reduced to 800. As an instance of the protective measures adopted by the department, we may cite the case of rabies. The Transvaal is free from this disease, but it is found in Rhodesia, and in the hope of preventing its introduction a strip of country fifty miles wide, along the northern border of the Transvaal, has been entirely cleared of dogs.

A large part of the time of the chief of the division of botany is taken up by consultative work. Information upon new crops, weeds, poisonous plants, forest trees, &c., is in constant demand, and, apart from interviews and attendances at shows, this work alone involves the writing of some 3000 letters per annum. A herbarium is being formed. Some progress has been made in crossing and selecting maize, but it is remarked that, owing to the pressure of other work, plant-breeding has not hitherto received the attention it deserves. An important section of the work of the division is that which deals with plant pathology. A pathologist was recently appointed by the department, and the number of diseases which he has already observed is referred to in the director's report as "amazing." Special attention has been directed to the rusts, and five have been so far identified, viz. *Puccinia graminis* on wheat and barley, a second form of *P. graminis* on oats, *P. triticini* on wheat, *P. coronifera* on oats, and *P. maydis* on maize. Some attention has been directed to disease-resistant varieties, and stress is laid on the fact that a cereal which may be immune to the attacks of one rust may be very susceptible to infection by another; the practical conclusion is drawn that every effort should be made to obtain disease-resisting varieties, and that the continued growing year after year of the same variety of any cereal should be avoided as much as possible.

The chemical division has been engaged in an examination of soils, and attention is directed to the fact that the soils of the Transvaal are generally well supplied with potash, but are deficient in phosphoric acid, lime, and organic nitrogen. In conjunction with the veterinary division, the chemist has carried out an investigation into the composition of the bone of animals suffering from osteo-porosis, and he finds that affected bones are deficient in total ash, lime, and phosphoric acid. The normal proportion of nitrogen to total ash is about 1 : 14; in diseased animals the proportion is approximately 1 : 11.

The "division of publications" issues a quarterly journal, each number of which extends to some 300 pages; there are two editions, an English of some 8000 copies, and a Dutch of about 2000 copies. The journal contains original articles, notes from the various divisions, extracts from foreign journals and Government circulars, market prices, customs returns and other figures of interest to farmers. In addition to the journal, this division publishes leaflets and bulletins; among the latter, those written by members of the veterinary division upon the common diseases of the live stock of the colony have been of most importance.

It is satisfactory to learn that the work of the department commended itself to the Public Service Commission which inquired into the working of all branches of the Civil Service. The commission report emphasises the importance to the Transvaal of agricultural research, and goes on to state that it "has been impressed by the zeal, devotion, and business-like methods which characterise the Department at present, and that it finds itself unable to suggest any improvements in the organisation, or in the distribution of the business."

THE ARC AND THE SPARK IN RADIO-TELEGRAPHY.[1]

THE discovery by Heinrich Hertz between 1887 and 1889 of experimental means for the production of electric waves, and Branley's discovery that the conductivity of metallic particles is affected by electric waves, form the foundation on which, in 1896, Signor Marconi built up his system of wireless telegraphy.

Many of the early investigators certainly had glimpses of a future system of being able to transmit messages without connecting wires, for as early as 1892 Sir William Crookes predicted in the *Fortnightly Review* the possibility of telegraphy without wires, posts, cables, or any of our costly appliances, and said, granting a few reasonable postulates, the whole thing comes well within the realms of possible fulfilment.

Two years later Sir Oliver Lodge gave his memorable lecture on the work of Hertz, and carried the matter a step nearer the practical stage.

There will not be time to dwell to-night on the early history of the art and its development. It will be necessary, however, to explain some of the fundamental properties of signalling by means of Hertzian waves in order to be able to bring out clearly the relative advantages and disadvantages of the two rival methods now in practical use for producing Hertzian waves for wireless telegraphy.

The fundamental part of the transmitting apparatus may be said to consist of a long conductor generally placed vertically, in which an alternating or oscillating current is set up by some suitable means. Such a conductor radiates energy in the form of Hertzian waves at right angles to itself into space, in very much the same way that an ordinary candle sends out light in all directions. This radiation, though it is strictly in the nature of light, is invisible to our eyes, as the frequency is too low.

