and spark gap, has the same natural time period of oscillation as the *open* circuit consisting of the antenna, secondary coil and adjustable inductance. When this is the case, if discharges are made across the spark gap oscillations are excited in the closed circuit, and these induce other syntonic oscillations in the antenna circuit. J. A. Fleming devised an arrangement in which a multiple transformation takes place, two oscillation circuits being inter­linked inductively, and the last one acting inductively on the open or antenna circuit. J. S. Stone similarly devised a multiple in­ductive oscillation circuit with the object of forcing on the antenna circuit a single oscillation of definite frequency.@@1 In the case of the inductive mode of exciting the oscillations an important quantity is the *coefficient of coupling* of the two oscillation circuits. If L and N are the inductances of any two circuits which have a co­efficient of mutual inductance M, then M∕√(LN) is called the coefficient of coupling of the circuits and is generally expressed as a percentage. Two circuits are said to be closely coupled when this coefficient is near unity and to be loosely coupled if it is very small. It can be shown that if two circuits, both having capacity (C) and inductance (L), are coupled together inductively, then, when oscillations are set up in one circuit, oscillations of two periods are excited in the other differing in frequency from each other and from the natural frequency of the circuit. If the two circuits are in tune so that the numerical product of capacity and inductance of each circuit is the same or C1L1 = C2L2+CL and if *k* is the coefficient of coupling then the natural frequency of each circuit is *n*=1*∣2π∙f* (CL), and when coupled two oscillations are set up in the secondary circuit having frequencies *nl* and n2 such that Wι=n∕√ (ι-⅛) and *n1=n∣^ (ι+k).* Since in all cases of

wave motion the wave-length λ is connected with the frequency *n* and the velocity of propagation *v* by the relation *v = nλ,* it follows that from such an inductively coupled tuned antenna electric waves of two wave-lengths are sent out having lengths λι and λι such that λι = λ√(l-⅛) and λ2 = λ√(l⅛⅛), where λ is the natural wave-length. It is seen that as the coupling ⅛ becomes small these two wave­lengths coalesce into one single wave length. Hence there are advantages in employing a very loose coupling.

(iii) The antenna may be direct-coupled to the closed oscillatory circuit in the manner suggested by. F. Braun, A. Slaby and O. Lodge. In this case a closed condenser circuit is formed with a battery of Leyden jars, an inductance coil and a spark gap, and oscillations are excited in it by discharges created across the spark gap by an induction coil or transformer. One end of the inductance coil is connected to the earth, and some other point on the closed con­denser circuit to an antenna of appropriate length. When oscilla­tions are created in the closed circuit syntonic oscillations are created in the antenna and electric waves radiated from it (fig. 41). In many cases additional condensers or inductance coils are inserted in various places so that the arrangement is somewhat disguised, but by far the larger part of the electric wave wireless telegraphy in 1907 was effected by transmitters having antennae either in­ductively or directly coupled to a closed condenser circuit containing a spark gap.

In practical wireless telegraphy the antenna is generally a collec­tion of wires in fan shape upheld from one or more masts or wooden towers. Sometimes the prolongations of these wires are carried horizontally or dipped down so as to form an umbrella antenna (fig. 42). The lower ends of these wires are connected through the secondary coil of an oscillation transformer to an earth plate, or to a large conductor placed on or near the earth called a “ balancing capacity.” If the direct coupling is adopted then the lower end of the antenna is. connected directly to the condenser circuit. The main capacity in this last circuit consists of a battery of Leyden

jars or of Leyden panes immersed in oil or some form of air con­denser, and the inductance coil or primary circuit of the oscillation transformer consists of a few turns of highly insulated wire wound on a frame and immersed in oil. The oscillations are controlled either by a key inserted in the primary circuit of the exciting in­duction coil or transformer, or by a key cutting in and out of the primary condensers or throwing inductance in and out of the closed oscillation circuit. In one of these ways the oscillations can be created or stopped at pleasure in the radiating antenna, and hence groups of electric waves thrown off at will.

*Production of Electric Waves of Large Amplitude.—*In creating powerful electric waves for communication over long distances it is necessary to employ an alternating current transformer (see Transformers) supplied with alternating currents from a low frequency alternator D driven by an engine to charge the condenser (fig. 43). The transformer T1 has its secondary or high-pressure terminals connected to spark balls Si, which are also connected by a circuit consisting of a large glass plate condenser C1 and the primary circuit of an air-core trans­former T2, called an oscillation transformer. The secondary circuit of this last is either connected between an aerial A and the earth E, or it may be again in turn connected to a second pair of spark balls S2, and these again to a second con­denser C2, oscillation transformer T2, and the aerial A. In order to produce electric oscillations in the system, the first or alternating current transformer must charge the condenser con­nected to its secondary terminals, but must not produce a permanent electric arc between the balls. Various devices have been suggested for extinguishing the arc and yet allowing the condenser oscillatory discharge to take place. Tesla effected this purpose by placing the spark balls transversely in a powerful magnetic field. Elihu Thomson blows on the spark balls with a powerful jet of air. Marconi causes the spark balls to move rapidly past each other or causes a studded disk to move between the spark balls. J. A. Fleming devised a method which has prac­tical advantages in both preventing the arc and permitting the oscillatory currents to be controlled so as to make electric wave signals. He inserts in the primary circuit of the alternating

current transformers one or more choking or impedance coils R1, R2 (fig. 43), called “ chokers,” which are capable, one or all, of being short-circuited by keys K1, K2. The impedance of the primary or alternator circuit is so adjusted that when both the chokers are in circuit the current flowing is not sufficient to charge the condensers; but when one choker is short-circuited the impedance is reduced so that the condenser is charged, but the alternating arc is not formed. In addition it is necessary to

@@@1 See J. S. Stone, *U.S.A.* *Pat. Spec.,* Nos. 714756 and 714831.