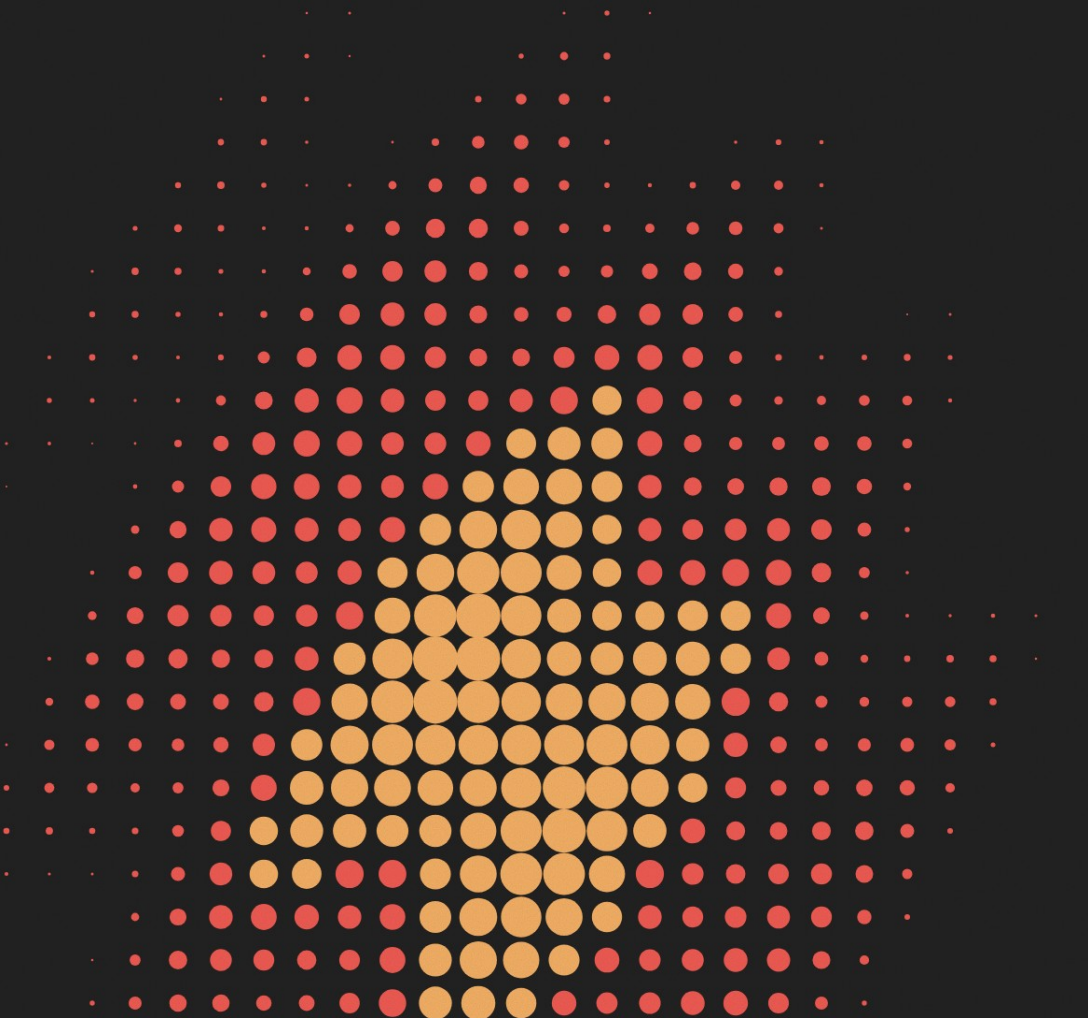




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First published: 1903
Public domain edition

JVA Editora



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[From the POPULAR SCIENCE MONTHLY, June-December, 1903.]

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HERTZIAN WAVE WIRELESS TELEGRAPHY.^[1]

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THE immense public interest which has been aroused of late years in the subject of telegraphy without connecting wires has undoubtedly been stimulated by the

The achievements of Mr. Marconi in effecting communication over great distances by means of Hertzian waves. The periodicals and daily journals, which are the chief avenues through which information reaches the public, whilst eager to describe in a sensational manner these wonderful applications of electrical principles, have done little to convey an intelligible explanation of them. Hence it appeared probable that a service would be rendered by an endeavour to present an account of the present condition of electric wave telegraphy in a manner acceptable to those unversed in the advanced technicalities of the subject, but acquainted at least with the elements of electrical science. It is the purpose of these articles to attempt this task. We shall, however, limit the discussion to an account of the scientific principles underlying the operation of this particular form of wireless telegraphy, omitting, as far as possible, references to mere questions of priority and development.