If we set up any other conductor approximately parallel to the first, there will be produced in this second conductor alternating or oscillating currents having the same frequency as those in the first conductor, and which can be detected by suitable instruments.

The simplest and one of the earliest methods for producing Hertzian waves for use in wireless telegraphy consisted in charging up, by means of an induction coil, a vertical insulated conductor, which was allowed to discharge itself to earth by means of a spark taking place between its lower end and another conductor which was connected to earth. To detect the Hertzian waves Marconi employed an improved form of the Branley filings tube, which is known as the coherer.

In order to transmit messages the radiation is started and stopped so as to form short and long signals, or dots and dashes of the Morse code, out of which the whole alphabet is built up in the well-known way.

As I have already stated, the radiation takes place round the vertical conductor approximately equally in all directions. Suppose that I set up my transmitting apparatus here in Leicester, a receiving station set up either in Nottingham, Derby, Rugby, or Peterborough would be able to receive the message equally well. Should I wish to send a message from here to Nottingham at the same time that Derby wishes to speak to Rugby, then the receiving station at Nottingham would receive both the message from Leicester which it should receive, and the message from Derby which it was not required to receive.

To get over this difficulty, known as "interference," a large number of devices have been patented. The most successful in practice is syntony, or tuning; in this method each station has allotted to it one definite frequency or tune, and the apparatus is so arranged at each station that it will only be affected by messages which are radiated by other stations on its own frequency or tune, and not by any other radiations. To take a musical analogy, supposing I had somebody who was either deaf to all notes of the piano except, say, the middle "C," or had such a musical ability that he could tell at once when I struck the middle "C," then I could transmit to that person a message in the ordinary Morse code by playing on the middle "C," and that person, whom I shall call Mr. C., would not take any notice of the fact that I might also be playing on the notes D, E, F, G, &c., but Mr. C. would confine his attention entirely to what is being done with the middle "C." It is conceivable that I might find a series of persons or train them so that they could each pick out and hear one note only of the piano, irrespective of what was being played on the other notes or of any other noises that were taking place. Taking an ordinary seven-octave piano, and neglecting for a moment the black notes, this would give me fifty-six distinct notes on which I could transmit messages; so that, transmitting from Leicester, I might send messages simultaneously to fifty-six different towns.

[1] Discourse delivered at the Leicester meeting of the British Association on Friday evening, August 2, by Mr. W. Duddell, F.R.S.

The number of possible simultaneous messages depends on the number of octaves there are on the piano used, and on how close together the different notes are which can be used without producing confusion. For instance, it might be quite easy to train someone to distinguish with certainty between "C" and "E," and pick out signals on "C" at the same time that signals are being sent on "E." It is certainly more difficult to do this with two notes that are closer together, say "C" and "D," and still more difficult if the half-tones are used as well. The problem, therefore, in wireless telegraphy is to arrange the receiving apparatus so that it can hear, or perhaps I should say, more accurately, so that it can only see, notes of one definite frequency or pitch, and not be affected by any other notes, even though of but slightly different pitch. Another requirement to obtain good working is that we should use as little power as possible at our transmitting station consistent with obtaining enough power in our receiving instruments to work them with certainty.

I have a mechanical model to illustrate how we are able to make our receiving instruments very sensitive to one frequency, and only slightly affected by frequencies which differ but slightly from its proper frequency.

The transmitter in the model consists of a disc that can be rotated slowly at any speed I like, with a pin fixed eccentrically on its face. This pin can be connected to a vertical wire which moves up and down as the disc rotates. I shall assume that the movement of this wire corresponds with the movement of the electricity in the vertical conductor. As a receiving apparatus I have a pendulum, and representing the ether between the transmitter and receiver I have an elastic thread connecting the pin in the disc to the pendulum.

