SIGNALING THROUGH SPACE WITHOUT WIRES.*

By W. H. Preece, C.B., F.R.S.

Science has conferred one great benefit on mankind. It has supplied us with a new sense. We can now see the invisible, hear the inaudible, and feel the intangible. We know that the universe is filled with a homogeneous continuous elastic medium which transmits heat, light, electricity, and other forms of energy from one point of space to another without loss. The discovery of the real existence of this "ether" is one of the great scientific events of the Victorian era. Its character and mechanism are not yet known by us. All attempts to "invent" a perfect ether have proved beyond the mental power of the highest intellects. We can only say with Lord Salisbury that the ether is the nominative case to the verb "to undulate." We must be content with a knowledge of the fact that it was created in the beginning for the transmission of energy in all its forms, that it transmits these energies in definite ways and with a known velocity, that it is perfect of its kind, but that it still remains as inscrutable as gravity or life itself.

Any disturbance of the ether must originate with some disturbance of matter. An explosion, cyclone or vibratory motion may occur in the photosphere of the sun. A disturbance or wave is impressed on the ether. It is propagated in straight lines through space. It falls on Jupiter, Venus, the earth, and every other planet met with in its course, and any machine, human or mechanical, capable of responding to its undulations indicates its presence. Thus the eye supplies the sensation of light, the skin is sensitive to heat, the galvanometer indicates electricity, the magnetometer shows disturbances in the earth's magnetic field. One of the greatest scientific achievements of our generation is the magnificent generalization of Clerk-Maxwell that all these disturbances are of precisely the same kind, and that they differ only in degree. Light is an electromagnetic phenomenon, and electricity in its progress through space follows the laws of optics. Hertz proved this experimentally, and few of us who heard it will forget the admirable lecture on "The Work of Hertz" given in this hall by Prof. Oliver Lodge three years ago.

By the kindness of Prof. Silvanus Thompson I am able to illustrate wave transmission by a very beautiful apparatus devised by him. At one end we have the transmitter or oscillator, which is a heavy suspended mass to which a blow or impulse is given, and which, in consequence, vibrates a given number of times per minute. At the other end is the receiver, or resonator, timed to vibrate to the same period. Connecting the two together is a row of leaden balls suspended so that each ball gives a portion of its energy at each oscillation to the next in the series. Each ball vibrates at right angles to or athwart the line of propagation of the wave, and as they vibrate in different phases you will see that a wave is transmitted from the transmitter to the receiver. The receiver takes up these vibrations and responds in sympathy with the transmitter. Here we have a visible illustration of that which is absolutely invisible. The wave you see differs from a wave of light or of electricity only in its length or in its frequency. Electric waves vary from units per second in long submarine cables to millions per second when excited by Hertz's method. Light waves vary per second between 400,000,000,000 in the red to 800,000,000,000 in the violet, and electric waves differ from them in no other respect. They are reflected, refracted, and polarized, they are subject to interference, and they move through the ether in straight lines with the same velocity, viz., 186,400 miles per second—a number easily recalled when we remember that it was in the year 1864 that Maxwell made his famous discovery of the identity of light and electric waves.

Electric waves, however, differ from light waves in this, that we have also to regard the direction at right angles to the line of propagation of the wave. The model gives an illustration of that which happens along a line of electric force; the other line of motion I speak of is a circle around the point of disturbance, and these are called lines of magnetic force. The animal eye is tuned to one series of waves, the "electric eye," as Lord Kelvin called Hertz's resonator, to another. If electric waves could be reduced in length to the forty-thousandth of an inch, we should see them as colors.

One more definition and our ground is cleared. When electricity is found stored up in a potential state in the molecules of a dielectric like air, glass or gutta percha, the molecules are strained, it is called a charge, and it establishes in its neighborhood an electric field. When it is active or in its kinetic state in a circuit, it is called a current. It is found in both states, kinetic and potential, when a current is maintained in a conductor. The surrounding neighborhood is then found in a state of stress, forming what is called a magnetic field.

In the first case the charges can be made to rise and fall and to surge to and fro with rhythmic regularity, exciting electric waves along each line of electric force, at very high frequencies, and in the second case the currents can rise or alternate in direction with the same regularity, but with very different frequency, and originate electromagnetic waves whose wave fronts are propagated in the same direction.

