could be reflected and converged by cylindrical parabolic mirrors. He operated with electric waves two or three feet in wave-length. Experiments precisely analogous to optical ones can be performed with somewhat shorter waves. Marconi in his first British patent (No. 12039 of 1896) brought forward the idea of focusing a beam of electric radiation for telegraphic purposes on a distant station by means of parabolic mirrors, and tried this method successfully on Salisbury Plain up to a distance of about a couple of miles. As, however, the wave­length necessary to cover any considerable distance must be at least *200* or 300 ft., it becomes impracticable to employ mirrors for reflection. The process of reflection in the case of a wave motion involves the condition that the wave-length shall be small compared with the dimensions of the mirror, and hence the attempt to reflect and converge electric waves 1000 ft. in length by any mirrors which can be practically constructed would be like attempting optical experiments with mirrors one-hundred-thousandth of an inch in diameter.

Another closely connected problem is that of locating or ascertaining the direction of the sending station. To deal with the latter question first, one of the earliest suggestions was that of J. S. Stone *(U.S.A. Pat. Spec.,* Nos. 716134 and 716135, also reissue No. 12148), who proposed to place two receiving antennae at a distance of half a wave-length apart. If these two were broadside on to the direction of the sending station oscillations in the same phase would be produced in them both, but if they were in line with it then the oscillations would be in opposite phases. It was then proposed to arrange a detector so that it was affected by the algebraic sum of the two oscilla­tions, and by swivelling round the double receiving antennae to locate the direction of the sending station by finding out when the detector gave the best signal. Even if the proposal had been practicable with waves 1000 or 2000 ft. in length, which it is not, it is essentially based upon the supposition that the damping of the waves is negligible. A proposal was made by L. de Forest *(U.S.A. Pat. Spec.,* No. 771818) to employ a receiving antenna consisting of vertical wires held in a frame which could be swivelled round into various positions and used to locate the position of the sending station by ascertaining the position in which the frame must be placed to create in it the maximum oscillatory current. Other inventors had pro­fessed to find a solution of the problem by the use of looped receiving antennae or antennae inclined in various directions.

G. Marconi, however, gave in 1906 the first really practical solu­tion of the problem by the use of bent transmitting and receiving antennae. He showed that if an antenna were constructed with a short part of its length vertical and the greater part horizontal, the lower end of the vertical part being earthed, and if oscillations were created in it, electric waves were sent out most powerfully in the plane of the antenna and in the direction opposite to that in which the free end pointed. Also he showed that if such an antenna had its horizontal part swivelled round into various directions the current created in a distant receiver antenna varied with the azimuth, and when plotted out in the form of a polar curve gave a curve of a peculiar figure-of-8 shape.@@1 The mathematical theory of this antenna was given by J. A. Fleming *(Proc. Roy. Soc.,* May 1906, also *Phit. Mag.,* December 1906). Marconi also showed that if such a bent receiving antenna was used the greatest oscillations were created in it when its insulated end pointed directly away from the sending station. In this manner he was able to provide means for locating an invisible sending station. F. Braun also gave an interesting solution of the problem of directive telegraphy.@@2 In his method three vertical antennae are employed, placed at equi­distant distances, and oscillations are created in the three with a certain relative difference of phase. The radiations interfere in an optical sense of the word, and in some directions reinforce each other and in other directions neutralize each other, so making the resultant radiation greater in some directions than others. Very valuable work in devising forms of antennae for directive radio-telegraphy has been done by MM. Bellini and Tosi, who have devised instruments, called radiogonimeters, for projecting radiation in required directions and locating the azimuth of a transmitting station.