When I set the disc rotating slowly the elastic thread is alternately stretched out and relaxed, and the pendulum is a little affected. If I gradually increase the speed of the disc at one definite speed it will be found that the pendulum is set into violent oscillation, and by observation it will be found that when this is the case the disc makes one complete revolution in exactly the same time that the pendulum would make one complete swing if left to itself; that is to say that the disc and the pendulum make the same number of swings per second or have the same frequency; in music they would be said to be in tune with each other. If instead of allowing the disc to rotate continuously I allow it to make only half a dozen revolutions, then the pendulum will be affected, but much less strongly. The greater the number of revolutions the disc makes up to a certain maximum number, the more the pendulum will be caused to swing.

Instead of starting and stopping the disc, I can keep the disc rotating, and start and stop the pulls on the elastic thread by moving the pin in the face of the disc in and out from the centre, which produces a movement which much more nearly corresponds with the actual current in the vertical wire as used in spark telegraphy.

It is necessary here to explain the relationship that exists between the wave-length, the frequency, and the velocity of propagation of Hertzian waves. The waves travel with, as far as we know, the same velocity as light, namely, 300,000,000 metres, or 186,000 miles, per second. Between these quantities we have the relationship that the product of the wave-length by the frequency is equal to the velocity of propagation, or, as I have already mentioned, the velocity of light.

The wave-lengths which are of practical use in wireless telegraphy at the present time range between 100 and 3000 metres, though, of course, it is quite possible to use for special purposes wave-lengths outside these limits. The corresponding frequencies in practical use are therefore between 3,000,000 and 100,000 complete periods per second. We require, therefore, to produce in the vertical conductor alternating or oscillating currents of any frequency within this range, and to have a sufficient number of oscillations following one another without interruption to allow of good syntony being obtained.

There are three methods of producing these currents—namely, the alternator, the spark, and the arc methods.

There are great difficulties in the way of constructing an alternator to give such high-frequency currents, and I can best illustrate this by taking an example. Suppose that it is required to build an alternator to work at the lowest frequency, namely, 100,000 periods per second, and let us assume that we can drive this alternator by means of a turbine at the high speed of 30,000 revolutions per minute. This alternator could not have a diameter much above 6 inches for fear of bursting; and, as it makes 500 revolutions per second, it would have to generate 200 complete periods for each revolution, so that the space available for the windings and poles for one complete period will be less than 1/10 inch, a space into which it is quite impossible to crush the necessary iron and copper to obtain any considerable amount of power. In spite of the small space that we have allotted to each period, as there are 100,000 periods per second, the speed of the surface of the moving part works out at more than 500 miles per hour. A small alternator has been built to give more than 100,000 frequency, but the amount of power it produced was extremely small. Several experimenters have stated lately that they have built alternators giving these high frequencies and a considerable amount of power, but, so far as I am aware, there is no trustworthy data available as to the design of these machines.

If it should prove possible to construct alternators for these very high frequencies, we shall be able to obtain a sufficient number of consecutive oscillations of the current in the aërial of definite frequency to enable very sharp syntony to be obtained. Not only will this greatly reduce interference troubles in wireless telegraphy, but such alternators will be of the greatest value for wireless telephony.

The earliest method of producing high-frequency oscillations was proposed by Lord Kelvin, who pointed out that if a Leyden jar or condenser be allowed to discharge through a circuit possessing self-induction or electrical inertia, then under certain conditions the discharge of the jar is oscillatory, that is to say, that the electricity flows backwards and forwards in the circuit several times before the jar or condenser becomes finally discharged. I think that perhaps the best way to make this matter clear is by demonstrating experimentally with an oscillograph the nature of the discharge of a condenser and how it is affected by the resistance and self-induction in the circuit. As a mechanical analogy one may look upon the charged condenser as a weight attached to a spring which has been pulled away from its position or rest. To discharge the condenser we let go the weight, and it begins to oscillate backwards and forwards, and, after making a greater or less number of oscillations, finally comes to rest. The number of oscillations per second will depend upon the strength of the spring and the mass of the weight, which correspond with the capacity and self-induction in our electrical circuit. The number of oscillations before the weight finally comes to rest is determined by the friction which tends to stop the weight, or by the resistances and other losses in the electrical circuit.