The first is the method of Hertz, which has recently been turned to practical account by Mr. Marconi, and the second is the method which I have been applying, and which, for historical reasons, I will describe to you first.

In 1884 messages sent through insulated wires buried in iron pipes in the streets of London were read upon telephone circuits, erected on poles above the housetops 80 feet away. Ordinary telegraph circuits were found in 1885 to produce disturbances 2,000 feet away. Distinct speech by telephone was carried on through one-quarter of a mile, a distance that was increased to 1¼ miles at a later date. Careful experiments were made in 1886 and 1887 to prove that these effects were due to pure electromagnetic waves and were entirely free from any earth conduction. In 1892 distinct messages were sent across a portion of the Bristol Channel, between Penarth and Flat Holm, a distance of 3·3 miles.

Early in 1895 the cable between Oban and the Isle of Mull broke down, and as no ship was available for repairing and restoring communication, communication was established by utilizing parallel wires on each side of the channel and transmitting signals across this space by these electromagnetic waves.

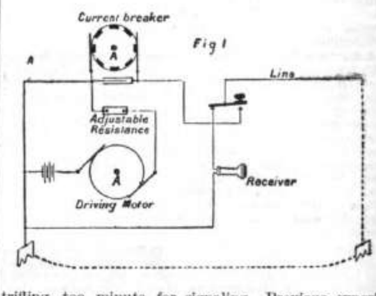
WILLIAM MARCONI, INVENTOR OF THE APPARATUS FOR TELEGRAPHING WITHOUT WIRES.

The apparatus (Fig. 1) connected to each wire consists of: (a) A rheotome or make and break wheel, causing about 260 undulations per second in the primary wire. (b) An ordinary battery of about 100 Leclanche cells, of the so-called dry and portable form. (c) A Morse telegraph key. (d) A telephone to act as receiver. (e) A switch to start and stop the rheotome. Good signals depend more on the rapid rise and fall of the primary current than on the amount of energy thrown into vibration. 260 vibrations per second give a pleasant note to the ear, easily read when broken up by the key into dots and dashes.

In my electromagnetic system two parallel circuits are established, one on each side of a channel or bank of a river, each circuit becoming successively the primary and secondary of an induction system, according to the direction in which the signals are being sent. Strong alternating or vibrating currents of electricity are transmitted in the first circuit so as to form signals, letters, and words in Morse characters. The effects of the rise and fall of these currents are transmitted as electromagnet waves through the intervening space, and if the secondary circuit is so situated as to be washed by these ethereal waves, their energy is transformed into secondary currents in the second circuit, which can be made to affect a telephone, and thus to reproduce the signals. Of course their intensity is much reduced, but still their presence has been detected, though five miles of clear space have separated the two circuits.

Such effects have been known scientifically in the laboratory since the days of Faraday and of Henry, but it is only within the last few years that I have been able to utilize them practically through considerable distances. This has been rendered possible through the introduction of the telephone.

Last year—August, 1896—an effort was made to establish communication with the North Sandhead (Goodwin) Lightship. The apparatus used was manufactured by Messrs. Evershed & Vignoles, and a most ingenious relay to establish a call was invented by Mr. Evershed. One extremity of the cable was coiled in a ring on the bottom of the sea, embracing the whole area over which the lightship swept while swinging to the tide, and the other end was connected with the shore. The ship was surrounded above the water line with another coil. The two coils were separated by a mean distance of about 200 fathoms, but communication was found to be impracticable. The screening effect of the sea water and the effect of the iron hull of the ship absorbed practically all the energy of the currents in the coiled cable, and the effects on board, though perceptible, were very

