three days longer to reach the Commemoracao. The spot was called Barao de Melgaço, and marked practically the end of the telegraph line. The trip from Tapirapoan to the Commemoracao had required exactly 40 days; the distance is approximately 548 miles. Many of the pack animals were in such poor condition that they had to be shot. It is impossible to say how many had been lost on the way, but the number was very large.

Barao de Melgaço seemed to be the headquarters of annoying insects and disease. Most of the handful of men at work on the telegraph line were ill with fever and beriberi, and there had been twelve deaths just before our arrival.

We had expected to find canoes awaiting us, but as there were none, the men cut down a tree of ample size and began making one. This work, we estimated, would require a month; but after a wait of two weeks a large canoe arrived from down the river.

The time at Barao de Melgaço was profitably if not pleasantly spent. All about the little clearing rose the stately Amazonian forest, providing admirable collecting grounds. Many birds and mammals were taken, all new to the collection. The latter included an undescribable spider monkey and a saki[17] of a new genus.

We started down the Commemoracao March 13th, and traveling rapidly with the current reached the Pimiento Bueno, 80 kilometers below, that night. The junction of the two rivers forms the Gy Paraná.

The Gy Paraná at its very beginning is a mighty river, a thousand yards wide, and day by day as we raced with its swirling torrent we watched its rapid growth until near the mouth it reached a breadth of at least two miles. The country on both banks is heavily forested, and along the upper course is inhabited by a tribe of Indians which had been absolutely unknown. We were the first white men to see them, and they had never seen white men before. In appearance they differed greatly from their neighbors, the Nhambiquara. We met seven, all men, and finally induced them to accept gifts of beads and knives, in return for which they gave us wonderfully decorated arrows six feet tall.

The Gy Paraná abounds in formidable rapids, like many South American rivers, and we had numerous overland portages, the longest being about three miles, around the falls of São Vicente. Insects are abundant, and the whole region is a vast breeding ground for malaria. A number of rubber camps are situated on the lower river, the forests being rich in hevea. We reached Manaos April 10th, having stopped at Calama, a station on the Madeira, for a short period of collecting.

As the Dúvida party had not arrived, I almost immediately left for the Rio Solimoes where several weeks were spent to advantage adding to the collections. Among the large number of specimens collected were agoutis, woolly monkeys, squirrel monkeys, sloths, many small rodents and squirrels, all new to us; and the complete material for a group of hoatzins or lizard-birds was also collected. The collections now numbered about 1,500 birds and about 415 mammals, practically all of species unknown to us, and some of which are no doubt new to science.

Colonel Roosevelt's party reached Manaos the last day of April, but the story of their experiences on the unexplored river is too well known to warrant review.

[17] Saki: a South American monkey with a bushy tail and a ruff of long hair around the face.

Wireless Transmission of Energy—II*

An Explanation of its General Nature and Relationship to Transmission by Wire

By Elihu Thomson

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2050, Page 253, April 17, 1915

LET US suppose that the charge is positive at the top, and necessarily the surface below and surrounding the mast will be negative. Electrostatic lines will extend from the mast, and particularly from the expansion at the top down to the earth's surface in all directions around the antenna, as in the figure. The medium around the antenna will be stressed electrostatically. This would be all, provided the charges were stationary, but the system we are considering is dynamic. The plus charge is replaced by a minus charge at the top, and a current of a high frequency runs up and down the antenna, but so also does this current extend into the sea

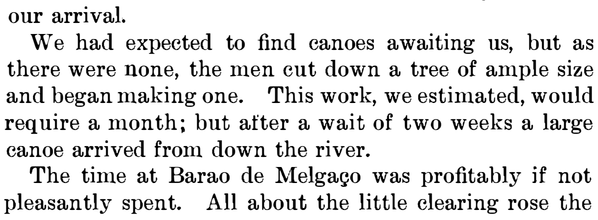

Fig. 21A.

radially from the foot of the antenna, replacing the negatively charged area by a positively charged zone, as it were, while the top of the antenna is now negative where it was formerly positive. (Fig. 21a, one side only shown, and Fig. 21b, in plan.)

