of a condenser produces an electric spark which under proper conditions creates an effect propagated out into space as an *electric wave.* He employed as a detector of this wave a simple, nearly closed circuit of wire called a Hertz resonator, hut it was subsequently discovered that the metallic microphone of D. E. Hughes was a far more sensitive detector. The peculiar action of electric sparks and waves in reducing the resistance of discontinuous conductors was rediscovered and investigated by Calzecchi Onesti,@@1 by Branly,@@2 Dawson Turner,@@3 Minchin, Lodge,@@4 and many others. Branly was the first to investigate and describe in 1890 the fact that an electric spark at a distance had the power of changing loose aggregations of metallic powders from poor to good electric conductors, and he also found that in some cases the reverse action was produced. Lodge parti­cularly studied the action of electric waves in reducing the resistance of the contact between two metallic surfaces such as a plate and a point, or two balls, and named the device a "coherer.” He constructed one form of his coherer of a glass tube a few inches long filled with iron borings or brass filings, having contact plates or pins at the end. When such a tube is inserted in series with a single voltaic cell and galvanometer it is found that the resistance of the tube is nearly infinite, provided the filings are not too tightly squeezed. On creating an electric spark or wave in the neighbourhood of the tube the resistance suddenly falls to a few ohms and the cell sends a current through it. By shaking or tapping the tube the original high resistance is restored. In 1894 he exhibited apparatus of this kind in which the tapping back of the tube of filings was effected automatically. He ascribed the reduc­tion of resistance of the mass to a welding or cohering action taking place between the metallic particles, hence the name “ coherer.” But, as Branly showed, it is not universally true that the action of an electric wave is to reduce the resistance of a tube of powdered metal or cause the particles to cohere. In some cases, such as that of peroxide of lead, an increase of resistance takes place.

Between 1894 and 1896 G. Marconi gave great attention to the improvement of devices for the detection of electric waves.

He made his sensitive tube, or improved coherer, as follows:—A glass tube having an internal diameter of about 4 millimetres has sealed into it two silver plugs PP by means of platinum wires WW (fig. 37); the opposed faces of these plugs are perfectly smooth, and are placed within a millimetre of each other. The interspace is filled with a very small quantity of nickel and silver filings, about 95 per cent. nickel and 5 per cent. silver, sufficient to fill loosely about half the cavity between the plugs, which fit tightly into the tube.@@5 The tube is then exhausted of its air, and attached to a bone or glass rod as a holder. This form of electric wave detector proved itself to be far more certain in operation and sensitive

than anything previously invented. The object which Marconi had in view was not merely the detection of electric waves, but their utilization in practical wireless telegraphy. Sir William Crookes had already suggested in 1892 in the *Fortnightly Review* (February 1892) that such an application might be

made, but no one had overcome the practical difficulties or actually shown how to do it.

G. Marconi, however, made the important discovery that if his sensitive tube or coherer had one terminal attached to a metal plate lying on the earth, or buried in it, and the other to an insulated plate elevated at a height above the ground, it could detect the presence of very feeble electric waves of a certain kind originating at a great distance. In conjunction with the above receiver he employed a transmitter, which consisted of a large induction or spark coil S having its spark balls placed a few millimetres apart; one of these balls was connected to an earth

plate E and the other to a plate or wire insulated at the upper end and elevated above the surface of the earth. In the primary circuit of the induction coil I he placed an ordinary signalling key K, and when this was pressed for a longer or shorter time a torrent of electric sparks passed between the balls, alternately charging and discharging the elevated con­ductor A1 and creating electrical oscillations (see Electro- Kinetics) in the wire. This elevated conductor is now called the *antenna, aerial wire,* or *air wire.* At the receiving station Marconi connected a single voltaic cell B1 and a sensitive tele­graphic relay R in series with his tube of metallic filings C, and interposed certain little coils called choking coils. The relay was employed to actuate through a local battery B2 an ordinary Morse printing telegraphic instrument Μ. One end of the sensitive tube was then connected to the earth and the other end to an antenna or insulated elevated conductor A2. Assum­ing the transmitting and receiving apparatus to be set up at distant stations (see fig. 38@@6), the insulated wires or plates being upheld by masts, its operation is as follows:—When the key in the primary circuit of the induction coil is pressed the transmitting antenna wire is alternately charged to a high potential and discharged with the production of high frequency oscillations in it. This process creates in the space around electric waves or periodic changes in electric and magnetic force round the antenna wire. The antenna wire, connected to one spark ball of the induction coil, must be considered to form with the earth, connected to the other spark ball, a condenser. Before the spark happens lines of electrostatic force stretch from one to the other in curved lines. When the discharge takes place the ends of the lines of electric force abutting on the wire run down it and are detached in the form of semi­loops of electric force which move outwards with their ends on the surface of the earth. As they travel they are accompanied by lines of magnetic force, which expand outwards in ever­widening circles.@@7 The magnetic and electric forces are directed alternately in one direction and the other, and at distances which are called multiples of a *wave length* the force is in the same direction at the same time, but in the case of damped waves has not quite the same intensity. The force at any one point also varies cyclically, that is, is varying at any one point

*@@@1 Nuovo cimento,* series iii. vol. xvii.

*@@@2 Comptes rendus,* vols. cxi., cxii.; see also *The Electrician,* xl. 87, 91, 166, 235, 333 and 397; xli. 487; xlii. 46 and 527; and x!iii. 277.

*@@@3 Report Brit. Assoc.,* 1892.

@@@4 Lodge, *Signalling through Space without Wires,* 3rd ed., p. 73, 1899.

@@@5 See G. Marconi, *Brit. Pat. Spec.,* 12039 of 1896.

@@@6 Figures 38, 39, 41, 42, 44, 45, 46, 47, 48 and 49 are drawn from Professor J. A. Fleming's *Electric Wave Telegraphy,* by per­mission of Longmans, Green & Co.

@@@7 For a more complete account of the nature of an electric wave the reader is referred to Hertz’s *Electric Waves,* and to the article Electric Wave. See also *The Principles of Electric Wave Tele­graphy,* by J. A. Fleming.