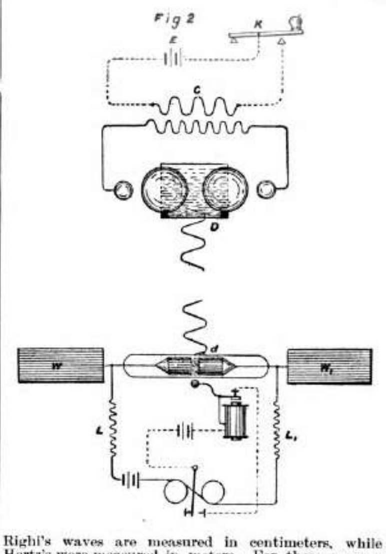


trifling—too minute for signaling. Previous experiments had failed to show the extremely rapid rate at which energy is absorbed with the depth or thickness of sea water. The energy is absorbed in forming eddy currents. Although this experiment has failed through water, it is thoroughly practical through air to considerable distances, where it is possible to insert wires of similar length on each side of the distance to be crossed. It is not always possible, however, to do this, nor to get the requisite height to secure the best effect. It is impossible on a lightship, and on rock lighthouses. There are many small islands—Sark, for example—where it cannot be done.

In July last Mr. Marconi brought to England a new plan. My plan is based entirely on utilizing electromagnetic waves of very low frequency. It depends essentially on the rise and fall of currents in the primary wire. Mr. Marconi utilizes electric or Hertzian waves of very high frequency, and they depend upon the rise and fall of electric force in a sphere or spheres. He has invented a new relay which, for sensitiveness and delicacy, exceeds all known electrical apparatus.

The peculiarity of Mr. Marconi's system is that, apart from the ordinary connecting wires of the apparatus, conductors of very moderate length only are needed, and even these can be dispensed with if reflectors are used.

The Transmitter.—His transmitter is Prof. Righi's form of Hertz's radiator—see Fig. 2. Two spheres of solid brass, 4 in. in diameter—A and B—are fixed in an oil tight case of insulating material, so that a hemisphere of each is exposed, the other hemisphere being immersed in a bath of vaseline oil. The use of oil has several advantages. It maintains the surfaces of the spheres electrically clean, avoiding the frequent polishing required by Hertz's exposed balls. It impresses on the waves excited by these spheres a uniform and constant form. It tends to reduce the wave lengths—



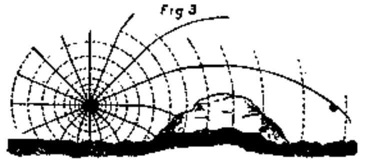
Righi's waves are measured in centimeters, while Hertz's were measured in meters. For these reasons the distance at which effects are produced is increased. Mr. Marconi uses generally waves of about 120 centimeters long. Two small spheres, a and b, are fixed close to the large spheres and connected each to one end of the secondary circuit of the "induction coil," C, the primary circuit of which is excited by a battery, E, thrown in and out of circuit by the Morse key, K. Now, whenever the key, K, is depressed sparks pass between 1, 2 and 3, and since the system, A B, contains capacity and electric inertia, oscillations are set up in it of extreme rapidity. The line of propagation is D d, —Fig. 2—and the frequency of oscillation is probably

* Friday evening discourse delivered before the Royal Institution, June 4, 1897. We are indebted to London Engineer and L'Illustration for the engravings published herewith.

about 250 millions per second. The distance at which effects are produced with such rapid oscillations depends chiefly on the energy in the discharge that passes. A 6 in. spark coil has sufficed through 1, 2, 3, up to four miles, but for greater distances we have used a more powerful coil—one emitting sparks 20 in. long. It may also be pointed out that the distance increases with the diameter of the spheres, A and B, and it is nearly doubled by making the sphere solid instead of hollow.

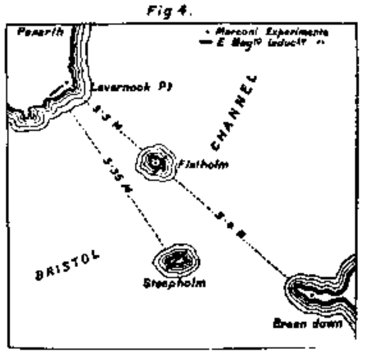
The Receiver.—Marconi's relay—see Fig. 2—consists of a small glass tube four centimeters long, into which two silver pole pieces are tightly fitted, separated from each other by about half a millimeter—a thin space which is filled up by a mixture of fine nickel and silver filings, mixed with a trace of mercury. The tube is exhausted to a vacuum of four millimeters and sealed. It forms part of a circuit containing a local cell and a sensitive telegraph relay. In its normal condition the