As this action goes on, however, the zone of charged surface widens, and ether waves are, so to speak, detached from the antenna, and electrostatic lines join now through the air or ether above the successive zones which surround the antenna as great circles or flat rings of the sea surface. A plus area is followed by a minus, a minus by a plus, etc., and to indicate the effect in the space above, we draw lines which follow these areas, extending up into the ether above the surface, but moving away from the antenna with the velocity of light. The moving charges in the sea surface represent radial currents which are in opposite phase at different portions of the sea surface, and spreading at 186,000 miles per second, and these currents necessarily generate magnetism or lines of magnetic force in the medium directly above them. These lines extend around in zones with diminishing intensity upward from the sea surface as the distance from the surface increases. Even within the water itself a similar action, but more restricted, takes place. The charges in the water are connected by electrostatic stress lines, and the compensating magnetic field follows the current, but this "under water" effect does not concern us, as what we work with is the energy conveyed in the shape above the sea, the other not being so easily recoverable.

The system as thus far constituted is merely an arrangement for delivering energy in high-frequency waves to the widespread medium around the antenna. There is no selective action whereby it is focused anywhere—it is as a "voice crying in the wilderness." It can be picked up or recognized in any direction by anyone who is within range. If, now, we are to receive signals such as are made by interrupting or disturbing at intervals this system of radiation of energy, as in ordinary telegraphy, we must set up somewhere a receiving apparatus which will enable us to pick up whatever small fraction of the energy reaches it and, if possible, a sufficient fraction of such energy for the recognition of the signals. If the signal can be recognized —no matter how small the fraction of the energy sent out is which we collect at the receiving station—the system succeeds. There is no question of efficient transmission, as there is in the ordinary power-transmission systems. The latter are for the transmission of energy with as little loss as possible, the former for the transmission of signals only.

In the antenna transmission just considered it is assumed that the surface of the earth is, generally speaking, a good electric conductor. The surface of the sea is sufficiently good. Dry land surface, however, is not a good conducting sheet, and even though moist it is generally so irregularly conducting that obliteration of the waves and loss or absorption of the energy must necessarily occur. Obstacles, such as dry rock ranges, may absolutely prevent the waves from passing over them. It must be borne in mind that these waves have no inertia, as such, and that the energy must be guided to its destination by a conducting sheet. This calls to mind the efforts that were made to connect Lynn and Schenectady by a wireless system, but without success. Occasionally signals were received, but in general they were too indistinct to be recognized. It is more than probable that the dry rock ranges of the Berkshires in western Massachusetts were sufficient of an obstacle to prevent the energy of the waves getting across them.

It is also to be questioned whether there may not be another action which interferes with and disturbs the integrity of the waves. It is conceivable that waves may follow a water surface, even around a cape, and that a portion of the energy may take a short cut across the land of the cape. If this be so, the longer course would be around the cape, the shorter course across the land. The wave-lengths would remain the same, and an out-of-phase relation or interference phenomenon would take place to a greater or less extent. It is manifestly necessary that the energy, by whatever course it follows, shall reach the receiving apparatus in phase.

Let us now consider for a moment the conditions at great distances over the earth's surface. At moderate distances from the transmitting antenna the surface may be considered as flat. The conducting sheet guiding the energy is flat or plane, but at great distances the curvature of the earth's surface becomes an important factor. For a time there was a great deal of discussion as to the reason why the energy in the wireless transmission seemed actually to follow the curvature of the earth, instead of going straight away, as in the case of Hertzian or heat and light waves. If the waves had been generated by a large Hertzian oscillator, it would not be possible for them to so follow the earth's curvature, but inasmuch as they are in wireless work produced and, as it were, positioned upon a conducting sheet (the sea surface), then it follows that the energy must be guided by that conducting sheet or surface, regardless of its extent or its curvature. I have never been able to understand why so much discussion has been needed to clear up this point. Wireless waves have no inertia—they follow the course of the charges which produce the stress and of the magnetic field, due to these charges in motion. These charges in motion are the currents in the conducting sheet, which may or may not be curved. In the curved surface of the ocean the zones of charge continually expanding, plus and minus, respectively, are still connected by the electrostatic lines above them, and the moving charges still generate the same magnetic field as they traverse radially or outwardly in the curved instead of the plane sheet (Fig. 22),

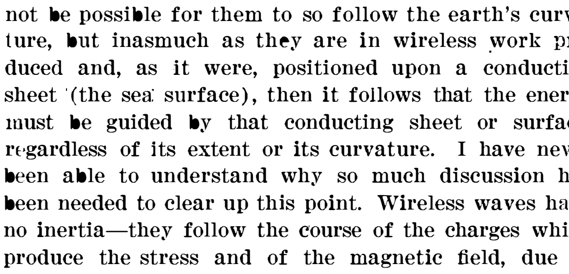

Fig. 22.

and this curved conductor still guides the energy, just as the wire does in ordinary transmission. It would seem, if this is the correct view, that at a distance comparable with that of a quadrant of the earth's circumference the form of the wave would be such as to cause the stress lines to lean backward with respect to the surface, tending to keep their original relation to the transmitting antenna as they were detached therefrom (Fig. 22, at *L*). This assumes that the velocity of transmission is the same as that of the speed of light, both for the currents in the sea and for the stresses above it.