In practice the aërial conductor acts as a Leyden jar or condenser. It is charged with electricity and allowed to discharge, the current oscillating backwards and forwards in the aërial during the discharge. In many installations Leyden jars or condensers are electrically connected to the aërial, so that the oscillations taking place in them are transmitted to the aërial. Any remarks, therefore, that I may make as to the oscillations which may be set up in condensers apply equally well to the oscillations in the aërial in wireless telegraphy.

For wireless telegraphy it is usual to charge the condenser or aërial by means of an induction coil or an alternator to a very high voltage, and it is allowed to discharge by means of a spark between the two electrodes which form the ends, so to speak, of a gap in the electrical circuit. As long as the pressure is low the spark gap is a perfect insulator; when the pressure becomes high enough, the air between the electrodes breaks down and a spark passes the gap, becomes conducting, and allows the condenser to discharge. The property of the spark gap of passing almost instantaneously from a condition of being an insulator for electricity to being an extremely good conductor for electricity is of the utmost value in the spark method of wireless telegraphy. The more perfectly the spark gap insulated before the discharge takes place, and the more perfectly it conducts after the discharge has taken place, the better it is for our purpose.

If I take two electrodes sufficiently far apart in air, and gradually raise the electrical pressure between them, the first indication that anything is going to happen is the formation of fine violet aigrettes on the more pointed or rougher parts of the electrodes. This is known as the brush discharge. By gradually raising the pressure, this brush discharge extends further out into the air, until finally the air between the two electrodes becomes so strained that it breaks down and the real spark passes.

The long thin spark that occurs in this case is not very suitable for wireless telegraphy, as its resistance is too high. Ordinary lightning flashes are good examples of long sparks on a very large scale. If instead of working with the electrodes far apart they are placed nearer together, and if the electrical pressure is supplied from a very powerful source, then directly the spark passes it forms a thick discharge having the appearance of a flame in which the nitrogen of the air is actually being burnt; a process which, it is hoped, in the future may have immense importance in the supply of artificial nitrates for agriculture. This flame-like discharge has a low electrical resistance, but has the effect that it so heats or modifies the air that it is difficult to get the air to insulate again, after one discharge, ready for the next.

If a large quantity of electricity is discharged through the spark gap, and if the spark lasts a very short time compared with the interval between successive sparks, then a highly-conducting spark can be obtained, as well as a good insulation between the sparking terminals when no discharge is passing.

In order to help to bring the gap back to its insulating condition after each discharge, many devices are employed, such as subdividing the spark into several shorter sparks, cooling the electrodes, blowing air across the spark gap, &c. When the condenser or antenna discharges through the spark gap, oscillations are set up which radiate Hertzian waves.

In practice in wireless telegraphy it is difficult to obtain a large number of oscillations during each discharge as corresponding with each oscillation; the antenna radiates energy. A large number of oscillations means, if we keep amplitude of each the same, that we are radiating a large quantity of energy. Besides this radiated energy, which is useful for transmitting messages, there is also energy wasted in heat in the spark gap, in the conductors, in the glass or other insulation of the condensers. It is this useless part which we require to make as small as possible.

I have lately had an opportunity to determine how many oscillations actually take place in a certain wireless transmission. The experiment was made by photographing the spark as seen in a mirror rotated at a very high speed, and it was found that each spark consisted of nine or ten complete oscillations.

If all the oscillations had been of equal strength or amplitude, and if the receiving circuit had been similar to my pendulum in my mechanical model, then there would be very little to be gained by increasing the number of oscillations. As the oscillations die away in the spark method, two or three times this number would probably be required for the best effect. As a matter of experiment, very good tuning was obtained with the wireless transmission referred to above.

As an example of the sharpness of tuning obtainable by the spark method, the following test carried out on the Lodge-Muirhead installation at Hythe may be of interest.

The station at Hythe had to receive messages from Elmer's End at a distance of fifty-eight miles over land, in spite of the fact that the Admiralty station at Dover, only $9\frac{1}{4}$ miles distant, was transmitting as powerfully as it could, in order to produce interference, and that the regular communications were going on in the Channel between the shipping. It was found possible with a difference of wave-length of 6 per cent. to cut out the interference from the Dover station.