Fig 3



metallic powder is virtually an insulator. The particles lie higgledy-piggledy, anyhow in disorder. They lightly touch each other in an irregular method, but when electric waves fall upon them they are "polarized," order is installed. They are marshaled in serried ranks, they are subject to pressure; in fact, as Prof. Oliver Lodge expresses it, they "cohere"—electrical contact ensues, and a current passes. The electric resistance of Marconi's relay—that is, the resistance of the thin disk of loose powder—is practically infinite when it is in its normal or disordered condition. It is then, in fact, an insulator. This resistance drops sometimes to 5 ohms, when the absorption of the electric waves by it is intense. It therefore becomes a conductor. It may be that we have in the measurement of the variable resistance of this instrument a means of determining the intensity of the energy falling upon it. This variation is being investigated, both as regards the magnitude of the energy and the frequency of the incident waves. Now such electrical effects are well known. In 1866 Mr. S. A. Varley introduced a lightning protector constructed like the above tube, but made of boxwood and containing powdered carbon. It was fixed at a shunt to the instrument to be protected. It acted well, but was subject to this coherence, which rendered the cure more troublesome than the disease, and its use had to be abandoned. The same action is very common in granulated carbon microphones like Hunning's, and shaking has to be resorted to decohere the carbon particles to their normal state. Mons. E. Branly—1890—showed that copper, aluminum, and iron filings behaved in the same way. Prof. Oliver Lodge, who has done more than any one else in England to illustrate and popularize the work of Hertz and his followers, has given the name "coherer" to this form of apparatus. He has much improved it. Marconi "decoheres" by making the local current very rapidly vibrate a small hammer head against the glass tube, which it does effectually, and in doing so makes such a sound that reading Morse characters is easy. The same current that decoheres can also record Morse signals on paper by ink. The exhausted tube has two wings which, by their size, tune the receiver to the

Fig 4.



transmitter. Choking coils prevent the energy escaping. The analogy to Prof. Silvanus Thompson's wave apparatus is evident. Oscillations set up in the transmitter fall upon the receiver tuned in sympathy with it, coherence follows, currents are excited, and signals made.

In open clear spaces within sight of each other nothing more is wanted, but when obstacles intervene and great distances are in question, height is needed, tall masts, kites and balloons have been used. Excellent signals have been transmitted between Penarth and Brean Down, near Weston-super-Mare, across the Bristol Channel, a distance of nearly nine miles—Fig. 4. I must now show the system in operation. Mirrors also assist and intensify the effects. They were used in the earlier experiments, but they have been laid aside for the present, for they are not only expensive to make, but they occupy much time in manufacture.

It is curious that hills and apparent obstructions fail to obstruct. The reason is probably the fact that the lines of force escape these hills. When the ether is entangled in matter of different degrees of inductivity the lines are curved as, in fact, they are in light. Fig. 3 shows how a hill is virtually bridged over by these lines, and consequently some electric waves fall on the relay. Weather seems to have no influence: rain, fogs, snow, and wind avail nothing. The wings shown in Fig. 2 may be removed. One pole can be connected with earth, and the other extended up to the top of the mast, or fastened to a balloon by means of a wire. The wire and balloon covered with tin foil or kite becomes the wing. In this case one pole of the transmitter must also be connected with earth. This is shown by Fig. 5. There are some apparent anomalies that have developed themselves during the experiments. Mr. Marconi finds that his relay acts even when it is placed in a perfectly closed metallic box. This is the fact that has given rise to the rumor that he can blow up an ironclad ship. This might be true if he could plant his properly tuned receiver in the magazine of an enemy's ship. Many other funny things could be done if this were possible. I remember in my childhood that Capt. Warner blew up a ship at a great distance off Brighton. How this was done was never known, for his secret died shortly afterward with him. It certainly was not by means of Marconi's relay.