Marconi's success as a wireless pioneer depended largely upon the choice of a sufficiently sensitive receiver. Two elements are necessary in the receiver. First, a conducting structure which gathers up the energy from the medium, the ether, above the earth's surface. The other element is a sufficiently delicate means for detecting the slightest changes of electrical condition, not only actuated by what little energy is received, but so modifying it that it can operate a signal which can be seen or heard. Usually the receiving an-

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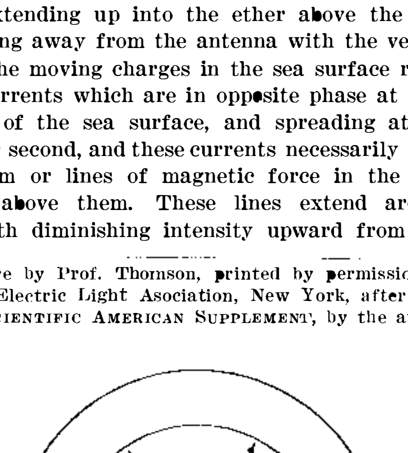
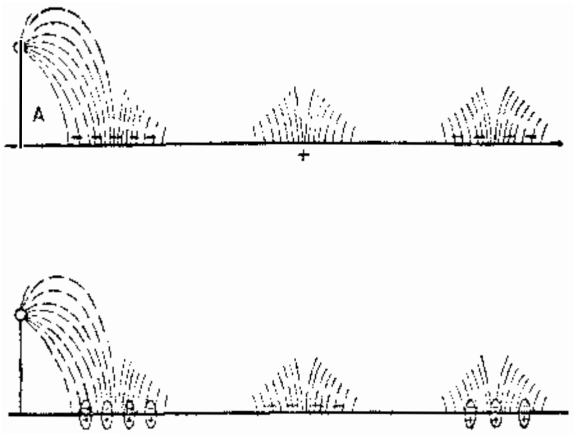


Fig. 21B.

tenna is a vertical conducting mast or cage, like the sending antenna. In fact, the functions of sending and receiving are interchangeably used on the same structure; the same antenna may be at one time used for transmitting and at another time for receiving.

The receiving antenna (Fig. 22) serves to relieve the electrostatic stress in its vicinity, much as a lightning rod may act to relieve cloud to earth stresses. If its direction could be made to follow or be parallel to the actual course of the transmitted lines in the space near it, it would be most effective, and if, further, it could extend sidewise over a considerable extent of the wave front, it would gather up more energy. These conditions, however, can at best be only approximately met. If the receiving antenna were of such a character as to have no oscillation rate of its own (a damped circuit) it would receive energy in a small amount from the transmitting antenna independent of the frequency, but as this would in most cases be far from sufficient, it is desirable to accumulate energy in the receiver from a train of waves at a definite rate. To do this the principle of syntony or tuning is brought in. Everyone is familiar with the two tuning forks, where one is sounded and the other is placed at a distance away. If the two forks are not in harmony, no effect of the one fork on the other follows, but if they are accurately tuned in unison, the sound of one fork at a considerable distance from the other starts the second in vibration and produces an audible sound from it. The second fork is, in fact, a structure particularly well adapted to gather up the energy of the sound waves which reach it, receiving from each wave a small portion of energy and accumulating such energy until the fork itself is brought into palpable vibration. By applying this principle in wireless telegraphy, that is, by causing the rate of vibration or frequency of the electrical waves to be the same in the transmission and in the receiving antennæ systems, constructing both to possess a normal rate as if they were to be electrical tuning forks of the same pitch, the amplitude of the received impulses is so greatly increased that signal strength is reached where otherwise failure would have resulted. The one thing which has characterized the more recent advances in wireless telegraphy has been the accuracy of tuning and the removal of disturbing influences which would interfere with the tuning.



Figs. 23 and 24.