*Improvements in the Production of Continuous Trains of Elec­tric Waves.—*All the above-described apparatus employed in

connexion with wireless telegraph transmitters, in which the oscillatory discharge of a condenser is used to create oscillations in an antenna, labours under the disadvantage that the time occupied by the oscillations is a very small fraction of the total time of actuation. Thus, for instance, when using an induction coil or transformer to charge a condenser, it is not generally convenient to make more than 50 discharges per second, but each of these may create a train of oscillations consisting of, say, 20 to 50 waves. Supposing, then, that these waves are 1000 ft. in wave-length, the frequency of the oscillations would by 1,000,000 per second, and accordingly 50 of these waves would be emitted in 1∕20,000th part of a second; and if there are 50 groups of waves per second, the total time occupied by the oscillations in a second would only be 1∕400th part of a second. In other words, the intervals of silence are nearly 400 times as long as the intervals of activity. It very soon, therefore, be­came clear to inventors that a very great advantage would be gained if some means could be discovered of creating high frequency oscillations which were not intermittent but con­tinuous. The condenser method of making oscillations is analogous to the production of air vibrations by twanging a harp string at short intervals. What is required, however, is something analogous to an organ pipe which produces a con­tinuous sound.

A method of producing these oscillations devised by Valdemar Poulsen is based upon the employment of what is called a musical arc. W. Duddell discovered in 1900 that if a continuous current carbon arc had its carbon electrodes connected by a condenser in series with an inductance, then under certain conditions oscillations were excited in this condenser circuit which appeared to be con­tinuous. Poulsen immensely improved this process by placing the arc in an atmosphere of hydrogen, coal-gas or some other non­oxidizing gas, and at the same time arranging it in a strong magnetic field.@@3 In this way he was able to produce an apparatus which created continuous trains of oscillations suitable for the purposes of wireless telegraphy. The so-called musical arc of Duddell has been the subject of considerable investigation, and physicists are not entirely in accordance as to the true explanation of the mode of production of the oscillations. It appears, however, to depend upon the fact that an electric arc is not like a solid conductor. Increase in the voltage acting upon a solid conductor increases the current through it, but in the case of the electric arc an increase in current is accompanied by a fall in the difference of potential of the carbons, within certain limits, and the arc has therefore been said to possess a negative resistance.@@4

Poulsen's method of producing continuous or undamped electrical waves has been applied by him in radio-telegraphy. The electric arc is formed between cooled copper (positive) and carbon (negative) electrodes in an atmosphere of hydrogen or coal-gas. In recent apparatus, to enable it to be used on board ship, a hydrogeneous spirit is used which is fed drop by drop into the chamber in which the arc is worked. Across the arc is a transverse or radial magnetic field, and the electrodes are connected by an oscillatory circuit consisting of a . condenser and inductance. The antenna is con­nected either directively or inductively with the circuit. At the receiving end are a similar antenna and resonant circuit, and a telephone is connected across one part of the latter through an automatic interrupting device called by Poulsen a “ ticker." To send signals the continuous or nearly continuous train of waves must be cut up into Morse signals by a key, and these are then heard as audible signals in the telephone. An important modification of this method enables not only audible signals but articulated words to be transmitted, and gives thus a system of wireless telephony. This has. been achieved by employing a microphone transmitter at the sending end to vary the amplitude but not the wave-length of the emitted waves, and at the receiving end using an electrolytic receiver, which proves to be not merely a qualitative but also a quantitative instrument, to make these variations audible on a telephone. The system has already been put into practice in Germany by the *Gesellschaft für drahtlose Telegraphie,* and in the United States by R. A. Fessenden. This last-named inventor has

@@@1 See G. Marconi, *Proc. Roy. Soc.,* 1906, A 77, p. 413.

@@@2 F. Braun, *The Electrician,* May 25 and June 1, 1906.

@@@3 See V. Poulsen, *Brit. Pat. Spec.,* No. 15599 of 1903; also a lecture given in London, November 27, 1906, “On a Method of producing undamped Electrical Oscillations and their employment in Wireless Telegraphy," *Electrician,* 1906, 58, p. 166.

@@@4 Reference may be made to W. Duddell, “ On Rapid Variations in the Current through the Direct Current Arc,” *Journ. Inst. Elec. Eng.,* 1900, 30, p. 232; P. Janet, "On Duddell's Musical Arc.” *Comptes rendus,* 1902, 134, p. 821; S. Maisel, *Physik. Zeits.,* September 1, 1904, and January 15, 1905, or *L’Éclairage électrique,* 1904, 41, p. 186; J. A. Fleming, *The Principles of Electric Wave Telegraphy,* 1906, p. 73.