The distance to which signals have been sent is remarkable. On Salisbury Plain Mr. Marconi covered a distance of four miles. In the Bristol Channel this has been extended to over eight miles, and we have by no means reached the limit. It is interesting to read the surmises of others. Half a mile was the wildest dream.* It is easy to transmit many messages in any direction at the same time. It is only necessary to tune the transmitters and receivers to the same frequency or "note." I could show this here, but we are bothered by reflection from the walls. This does not happen in open space. There are a great many practical points connected with this system that require to be thrashed out in a practical manner before it can be placed on the

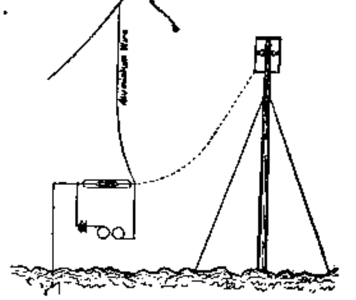


Fig 5

market, but enough has been done to prove its value and to show that for shipping and lighthouse purposes it will be a great and valuable acquisition.

PRACTICAL THOUGHTS ON DIET.

By J. HOBART EGBERT, A.M., M.D., Ph.D.

THE love of personal liberty, so patent in the human family, has long been a subject of comment, not only for philosophers, but for physiologists as well. To what extent one's desires may be accepted as proper guides in life is a question which constantly engages the attention of all those who labor for the promotion of public, as well as individual, welfare. Not a few—prominent among whom will be found the naturally strong and robust and the disheartened and desperate—are wont to disregard the higher organization of man—his vast personal liberty, bounded only by conscious reason—and to advocate that man's native tendencies will, like the unerring instinct of animals, direct him aright. Thus, Montesquieu expressed the sentiment of the multitude when he stated that the health purchased by a rigorous watching of the diet is but a tedious disease. But this belief, voiced by Montesquieu and reiterated by the liberty-loving masses, embodies a fallacy of no small magnitude or mean importance. When we consider the vast and direct influence of diet upon all the functions of life, when we reflect that man's education and not an inborn instinct directs him in the selection and proper use of food, and observe how invariably the penalty of abuse and transgression here, as elsewhere, sooner or later falls upon those who disregard the laws of Nature, we are led to know that to apply to diet—as to other habits of life—the principles of physiology and those allied sciences which reveal to us the laws governing the phenomena of Nature, is not to forfeit but to confirm, and by understanding their conditions to enlarge our liberty.

To those who would have as their only guide in dietetics a vigorous, and, doubtlessly perverted, appetite, we submit for careful consideration the following lines from the pen of England's profound physiologist and celebrated surgeon, Sir Henry Thompson. In a contribution to the Nineteenth Century this astute observer writes: "I have for some years past been compelled, by facts which are constantly coming before me, to accept the conclusion that more mischief in the form of actual disease, of impaired vigor, and of shortened life, accrues to civilized man, so far as I have observed in our own country and throughout Western and Central Europe, from erroneous habits in eating than from the habitual use of alcoholic drink, considerable as I know the evil of that to be. . . . I have come to the conclusion that a proportion amounting at least to more than one-half of the disease which embitters the middle and latter part of life among the middle and upper classes of the population is due to avoidable errors in diet. Further, while such disease renders so much of life for many disappointing, unhappy, and profitless, a term of painful endurance, for not a few it shortens life considerably."

The fact that many of the dietetic laws laid down by scientists have, when applied in actual life, been shown to be inadequate, is a stumbling block to many. The reason for this is not difficult of explanation, nor does it in any way lessen the value of the truth. In attempting to lay down hard and fast dietetic laws, pseudoscience has certainly evinced its incompetence by presuming to dictate laws to Nature rather than to expound existing truths; by confounding chemical with vital processes, and by disregarding the variations of force, organic strength, and particular requirements existing in different individuals and in the same individual under varying conditions of health, occupation, and environment. True science cannot be credited with such errors, for while its votaries may grossly err in their enunciations, the fundamental truths remain unchanged. Thus, through the pedantry of those who presume to interpret Nature's laws and formulate working codes applicable to life, the evils of ignorance and indiscretion are often thrust aside only to give place to the leaden tyranny of routine. What folly, as Herbert Spencer has observed, to suppose that the whole of dietetics lies in determining whether or not bread is more nutritive than potatoes, or in similar arguments. The physiologist of to-day is far wiser than the physiologist of yesterday, in that he recognizes in human intelligence a voice which speaks from within, and which evinces in mankind as in animals natural desires which require the cultivation and rational direction of education, rather than their overthrow and the substitution of purely artificial systems and habits of life.