In the arc method of producing continuous oscillations we employ, as before, a condenser and self-induction; but, instead of charging the condenser to a high voltage and allowing it to discharge by means of oscillations which die away, and then repeating the process over and over again, we actually maintain the condenser charging and discharging continuously without any intermission, so that we practically obtained a high-frequency alternating current in the aërial.

To impress the difference on your minds, I have an incandescent lamp, which I switch on and off rapidly about ten times, and then after a short time I repeat the same flickering of the light, and so on. The flickering of the light corresponds with the oscillations in the ordinary spark method, and the time spaces between the flickers represent the times during which the condenser or antenna is being charged ready to produce a fresh series of oscillations. In practice we may have as many as, say, a couple of hundred discharges of the condenser a second, and during each discharge we may get, say, ten complete oscillations, each oscillation lasting one-millionth of a second, if the wave-length is 300 metres; thus the total time that the condenser is discharging is only one one-hundred-thousandth of a second, or the five-hundredth part of the interval of time between two successive discharges. My lamp here flickers about five times per second, and makes ten flickers before it goes out; the total time that it is flickering is two seconds, and the time before it should start to flicker again to correspond with the practical wireless case is therefore 1000 seconds, or rather more than a quarter of an hour. If now I represent continuous oscillations, such as are obtained by the arc method with this lamp, I shall simply keep the lamp flickering continuously, and there will be no intervals whatever.

The arc method of producing continuous oscillations is founded on my musical arc. In order to explain this I must demonstrate some of the properties of the direct-current arc. If I vary the current flowing through the arc very slowly and note the potential difference corresponding with each value of the current, keeping everything else constant, I obtain a curve generally spoken of as the characteristic of the arc. These curves under different conditions have been very thoroughly investigated by Mrs. Ayrton.

With the carbon arc between electrodes in air the voltage decreases very rapidly when the current is gradually increased, starting from very low values. As the current becomes larger the rate of decrease of the voltage becomes less and less until it is, comparatively speaking, quite small, with a current of ten or twelve amperes. With the arc between metal electrodes similar results are obtained, except that the discontinuity in the curves, called the hissing point by Mrs. Ayrton, takes place at very small currents, generally well below one ampere.

With arcs burning in hydrogen, Mr. Upson has found that the curves are generally much steeper for the larger values of the current than for the corresponding arcs burning in air. This point is of great importance as explaining the value of the hydrogenic atmosphere used by Poulsen and referred to later.

In general, I may therefore say for the above arcs that increase in current through the arc is accompanied by decrease of the potential difference between its electrodes, and *vice versâ* decrease of the current causes increase in the potential difference; on the other hand, certain arcs, such as the arc between cored carbons, behave in an opposite manner, that is to say, current and potential difference increase and decrease together.

I demonstrated in 1900 that if I connect between the electrodes of a direct-current arc (or other conductor of electricity for which an increase in current is accompanied by a decrease in potential difference between the terminals) a condenser and a self-induction connected in series, I obtain in this shunt circuit an alternating current. I called this phenomenon the musical arc. The frequency of the alternating current obtained in this shunt circuit depends on the value of the self-induction and the capacity of the condenser, and may practically be calculated by Kelvin's well-known formula.

Besides the condition that an increase of current must be accompanied by a decrease in potential difference, it is necessary that the relative decrease in potential difference produced by a given increase in current, that is to say, the steepness of the characteristic, shall exceed a certain minimum value which depends on the losses in the shunt circuit. It is also necessary that an increase in current shall be accompanied by a decrease in potential difference, even when the current is varied very rapidly.

Let us consider what takes place when I connect this shunt circuit to an arc. At the moment of connection a current flows from the arc circuit into the condenser circuit, which tends to reduce the current flowing through the arc. This reduction of the current through the arc tends to raise the potential difference between its terminals, and causes still more current to flow into the condenser circuit, and I now have a condenser charged above the normal voltage of the arc. The condenser, therefore, begins to discharge through the arc, which increases the arc current and decreases the potential difference, so that the condenser discharges too much; the reverse process then sets in; the condenser becomes successively overcharged and undercharged, due to the fact that, instead of the potential difference between the terminals of the arc remaining constant and allowing the condenser to settle down with its proper corresponding charge, the potential difference actually decreases when the condenser is discharged and increases when it is charging, so as to help to keep up the flowing backwards and forwards of the current indefinitely.

