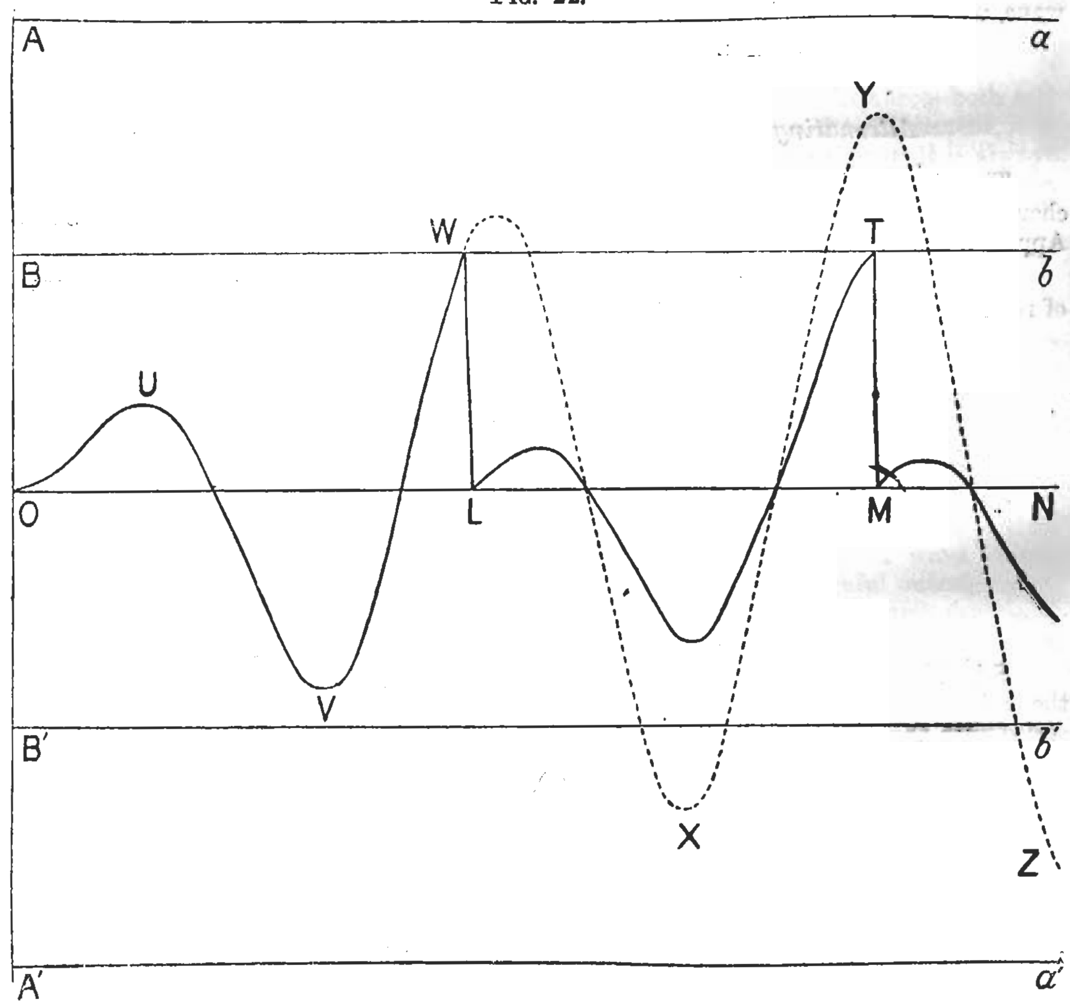
Here the ordinates measured along O A represent the P.D. across the condenser, and the abscissæ measured along O N the time that has elapsed since the circuit was made.

The P.D. increases each alternation, at first rapidly, then more slowly. During the first alternation it will rise to U, the condenser will then discharge and charge negatively, reaching the P.D. V. during the second alternation, and so on to W, X, Y, Z, &c. The maximum P.D., each alternation getting nearer and nearer to A a and A^1 a^1, the lines of maximum possible P.D. which would be reached after the circuit had been made for some time.

The circuit would behave in exactly the same way as a heavy pendulum immersed in a slightly viscous liquid and subjected to a regular gentle pull and push. The oscillations would gradually increase, at first rapidly, then more slowly, until the gentle pull and push were only strong enough to overcome the friction of the liquid. The viscosity of the liquid takes the place of electrical resistance.