Man's dietetic education begins in early childhood and continues throughout life. Some never receive other education in this direction than the example of others, while some, unsatisfied with strict adherence to an established precedent, by investigation, speculation and study enlarge the boundaries of their knowledge. Charles Lamb's "Dissertation on Roast Pig" fitly illustrates this theme and also points to the existence of what it now behooves us to consider more directly—to wit, a useful and natural appetite. To utterly ignore natural desires and maintain that judgment and education alone lead to the use of food suitable for the sustenance of the body would be to turn to the other and more irrational extreme. Charles Lamb's hero, in licking his burnt fingers—injured by handling the charred and heated remains of the litter—stirred up a latent appetite for roast pig and at once set about to appease it by devouring the still smoking carcass; and the train of incidents which followed the discovery of his violation of established rules show how, by a simple chain of natural circumstances, a rigid dogma may be overthrown. Yet who will argue that too much pork is not frequently eaten by many, or deny that educational training in things dietetic has not a direct influence upon the health and longevity of the Jewish people?

While there is a general correspondence in the kinds of food which the various members of the human family enjoy, there may also be observed in individuals a special inclination for certain articles of diet and a marked antipathy for others. Thus it is found that, to a normal appetite, disrelish for any special article of food is often indicative of its inadaptation to the needs of that particular individual, while the craving for some questionable article of diet may be indicative of its value as a nutriment to the individual under the existing circumstances. In a word, appetite for food is often not only the expression of desire but of fitness as well. But, alas! it is not an invariable and unfailing guide to felicity. Does not the earliest record of human affairs contain an intimation of the perverseness of man's appetite—and that of woman as well—in the command to Adam: "But of the tree of the knowledge of good and evil thou shalt not eat of it: for in the day that thou eatest thereof thou shalt surely die." Nor does science give a perfect rule applicable to each and every case—for experience, and not theory, may alone reveal the truth. Not until we shall have gained a more definite knowledge of that subtile force which we term vitality—that force in virtue of which we exist—shall we be able to restrict with exact limitations the natural tendencies of erring man.

Admitting the function of our natural inclinations in respect to food, and granting that they indicate the existence of important relations between ourselves and our environment, which are revealed to us in no other way, it is not yet demonstrated that they are unerring guides in human life. It is physiologically shown, as well as philosophically emphasized, that with man the natural tendency of all carnal desires is to excess, and hence we can concede the fundamental government of nutrition to appetite only when appetite leads to the fulfilling of instinctive impulses by the legitimate and rational gratification of natural desires. In a word, man is called upon to employ both reason and knowledge in aiding and controlling his natural desires.

To be guided by nature implies not only that we must have natural tastes to gratify, but also that they are given due opportunity to indicate their normal preferences. By the habitual use of strongly seasoned dishes, of artificial flavors, of modes of cooking which conceal the natural taste of the substance, and even of a great variety of dishes at a meal, the appetite is daily perverted. The chief aim seems to be to please the palate rather than to satisfy the wholesome hunger of the stomach. It is true that the enjoyment of food exerts an influence in promoting the activity of digestive processes, but the relish must be real and not imaginary—general, not merely local—for the best diet gives not only temporary, but permanent and genuine satisfaction. "It is more than probable," says Dr. Hinton, "that some men lead languid and unenjoyable lives in the midst of every advantage, chiefly for want of some little article of food which nature needs, and which under a simpler regimen their tastes would decisively demand." Nor is this an extravagant idea, for there is ample proof that the importance of special portions of our food cannot be estimated merely by the value of their direct contribution to the system. The yeast is small in quantity, but it is all-important to the loaf. And there is every reason to believe that certain portions of our food act a part which may be compared to that of yeast in respect to bread. Nutrition is by no means a simple transference of so much matter into the body, but a long series of changes, in which certain elements are subservient to others. The repair of the

* "Unfortunately, at present we cannot detect the electro-magnetic waves more than 100 ft. from their source."—Trowbridge, 1897, "What is Electricity?" page 255.

"I mention forty yards, because that was one of the first out-of-door experiments, but I should think that something more like half a mile was nearer the limit of sensibility. However, this is a rash statement, not at present verified."—Oliver Lodge, 1894, "The Work of Hertz," page 15.