The practical problem of electric wave wireless telegraphy, which has been variously called Hertzian wave telegraphy, Marconi telegraphy, or spark telegraphy (*Funkentelegraphie*), is that of the production of an effect called an electric wave or train of electric waves, which can be sent out from one place, controlled, detected at another place, and interpreted into an alphabetic code. Up to the present time, the chief part of that intercommunication has been effected by means of the Morse code, in which a group of long and short signs form the letter or symbol. Some attempts have been made with more or less success to work printing telegraphs and even writing or drawing telegraphs by Hertzian waves, but have not passed beyond the experimental stage, whilst wireless telephony by this means is still a dream of the future.

We shall, in the first place, consider the transmitting arrangements and, incidentally, the nature of the effect or wave transmitted; in the second place, the receiving appliances; and, finally, discuss the problem of the isolation or secrecy of the intelligence conveyed between any two places.

The transmitter used in Hertzian wave telegraphy consists essentially of a device for producing electric waves of a type which will travel over the surface of the land or sea without speedy dissipation, and the important element in this arrangement is the *radiator*, by which these waves are sent out. It will be an advantage to begin by explaining the electrical action of the radiator, and then proceed to discuss the details of the transmitting appliances.

It will probably assist the reader to arrive most easily at a general idea of the functions of the various portions of the transmitting arrangements, and in particular of the radiator, if we take as our starting point an analogy which exists between electric wave generation for telegraphic purposes and air wave generation for sound signal purposes. Most persons have visited some of the large lighthouses which exist around our coasts and have there seen a steam or air *siren*, as used for the production of sound signals

during fogs. If they have examined this appliance, they will know that it consists, in the first place, of a long metal tube, generally with a trumpet-shaped mouthpiece. At the bottom of this tube there is a fixed plate with holes in it, against which revolves another similarly perforated plate. These two plates separate a back chamber or wind chest from the tube, and the wind chest communicates with a reservoir of compressed air or a high-pressure steam boiler. In the communication pipe there is a valve which can be suddenly opened for a longer or shorter time. When the movable plate revolves, the coincidence or non-coincidence of the holes in the two plates opens or shuts the air passage way very rapidly. Hence when the blast of air or steam is turned on, the flow is cut up by the revolving plates into a series of puffs which inflict blows upon the stationary air in the siren tube. If these blows come at the rate, say, of a hundred a second, they give rise to aerial oscillations in the tube, which impress the ear as a deep, musical note or roar; and this continuous sound can be cut up by closing the valve intermittently into long and short periods, and so caused to signal a letter according to the Morse code, denoting the name of the lighthouse. In this case the object is to produce: first, aerial vibrations in the tube, giving rise to a train of powerful air waves; secondly, to intermit this wave-train so as to produce an intelligible signal; and thirdly, to transmit this wave as far as possible through space.

The production of a sound or air wave can only be achieved by administering a very sudden blow to the general mass of the air in the tube. This impulse must be sufficient to call into operation the inertia and elastic qualities of the air. It is found, moreover, that the amplitude of the resulting wave, or the loudness of the sound, is increased by suitably proportioning the length of the siren pipe and the frequency of the air puffs; whilst the distance at which it is heard depends also in some degree upon the form of the mouthpiece.

Inside the siren tube, when it is in operation, the air molecules are in rapid vibratory motion in the direction of the length of the tube. If we could at any one instant examine the distribution and changes of air pressure in the tube, we should find that at some places there are large, and at others small, variations in air pressure. These latter places are called the *nodes* of pressure. At the pressure nodes, however, we should find large variations in the velocity of the air particles, and these points are called the *antinodes* of velocity. In those places at which the pressure variation is greatest, the velocity changes are least, and *vice versa*. Outside the tube, as a result of these air motions in it, we have a hemispherical air wave produced, which travels out from the mouthpiece as a centre; and if we could examine the distribution of air pressure and velocity through all external space, we should find a distribution which is periodic in space as well as time, constituting the familiar phenomenon of an air wave.

Turning then to consider the production of an electric, instead of an air wave, we notice in the first place that the medium with which we are concerned is the *ether* filling all space. This ether permits the production of physical changes in it which are analogous to, but not identical in nature with, the pressures and movements which constitute a sound wave. The Hertzian radiator is an appliance for acting on the ether as the siren acts on the air. It produces a wave in it, and it can be shown that all the parts of the above described siren apparatus have their electrical equivalents in the transmitter employed in Hertzian wave wireless telegraphy.