Suppose the spark-gap is so set that a P.D. equal to O B (= O B′) will break it down. After the circuit is made, a time O L will elapse, then the P.D. will reach the point W,

FIG. 22.



and be great enough to form a spark, which will last for a very short time, far too short to be shown on the above curve, and the condenser will be completely discharged. The curve will start again from L, the P.D. increasing as before until when a time L M has elapsed, the P.D. will have reached the point T and the second spark will occur, and so on.

If the spark-gap were longer a spark would not occur at W, and more time would be required for the P.D. to grow for each spark, so that the train of sparks would be slower. In the same way a shorter spark would be more rapid. The sparks will be perfectly regular except for a small difference due to some sparks starting to form when the applied voltage is near its peak and others when it is zero, but this is very slight.

It will be noticed that immediately after a spark has formed the P.D. across the condenser is small, so that there will be very little tendency for an arc to form across the gap, just after the spark has ceased.

To practically work this acceptor circuit at, say, 20 words per minute, at least 20 sparks per second are necessary. To get this number of sparks the alternating voltage applied must be fairly great. In a well-proportioned arrangement the applied voltage would be about one-third that necessary for the maximum spark. To get a spark of one centimetre a maximum value of about 30,000 volts is necessary, so that the maximum value of the applied volts should be 10,000, which would be given by an alternating current of 7,100 volts R.M.S. value (*i.e.*, square root of the mean square voltage is 7,100 volts). This voltage is far too high for working with, and a transformer is necessary to step up the voltage to this value from, say, 70 or 100 volts, which is a convenient voltage to have at the key, &c.

This alternating current could be supplied at about 70 volts either from a small alternator driven by a motor or from a rotary converter. The latter requires less space than the two machines; it is lighter, cheaper, and works quite as well. A rotary converter consists of a direct-current shunt-wound motor, with connections tapped off from two fixed points on the armature, and joined up to two insulated slip rings from which the alternating current brushes are supplied. The connections are arranged so that when the point on the armature to which the first slip ring is joined is in connection at the commutator with the positive brush, the point to which the second slip ring is joined is in connection with the negative brush. The fixed points on the armature rotate with it, so that the slip rings are alternately, number one in connection with positive brush, number two with negative, and number one in connection with negative, number two with positive; as the armature rotates, and the voltage on the slip rings is alternating, its maximum value being equal to that of the direct current supply and the R.M.S. value of the alternating voltage is about 70 per cent. of this. Thus a motor running from 100 volts direct current would give about 70 volts alternating, or a little less if fully loaded. If the rotary converter has two pairs of poles, the alternating volts will change from maximum positive to negative and back to maximum positive again, twice every revolution, and there will be two complete cycles or periods each revolution. If only one pair of poles, one cycle per revolution. So that the frequency in cycles per second = revolutions per second × number of pairs of poles.

Power required.

The power required to work a given circuit is roughly given by $S\, l^2\, N$ watts.

S. is the number of jars in the condenser, l the length of maximum spark in cms., N the maximum speed of signalling required with the maximum spark in words per minute.

The formula assumes an efficiency of about 50 per cent.

Thus, "B" tune 17 jars, 9 mms. spark at 20 words per minute requires $17 \times (0{\cdot}9)^2 \times 20$ watts, *i.e.*, 280 watts approximately, or 4 ampères only at 70 volts.

And 160 jars, 1 cm. spark at 20 words per minute requires 3,200 watts.

The alternating current method of charging condensers is much more efficient than the present method using direct current with make and break. But with fair powers a shock from a circuit charged by alternating current would be very dangerous, and short-circuiting the spark through one's body would certainly be fatal, and precautions are necessary. Small choking coils and earthing condensers or lamps are also necessary to protect the step up transformer, &c. from inductive high-frequency currents.

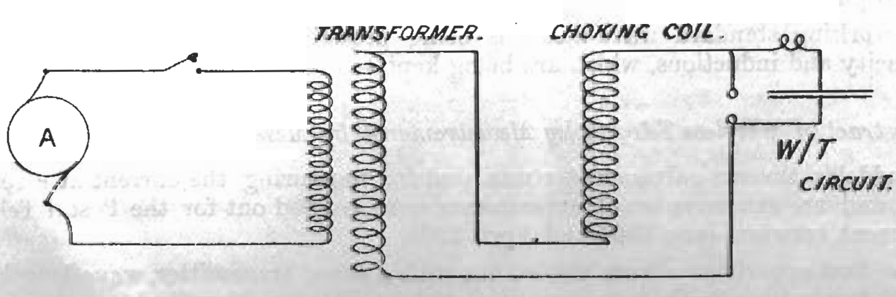
Frequency.