Formerly the transmitting circuit was excited by means which tended to disturb the actual normal rate. If excited inductively, the inducing or primary circuit had a rate of its own, which was apt to interfere with that of the vibrating antenna system. However, what is known as loose coupling (Fig. 20), instead of close coupling (Fig. 19), to the primary or exciting circuit causes such confusion of rates to be nearly negligible if, particularly in the exciting circuit, the current is well damped, as it is termed, or confined to a single brief impulse as far as possible. In such case the antenna circuit, in transmitting, acts as if it were a bell struck with a sudden quick blow, and it vibrates at its own rate without disturbance or interference. At the receiving end (and there may be, of course, many receivers in the space around the transmitting antenna), the "listening-in" process consists in adjusting the rate of vibration of the receiving circuit by variable condensers or inductances, so that the maximum loudness of the received signals is attained. The two systems, transmitting and receiving, are then in tune.

Accuracy of tuning is evidently very important if stations are to be simultaneously transmitting when near together, as only in that way can one station send out energy without interfering with the other; the particular receiver for which the signals are intended being tuned for the particular antenna sending these signals. In spite of the accuracy of tuning, however, high-power stations may, in fact, cause high frequency waves of high potential in all surrounding wire or metal structures if near enough. Burn outs, or even fires, may occur from this cause. Hence, it is desirable that high-power sending stations should be well removed from centers of population where there are electric circuits and electrical apparatus likely to be interfered with or injured.

It may be here pointed out that the limit of potential which is available in wireless transmission is the same as that of long distance transmission by wire and for the same cause. Naturally, if the potential on the sending antenna can be raised, the amount of energy which can be put into the wave impulses will be increased, but there comes a time when an increase of potential on the wires of the antenna gives rise to a corona loss, much as the increase of potential in wire transmission produces a corona loss. The conductors of the system, in such a case, are surrounded by a blue discharge which is even visible at night and which frequently can be heard. When this condition is reached every further increase of potential simply increases the corona loss without adding correspondingly to the energy transmission. Just as in wire transmission it can be avoided by increasing the diameter of the conductors, so in wireless work it could be avoided by constructing the antenna system of hollow tubes with smooth exteriors, and the imagination may be permitted to depict a sending tower of polished metal surmounted by a sphere of similar material and worked at millions of volts. No limit can be set to the amount of energy which might thus be radiated, and no limit as yet can be set to the distance around the earth to which signals might be sent by such means.

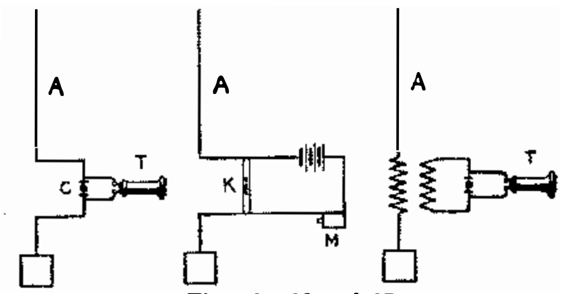
One curious fact which has been developed in the work of wireless signaling is that daylight, especially sunlight, is very detrimental to transmission as compared with the night. That is to say, if the wireless waves are to traverse the sea surface in sunshine, the chance of receiving them in sufficient force to produce signals at great distances is far less than when they are sent at night. It is probable that this difference is not due to any single cause—it may be the effect of a combination of causes. It is a notable fact, too, that this difference between the effectiveness of daylight transmission and night transmission is accentuated at the higher frequencies.

Though the cause is still somewhat obscure, we may venture a suggestion or hypothesis which may have a bearing on the case. Referring to Fig. 23, we have tried to show the condition. The electrostatic field at the water surface at the same instant is, as in Fig. 21, produced in zones around the antenna *A*, spreading with approximately the speed of light. It is well known that under the action of the violet and ultra-violet rays of light any surface having a negative charge will leak its charge and ionize the air near it. This may occur in sunlight over such areas as are marked minus in the figures, and the several minus signs would mark or indicate air ionized and negatively electrified over the negatively charged zones. No action would be expected over the positive areas or zones. But the zones are not stationary; they are widening very rapidly, so that a positive zone or zones takes the place of negative so far as any location is concerned. This may be expressed by saying that the water surface which at one instant was negative and gave out negative ions under the influence of light would, in an exceedingly small fraction of a second and before those ions could get away from electric contact with such surface, become positive and the free ions would now return and neutralize a portion of the positive charge. Thus the negative zones or wave elements would lose part of their charge to ionize air, and the positive waves would be weakened by such negative leak neutralizing them in part. This action, however feeble at each wave, would be continuous over hundreds if not thousands of miles, and continuously damp out the widening system of waves. The effect would be less marked with low-frequency waves, as there would be a proportionately less number of opportunities for this neutralization per second. Besides, with the lower frequency there is more time for the separation of the negative ions to such distance from the water surface that they do not combine with the positive charges, being, as it were, better insulated from them or diffused in the air stratum.