To understand the nature of an electric wave we must consider, in the first place, some properties of the ether. In this medium we can at any place produce a state called *electric displacement* or *ether strain* as we can produce compression or rarefaction in air; and, just as the latter changes are said to be created by mechanical force, so the former is said to be due to *electric force*. We can not define more clearly the nature of this ether strain or displacement until we know much more about the structure of the ether than we do at present. We can picture to ourselves the operation of compressing air as an approximation of the air molecules, but the difficulty of comprehending the nature of an electric wave arises from the fact that we cannot yet definitely resolve the notion of electric strain into any simpler or more familiar ideas.

We have to be content, therefore, to disguise our present ignorance by the use of some descriptive term, such as *electric strain*, *electrostatic strain* or *ether strain*, to describe the directed condition of the space around a body in a state of electrification which is produced by electric force. This electric strain is certainly not of the nature of a compression in the ether, but much more akin to a twist or rotational strain in a solid body.

For our present purpose it is not so necessary to postulate any particular theory of the ether as it is to possess some consistent hypothesis, in terms of which we can describe the phenomena which will concern us. These effects are, as we shall see, partly states of electrification on the surface or distributions of electric current in wires or rods, and partly conditions in the space outside them, which we are led to recognise as distributions of electric strain and of an associated effect called *magnetic flux*.

We find such a theory at hand at the present time in the electronic theory of electricity, which has now been sufficiently developed and popularised to make it useful as, a descriptive hypothesis.^[2] This theory has the great recommendation that it offers a means of abolishing the perplexing dualism of ether and ponderable matter, and gives a definite and, in a sense, objective meaning to the word electricity. In this physical speculation, the chief subject of contemplation is the electron, or ultimate particle of negative electricity, which, when associated in greater or less number with a matrix of some description, forms the atom of ponderable matter. To avoid further hypothesis,

this matrix may be called the *co-electron*; and we shall adopt the view that a single chemical atom is a union of a *co-electron* with a surrounding envelope or group of electrons, one or more of the latter being detachable. We need not stop to speculate on the structure of the atomic core or *co-electron*, whether it is composed of positive and negative electrons or of something entirely different. The single electron is the indivisible unit or atomic element of so-called negative electricity, and the neutral chemical atom deprived of one electron is the unit of positive electricity. On this hypothesis, the chemical atom is to be regarded as a microcosm, a sort of a solar system in miniature, the component electrons being capable of vibration relatively to the atomic centre of mass. Furthermore, from this point of view it is the electron which is the effective cause of radiation. It alone has a grip on the ether whereby it is able to establish wave motion in the latter.

Dr. Larmor has developed in considerable detail an hypothesis of the nature of an electron which makes it the centre or convergence-point of lines of a self-locked ether strain of a torsional type. The notion of an atom merely as a "centre of force" was one familiar to Faraday and much supported by Boscovich and others. The fatal objection to the validity of this notion as originally stated was that it offers no possibility of explaining the inertia of matter. On the electronic hypothesis, the source of all inertia is the inertia of the ether, and until we are able to dissect this last quality into anything simpler than the time-element involved in the production of an ether strain or displacement, we must accept it as an ultimate fact, not more elucidated because we speak of it as the inductance of the electron.

We postulate, therefore, the following ideas: We have to think of the ether as a homogeneous medium in which a strain of some kind, most probably of a rotational type, is possible. This strain appears only under the influence of an appropriate stress called the electric force, and disappears when the force is removed. Hence to create this strain necessitates the expenditure of energy. An electron is a centre or convergence-point of lines of permanent ether strain of such nature that it cannot release itself. To obtain some idea of the nature of such a structure, let us imagine a flat steel band formed into a ring by welding the ends together. There is then no torsional strain. If, however, we suppose the band cut in one place, one end then given half a turn and the cut ends again welded, we shall have on the band a self-locked twist, which can be displaced on the band, but which can not release itself or be released except by cutting the ring. Hence we see that to make an electron in an ether possessing torsional elasticity would require creative energy, and when made, the electron cannot destroy itself except by occupying simultaneously the same place as an electron of opposite type. Every electron extends, therefore, as Faraday said of the atom, throughout the universe, and the properties that we find in the electron are only there because they are first in the universal medium, the ether. Every line of ether or electric strain must,

therefore, be a self-closed line, or else it must terminate on an electron and a co-electron.