The oscillograph wave forms show what is going on very clearly, and they show that in general the swing of the current in the condenser circuit attains such a magnitude that when the condenser is charging it takes the whole of the current away from the arc, so as to make the arc, although burning on a direct current circuit, a pulsatory arc. The pulsation of the current through the arc causes the vapour column to grow bigger and smaller, and the light to vary. When the vapour column grows bigger and smaller it displaces the air around it and produces a note the pitch of which is determined by the frequency of the current in the shunt circuit.

The values of the capacities of a series of condensers have been calculated by Kelvin's formula to give the frequencies corresponding with a musical octave, and the nearest values in an ordinary laboratory box of condensers have been taken and connected to a keyboard. The result shows how nearly Kelvin's law is obeyed.

With this apparatus I can demonstrate the importance of tuning in electrical circuits, and perform electrically some experiments which I have already performed mechanically earlier this evening. I use the large coil which forms the self-induction in the circuit shunting the arc as a transmitting circuit for wireless telegraphy by the magnetic induction or Preece method; and I have a receiving circuit consisting of a coil of wire connected to a small lamp, and not connected in any way to the transmitting circuit. At a certain short distance between the transmitting coil and the receiving coils, the indicating lamp lights if I cause my arc to sound *any* one of the notes of the octave, and so produce an alternating current of corresponding frequency in the transmitting coil. If I now tune the receiving circuit, by connecting a condenser in it, the lamp on the receiving circuit will light at about five times the distance; but it will only light when one definite note is sounded by the arc. These are the two distinct advantages of tuning, namely, greater distance and syntony, or responding to only one definite note.

For wireless telegraphy by means of Hertzian waves, based on my arc method, we require much higher frequencies in the shunt circuit. If we attempt to obtain this higher frequency from the ordinary arc burning between solid carbons in air, we find that above a certain limit the oscillations will no longer take place. This is due to the fact that we are varying the current through the arc at this higher frequency too quickly for an increase in current to be accompanied by a decrease in potential difference. I have demonstrated that if I only vary the current through the ordinary current arc sufficiently rapidly, then an increase in current is accompanied by a proportionate increase in the potential difference, and the arc behaves just like an ordinary resistance. If we work with very small current arcs, we can obtain high-frequency musical arcs burning in air either between carbon or metal electrodes.

In a paper read before the International Electrical Congress at St. Louis in 1904, Mr. Poulsen showed that, by placing the arc in a flame, it was possible to obtain higher frequencies than when the arc was burning in air. Following this up, Mr. Poulsen came to the conclusion that the best results were obtained when the arc was burning in hydrogen, or a gas containing hydrogen; and he further added a magnetic field around the arc somewhat similar to that which has been previously used by Elihu Thomson.

The arc burning in coal gas in a powerful transverse magnetic field was used by Poulsen in his early experiments to produce the high-frequency current necessary for wireless telegraphy between Lyngby and Esbjerg, in Denmark. This apparatus has been further improved, and is now employed by the Amalgamated Radio-Telegraph Company in their station at Cullercoats and the other stations that they are erecting.

In both the arc and the spark methods of wireless telegraphy we employ a high-frequency alternating current in the aërial conductor. The essential difference between the two methods lies in the fact that with the spark method our alternating current in the aërial conductor first increased to a maximum value and then dies away rapidly, making only a limited number of oscillations, whereas in the arc method the oscillations are maintained continuously of unvarying amplitude.

With the arc method we are further able to choose the number of consecutive oscillations which make up each signal sufficiently great to obtain the very best syntony. On the other hand, improvement in the arrangement and construction of the apparatus for the spark method has so increased the number of oscillations corresponding with each spark that it may be that we shall be able to obtain a sufficient number in each train to give as good syntony by this method as that obtained with the arc method.