In Fig. 24 an attempt is made to picture this action of attenuation in the presence of light. The negative charges in the air layer, as in Fig. 23, have no positive charges under them, the encircling lines about the + and — signs indicating combination and neutralization.

When the wireless waves reach the receiving antenna, owing to attenuation from spreading or loss as above, they are very feeble. The daylight effect, as pointed out by Fessenden, is much less with the lower frequencies, such as 100,000 per second as compared with 600,000 or 800,000 waves. Consequently there is not the same great difference in strength of signals between night and day work with such lower frequencies. Moreover, frequencies of 100,000 or even 200,000 are capable of being generated directly by high speed high-frequency dynamos with the added advantage that the waves sent out are maintained at their full amplitude and are not, as with waves produced by spark discharges, subject to damping or decay from maximum to zero after a few oscillations.

Whatever the nature of the waves sent out, there is in all cases the need of an exceedingly sensitive apparatus for converting the slight electric effects upon the receiving antenna into signals. The original apparatus of Marconi included the Branly coherer, used by Lodge in Hertzian wave transmission as a detector. It is indicated in Fig. 26 at *K*, with its battery and sounder magnet *M*. The receiving antenna discharge in passing to earth broke down the insulation of the filings of the coherer, so that the local battery current could pass in the circuit, including a magnet *M*, and so record the signal. The liquid barretter of Fessenden, the various forms of rectifying crystal detectors and magnetic detectors, have been extensively used. Our time does not permit a detailed description. Fig. 25 indicates at *C* a crystal detector rectifying the impulses from antenna *A* so as to work a high-resistance telephone receiver *T*, to which the operator listens. Fig. 27 shows the same apparatus, but connected inductively to the antenna circuit by a transformer.



Figs. 25, 26 and 27.

Fessenden found that if the succession of decaying wave trains reaching the telephone *T* was such as to produce a low note, the signals were easily drowned by extraneous noises or induced effects. He found that the human ear reached a maximum of sensitiveness at about 900 waves of sound per second, so that the signals were heard distinctly when otherwise they would have been missed. This is the meaning of the substitution of dynamos of about 500 cycles for exciting the wireless antenna in place of the ordinary machines of lower frequency.

The problem of wireless telephony has attracted attention for a number of years past. I well remember witnessing some of the earlier work of Fessenden in this fascinating field, in which he was pioneer. The wireless telephone speech was free from all disturbing noises and interferences so common on ordinary telephone lines. Briefly, such telephony depends on the ability to control the voice waves and vary in accordance therewith the energy given out by the transmitting antenna and to do this with a fairly large output of energy.

By employing a method I described about 1892, it is possible to generate a continuous wave train by shunting a direct current arc with a capacity (condenser) in series with an inductance, the frequency rate depending on the electrical constants of these parts of the apparatus. This system, which was the subject of the United States patent taken out by me in the early nineties, has been variously called the Duddell singing arc, or later the Poulsen arc. Poulsen employed it with modifications in his system of wireless telephony. Long before this work of Poulsen, Fessenden had used a high-frequency dynamo for securing the continuous train needed. A suitable microphone transmitter was made to so alter the relations of the waves in transmitting and receiving antennæ, that voice waves could be received in an ordinary telephone connected with the receiving antenna system.

Much progress has been made in this department of wireless work, and such telephony between Europe and America may yet become practicable. Methods are being worked out whereby it may be possible to mold outputs of many kilowatts of energy so as to have them vary with the voice waves, and when this is done many problems, the solution of which now seems remote, may become solved and the results prove of great practical value. It was not, however, my intention to devote time to these later researches, but to endeavor to present to the mind's eye a view of the nature of wireless transmission which should show the similarities to ordinary transmission by wire and also the differences. Furthermore, I hope I have shown it to be evident that future transmission of energy at high efficiencies will still demand the wire core for guiding that energy to its destination.

Metric System in the British Pharmacopœia.—It is announced in the U. S. Commerce Reports, as a matter of interest to exporters of drugs and chemicals, that Great Britain has adopted the metric system in the new British Pharmacopœia, thus conforming to the usage of other countries.