So far we have only considered the electron at rest. If, however, it moves, it can be mathematically demonstrated that it must give rise to a second form of ether strain which is related to the electric strain as a twist is related to a thrust or a vortex ring to a squirt in liquid or a rotation to a linear progression. The ether strain which results from the lateral movement of lines of electric strain is called the *magnetic flux*, and it can be mathematically shown that the movement of an electron, consisting when at rest of a radial convergence of lines of electric strain, must be accompanied by the production of self-closed lines of magnetic flux, distributed in concentric circles or rings round it, the planes of these circles being perpendicular to the direction of motion of the electron.

This electronic hypothesis, therefore, affords a basis on which we can build up a theory affording an explanation of the nature of the intimate connection known to exist between ether, matter and electricity. The electron is the connecting link between them all, for it is in itself a centre of convergent ether strain; isolated, it presents itself as electricity of the negative or resinous kind; and, in combination with co-electrons and other electrons, it forms the atoms of ponderable matter. At rest the electron or the co-electron constitutes an electric charge, and when in motion it is an electric current. A steady flux or drift of electrons in one direction and co-electrons in the opposite direction is a continuous electric current, whilst their mere oscillation about a mean position is an alternating current. Furthermore, the vibration of an electron, if sufficiently rapid, enables it to establish what are called electric waves in the ether, but which are really detached and self-closed lines of ether strain distributed in a periodic manner through space.

We have, therefore, to start with, three conceptions concerning the electron, viz.: Its condition when at rest; its state when in uniform motion; and its operations when in vibration or rapid oscillation. In the first case, by our fundamental supposition, it consists of lines of ether strain of a type called the electric strain, radiating uniformly in all directions. When in uniform motion, it can be shown that these lines of electric strain tend to group themselves in a plane perpendicular to the line of motion drawn through the electron, and their lateral motion generates another class of strain called the magnetic strain, disposed in concentric circles described round the electron and lying in this equatorial plane.

The proof of the above propositions cannot be given verbally, but requires the aid of mathematical analysis of an advanced kind. The reader must be referred for the complete demonstration to the writings of Professor J. J. Thomson^[3] and Mr. Oliver Heaviside.^[4]

In the third case, when the electron vibrates, we have a state in which self-closed lines of electric strain and magnetic flux are thrown off and move away through the ether constituting electric radiation. The manner in which this happens was first described by Hertz in a Paper on "Electric Oscillations treated according to the Method of Maxwell."^[5] As this phenomenon lies at the very root of Hertzian wave wireless telegraphy, we must spend a moment or two in its careful examination.

Let us imagine two metal rods placed in line and constituting what is called a linear oscillator. Let these rods have adjacent ends separated by a very small air space, and let one rod be charged with positive and the other with negative electricity. On the electronic theory this is explained by stating that there is an accumulation of electrons in one and of co-electrons in the other. These charges create a distribution of electric strain throughout their neighbourhood, which follows approximately the same law of distribution as the lines of magnetic force

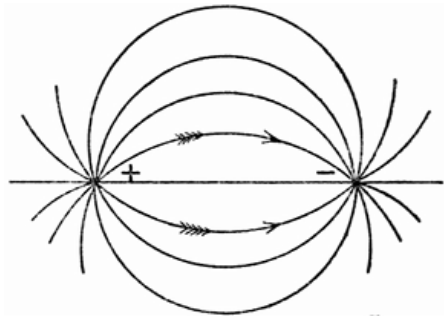


FIG. 1.—LINES OF ELECTRIC STRAIN BETWEEN A POSITIVE AND NEGATIVE ELECTRON AT REST.

of a bar magnet, and may be roughly represented as in Fig. 1. Suppose then that the air gap is destroyed, these charges move towards each other and disappear by uniting, the lines of electric strain then collapse, and as they shrink in give rise to circular lines of magnetic flux embracing the rods. This external distribution of magnetism constitutes an electric current in the rods produced by the movement of the two opposite electric charges. At this stage it may be explained that the electrons or atoms of electricity can in some cases make their way freely between the atoms of ponderable matter. The former are incomparably smaller than the latter, and in those cases in which this electronic movement can take place easily, we call the material a good conductor.

Suppose then the electric charges reappear in reversed positions and go through an oscillatory motion. The result in the external space would be the alternate production of lines of electric strain and magnetic flux, the direction of these lines being reversed each half cycle. Inside the rods we have a movement of electrons and co-electrons to and fro, electric charges at the ends of the rods alternating with electric currents in the rods, the charges being at a maximum when the current is zero, and the current at a maximum when the charges have for the moment disappeared. Outside the rods we have a corresponding set of charges, lines of electric strain stretching from end to end of the rod, alternating with rings of magnetic flux embracing the rod. So far we have supposed the oscillation to be relatively a slow one.