The arc method seems eminently suitable for very high speeds of working. As the oscillations are quite continuous, we can cut them up into groups to form the dots and dashes of the Morse alphabet, just as if we were working with a continuous current such as is used on land lines, so that there seems no reason why as high a speed of working should not be obtained from the arc method of wireless telegraphy as is obtainable by automatic signalling on land lines; for it is to be noted that the dot or shortest signal of the Morse alphabet, even at a speed of three or four hundred words per minute, will last long enough to consist of many hundreds of oscillations of the current in the aërial, so that there will be plenty of oscillations in the group forming the dot to give good syntony.

Turning to the spark method for high working speeds, we find a difficulty in that the dot of the Morse alphabet must at least occupy the average time required to charge the condenser or aërial and produce one spark, and preferably sufficiently long for several. We are therefore obliged in the spark method to use a high rate of sparking for high-speed signalling. This difficulty has not become very serious with the present low speeds of sending. When we come to use considerable amounts of power to transmit messages over long distances, and we also require a high speed of working, the practical difficulty in constructing apparatus suitable for sufficiently rapid sparking will become serious.

Mr. Marconi in 1905 claimed to have already reached a speed of 100 words per minute by the spark method, and lately there has appeared in the technical Press examples of high-speed signalling by the British Post Office over a distance of fifteen miles in which readable signals were received at a speed of seventy words per minute.

Turning to the receiving end, almost all the receivers that have been used in the spark method can be equally well used for the arc method; for it must be remembered that the transmission in either case is affected by Hertzian waves traversing space, and that the only fundamental difference consists in the number of oscillations in each train of waves. It must be noted, however, that in those methods in which a telephone receiver is used it is necessary to break up the continuous oscillations of the arc method into groups succeeding one another sufficiently rapidly to produce an audible sound in the receiver; for in the spark method the sounds we hear in the receiver correspond with the succession of impulses of the diagram, one for each spark at the transmitter. This chopping up of the continuous wave-train so as to produce audible signals in the receiving apparatus can be done either at the transmitting end or in the receiving apparatus. An example of this latter method is Poulsen's ticker.

The question whether receiving apparatus can be arranged so as to receive messages from stations equipped with the spark apparatus and from stations equipped with the arc apparatus is a matter of enormous importance at the present moment in view of the probable ratification of the Berlin Convention, which imposes an obligation on all commercial stations to inter-communicate without regard to the make or system of transmitting apparatus employed. I am of the opinion that there will be no difficulty in carrying this into effect provided that the stations using the spark method send out long trains of waves, as they should do to obtain syntonic working, which is also called for by the Berlin Convention.

An extremely interesting development which is now progressing rapidly owing to the possibility of producing continuous oscillations by the arc method is wireless telephony. Suppose that we can vary the intensity of the oscillations in a manner corresponding with the vibrations of the air which constitute sound and speech, then we should obtain at the receiving stations a train of Hertzian waves the amplitude of which varies in a corresponding way; by allowing these waves to act on a telephonic receiver which is sensitive to the intensity of the waves we shall obtain in the telephone a reproduction of the sounds. This has actually been carried into effect by employing an ordinary microphone to modify the current through the transmitting arc so as to vary the intensity of the oscillation current produced, and by employing what is known as a point-detector and a telephone at the receiving station.

Another method which may be used consists in causing the microphone to vary the frequency of the oscillations of the generator, and by arranging the receiver so that it is more or less strongly affected according to the frequency of the received waves.

I am informed that experiments have been made in wireless telephony in Berlin by the Amalgamated Radio-Telegraph Company between their stations in Mathieustrasse and Weissensee, 6·5 km. apart, with good results, and that it is now proposed to equip the stations at Oxford and Cambridge for the further perfecting of this application.

It is greatly to be desired that wireless telephony may develop rapidly, as it seems to me that for the purpose of communicating with ships wireless telephony will have great advantages over wireless telegraphy.

I am deeply indebted to Mr. Colson for all the facilities that he has placed at my disposal, and to his engineers for their assistance, which has enabled me to carry out the experiments in the lecture; and I have also to thank the Tramway Department for the special supply of current.

THE BRITISH ASSOCIATION.

SECTION K.

BOTANY.