For practical working a frequency of about 25 cycles per second is good, it is at present in use at Poldhu and is being adopted for the first sets of alternating-current exciting gear to be supplied to the Service.

When using alternating current the key is placed in series with the 70-volts alternating current, and with smaller powers works very well without a condenser across it. It is better not to have a condenser, as with it a small current will always be flowing, the supply being alternating, and the condenser is liable to get perforated.

A complete circuit would be as in Fig. 23.

FIG. 23.



The output from the rotary converter being 70 volts alternating, from the transformer 7,000 volts alternating, and across the spark gap 30,000 volts alternating, giving a spark of 1 cm.

The choking coil provides the induction L (*see* Fig. 21) for resonance.

Approximately, the proper induction for the choking coil will be given by—

$$\text{frequency in cycles per second} = \frac{4{,}800}{\sqrt{\text{S in jars} \times \text{L in henries}}}.$$

The arrangement will also work with a choking coil in the primary circuit of the transformer instead of in the secondary, or the induction can be part in the primary and part in the secondary. Putting a self-induction L in the primary is equivalent to putting

$$L \times \left\{\frac{\text{voltage from secondary}}{\text{voltage on primary}}\right\}^2$$

in the secondary. In the above example one henry in primary is equivalent to 10,000 henries in the secondary.

Tuning the transmitting circuit.

The circuit is best tuned by varying the speed of the rotary converter, using a field regulator. The choking coil is arranged to have approximately the proper value corresponding to the required frequency as given by above formula. The speed is then varied until the best spark is obtained and the arrangement works most smoothly.

If the speed is not correct, the rotary converter races or slows down when the key is pressed. Referring to Fig. 21, when the speed is too great and frequency too high, the back e.m.f. due to L is greater than that due to S, and only partially cancelled by it. The uncancelled part of L causes the current taken to lag.

When a lagging current is taken from a rotary converter the field magnets are partially demagnetised, and as the machine is also a direct-current shunt motor, demagnetising the field magnets increases the speed and the frequency gets still higher. Further, if the speed is too slow, part of the effect of S is uncancelled, and a leading current is taken which strengthens the field magnets and slows down the motor. So that if the speed is not right, it gets still further wrong when the key is pressed.

When the field is weakened by the speed being too great commutation is often disturbed, and violent sparking occurs at the brushes. In addition to this surging when the speed is not properly adjusted, the spark length is much reduced. It seems that the speed a little too slow does not make as much difference as if a little too fast.

Several extemporary arrangements have been tried in the "Vernon".

An ordinary induction coil can be used as a transformer; it is equivalent to a transformer stepping up the voltage about 140 times, together with a self-induction of about 100 to 200 henries in series. It is, however, inefficient and puts a considerable strain on the rotary converter.

The secondary of a coil can be used as a choking coil, L about 600 to 1,000 henries, but it is also inefficient. Using a coil as a transformer and the secondary of another coil as a choking coil in its secondary circuit, fair results can be obtained on "B" tune, the proper frequency being about 30 to 35 cycles per second or 900 to 1,150 revolution for a four-pole rotary converter. In trying these arrangements great care has to be taken that nobody is likely to get a shock, by touching both sides of the jars, or if one side of the jars is accidentally earthed, touching the other, as the shock would be dangerous.

Standardisation.

During the year a standard air capacity of 1,000 cms. was received from Messrs. Muirhead & Co. This was very carefully compared with the standard wave-length sending circuit which was calibrated last year (*see* A.R. 1904, p. 35).

Standard self-inductions, carefully measured and calculated, were used in conjunction with the standard capacity. Although when set at some wave lengths the "Vernon" standard differed by nearly 3 per cent., the mean of all observations showed less that ½ per cent. difference; and the circuit is considered accurate enough for most practical purposes.

A working standard wave-meter is being preserved in addition to the standard air capacity and inductions, which are being kept as the ultimate standards.

Abstract of Wireless Telegraphy Measurements, by Messrs. Duddell and Taylor.

Experiments by Duddell and Taylor.

Duddell's thermo-galvanometer was used for measuring the current at a receiving station, and an extensive set of experiments were carried out for the Postal Telegraph Department between June 1904 and April 1905.

The first experiments were carried out with a tuned transmitter, wave-length about 400–500 feet, with a fairly loose coupling, at short distances over land.

Further experiments were carried out at distances up to 60 miles over sea.

The following results were obtained:—

(1.) Varying the height of the transmitting aerial—

Current in receiving aerial = constant × current in transmitting aerial × its height.

(2) Arrangement of transmitting aerial varied, length constant.

Shape of Aerial.	Received Current.
Vertical - - - - - -	315 micro-ampères.
L - - - - - - -	208 "
┌ - - - - - -	238 "
┌╴ - - - - - -	148 "
Top of aerial rolled up - - -	158 "

The last four aerials were of the same height.

(3) Transmitting earth varied. Both earths consisted of a roll of wire netting 76 feet long, pressed down on grass by weights at edges, connection in the centre.

Transmitter Earth. Netting.	Current in Transmitting Aerial.	Current in Receiving Aerial.
All flat on earth -	·696 ampére.	2,042 micro-ampères.
Half rolled up -	·611 "	2,030 "
All rolled up, resting on earth.	·392 "	1,129 "

(4) Receiving earth varied.

Receiving Earth. Netting.	Current in Receiving Aerial.
All flat on earth - - -	2,042 micro-ampères.
Quarter rolled up from each end -	2,016 "
Half rolled up from one end -	1,797 "
All rolled up, resting on earth -	1,530 "
Lead sheathing of a long buried cable -	1,246 "
Wire stay supporting a pole -	1,346 "

Second experiment with receiving earths, at a distance of 6½ miles, shore station receiving, ship transmitting.

Earth.	Current in Receiving Aerial.
A cross of wire netting laid on ground, each arm 31 feet by 4 feet - -	352 micro-ampères.
Copper wire in a well of water -	306 "
Iron sheathings of a submarine cable -	211 "
Well and netting in parallel - -	313 "

Tuning was sharp with first earth, less sharp with second and fourth, and much less sharp with the third. With the third earth the receiver tuned at a different point.

(5) Height of receiving aerial varied, tuner being adjusted to keep receiver in tune.

Current in receiver = height of aerial × a constant, approximately.

(6) Resistance of receiving instrument varied. Maximum power was absorbed when R = about 45 ohms, using simple resonance with a 56-foot aerial wire. **Resistance.**

(7) Distance between transmitter and receiver varied.

First Experiment.—From 36 miles down to 5 miles. Current in receiving aerial × distance was practically constant. From 5 miles down to 2 miles it decreased, ship was then coming near in to some screening land.

Second Experiment.—From 60 miles down to 8 miles, current × distance was nearly constant, increasing slightly with decreasing distance. From 8 miles to 3 miles it increased nearly 50 per cent., and then, down to 1 mile, decreased.

Third Experiment.—This was similar to second, ship's track a few miles further north.

Current × distance was roughly constant between 60 miles and 18, increased from 18 to 12, then remained constant down to 5 miles, and afterwards decreased, being a minimum at about 1 mile.

Fourth Experiment.—This was made at short distances over land.

Current × distance decreased from 500 feet to 1,500 feet, then remained constant until 4,000 feet. Between 4,000 feet and 5,500 feet, there were several trees, they had the effect of reducing current × distance, it being only half as great at 5,500 feet as at 4,000 feet. Passing from 5,500 feet to 7,500 feet, current × distance increased, but not up to the same value as before the trees were passed.

Light effect.

(8.) Day and night effect. The current in receiving aerial was just as great in the day time as at night, but wave length and distance were short.

Remarks by " Vernon."

The experiments with different earth arrangements are very instructive. They show the undoubted superiority of surface earths. The actual ohmic resistance for direct currents must have been much less with the two cables used for receiving earths than with the wire netting. Their inferiority is very possibly due to skin effects. The earth being a fair conductor, any high-frequency current would remain on the surface and not sink deeper than perhaps 12 or 14 inches, so that the current from the wireless circuit would leave the cable where it entered the earth and flow in the surface soil instead of in the buried conductors. And as the area over which the current leaves the cable is small the current density in the soil would be great near to the point at which the cable enters the soil, and the resistance would be high. With the netting, current would pass from it to the ground all round its edge, and the current enter the soil over an extended area. It will also be noticed that the condition of the earth near the junction of the earth wire is more important than its condition well away from it, and that if there is already a good earth, it is harmful to connect a bad earth in parallel with it (*see* second experiment).

The irregularities in the value of current × distance, in the distance experiments, are probably due to the shape of the land near the shore station, there being screening from one direction and possibly reflection of waves arriving from another. The ship did not in these experiments steam straight away from the station, but steamed out, and then off at an angle.