OPENING ADDRESS BY PROF. J. B. FARMER, M.A., F.R.S., PRESIDENT OF THE SECTION.

CUSTOM has decreed that those who are charged with the responsibilities that to-day fall to my lot should endeavour to address themselves to the consideration of matters such as they may deem to be of advantage to others, or, at any rate, of interest to themselves. It is not, perhaps, always easy to combine these two courses, and if I choose the less altruistic one I experience the smaller compunction in doing so because the undisturbed repose that most Addresses enjoy when they have been decently put away between the covers of our Annual Report seems to indicate that an attempt to express the passing thought, however ephemeral its interest, may not be the worst introduction to the business of the advancement of our science.

Any attempt to give a survey of the progress and present position of botanical science, even were so large a task at all within my power, has almost ceased to be necessary, owing to the enterprise which has so admirably provided for its adequate fulfilment elsewhere. I propose, therefore, to try to put together, in a form as intelligible as I can, the result of reflections on some of the aspects of botany that are often not seriously regarded; perhaps because they belong rather to the nebulous region of speculation than to the hard (and sometimes dry) ground of accepted fact.

I am by no means blind to the risks incurred in venturing on such a course, but I believe that a glance directed, however imperfectly, towards some of the less obvious sides of our science may not be altogether futile, even though the attempts should evoke the criticism:

Dum vitat humum, nubes et inania captat.

The problems that confront us as botanists are far more numerous and far more complex than formerly. We are attached to a science that is rapidly growing, and this rapid advance is carrying with it a process of corresponding differentiation. Some years ago a danger arose, even within this Association, that we might have replaced differentiation, that quality which distinguishes the higher organisms, by a process of fission which is more characteristic of the lower ranks of life.

The products of the threatened fission would doubtless have pursued divergent paths, and the botanist of to-day would have been the poorer for it. He would have been lost to physiology, and all that physiology implies. Happily that danger was averted, and, to our lasting advantage as members of the botanical organism, our science escaped disruption, and physiological investigation still continues both to inspire, and to be aided by, other branches of botanical research. A physiological conception of morphological phenomena is the one that to me seems to afford the broadest outlook over our territory. It serves to check a tendency towards mere formalism on the one hand and to correct the not less baneful effects of a superficial teleology on the other. Both are real dangers, and we have all encountered examples of them.

In rating highly the value of maintaining a physiological attitude of mind towards the phenomena presented by the vegetable kingdom, one is mainly influenced by the logical necessity which such a position carries with it of constantly attempting to analyse our problems, as far as may be possible, into their chemical and physical components. It seems to me that this is the only really profitable method that we can bring to bear on the difficulties that lie before us, because in using it we are constantly forced to consider the *causes* which have led to the final result. Of course I am well aware that to some minds the very attempt to apply such a method beyond a very limited range may appear futile, or at least premature. But the goal of all scientific inquiry lies in the ultimate ascertaining of cause and effect, and only with this knowledge can we hope to get control over the results.

Chemistry and physics each present to their followers problems far more elementary than those with which we have to grapple; but the explanation of the great advances which these two branches have made lies essentially in the fact that an analysis of the factors involved has enabled the investigator intelligently to interfere with, and so to control, the mode of presentation of the reacting bodies to each other. And our own special problems, whether we confine ourselves to the simpler ones, or whether we approach the obscurer matters of organisation, heredity, and the like, are assuredly susceptible of a similar method of treatment. We can never expect to get further than to be able to modify the mode of presentation to each other of the materials that interact to produce what we call the manifestations of life; but the measure of our achievement will depend on the degree in which we are successful in accomplishing this.

Indeed, until we have analysed the nature of the reacting bodies, and also especially the particular conditions under which the reactions themselves are conducted, we are avoiding the first steps in the direction of ultimate success. At present, when we desire to know the taxonomic value of this or that character, we are perforce largely guided by purely empirical considerations. We find, for example, that a particular structure is very constant through a group of species otherwise closely resembling each other, and we rightly (but quite empirically) regard the possession of that character as a valuable indication of affinity within that alliance. But the very same feature in other groups may be highly variable, and lack all importance amongst them for