REPORT

OF

MAJOR GENERAL ARTHUR MACARTHUR

ON THE

ENCAMPMENTS FOR FIELD INSTRUCTION AND MANEUVERS IN THE PACIFIC DIVISION

1904

CAMP ATASCADERO
AMERICAN LAKE
HONOLULU

Department of California
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MAJOR GENERAL ARTHUR MACARTHUR.

HEADQUARTERS PACIFIC DIVISION,
SAN FRANCISCO, CAL., December 8, 1904.

The Military Secretary,
War Department,
Washington, D. C.

SIR: Reports appertaining to the joint encampments of regular troops and organized militia in the Departments of California and of the Columbia during the season of 1904 are respectfully transmitted herewith.

In organizing the maneuvers the location of a camp suitable for a large concentration of troops received the first consideration; in which connection it was apparent that a central position with reference to the geographical boundaries of the Pacific Division would fall somewhere in Northern California or Southern Oregon. Accordingly, inquiries were instituted early in the year with a view to finding within such limits a site suitable for the occupancy of all the regular troops and organized militia concerned. Owing to the mountainous nature of the country it was impossible to find, contiguous to the only line of railroad that traversed the section referred to, a place that was in any way adapted to such an assembly.

It was very soon ascertained that the only grounds suitable for large camps were located within the northern and southern zones of the division, in consequence of which it was regarded as inexpedient, both on account of time and money, to attempt to unite the entire force in one place. Combined maneuvers in each department were, therefore, determined upon and carried out in pursuance of authority to that effect, contained in a letter from the Chief of Staff, dated April 6, 1904.

American Lake, in the vicinity of Tacoma, Washington, was selected as the rendezvous for the Department of the Columbia, and the Rancho del Encinal, San Luis Obispo County, California, for the Department of California; and the congregation of the troops designated for each camp was accomplished at the points selected with celerity and economy, as may be seen by reference to the report of the Chief of Staff, which is appended hereto marked "A".

In the first instance the idea of a division encampment was abandoned with great reluctance, as it was then believed that the useful effect of the training would be directly in proportion to the number of troops assembled; but the experience of the department encampments justifies the conclusion that the duration of a camp is of more importance than the number of troops assembled therein, provided a 'sufficient number of men are brought together to effectively exemplify all essential field operations, and, further, provided that it is necessary to sacrifice either time or numbers. That is to say, a camp of five thousand men for ten days is more effective for all professional purposes than a camp of ten thousand men for five days. Aside from saving much time that would otherwise be spent in travel, the small camp is also a great money-saver, on account of transportation, as the basic idea of such an institution is to draw the troops from a circumscribed area adjacent thereto.

In pursuance of the view that a system of department camps is best adapted to the necessities of the Pacific Division, the immediate acquisition of a camp site for each department is recommended; that is to say, the immediate purchase of two camp sites on the Pacific Coast.

The most notable event connected with the field exercises herein referred to resulted from the exceedingly resourceful manner in which 1st Lieutenant W. M. Goodale, Signal Corps, discharged his duties at American Lake. Under the pressure of emergencies which arose in pursuance of his field work, he attempted to obtain "ground" for the return circuit of an electrical wire by means of nails driven into trees. The experiments were surprisingly successful, and inasmuch as the empirical discovery thus made has already become the subject of systematic investigations, which may contribute materially and substantially to the scientific knowledge of the world, it is desired to make a permanent record of the initial steps in the premises by inserting extracts from Lieutenant Goodale's interesting reports of the transactions; in which connection also especial attention is invited to the ingenious manner in which the Signal Corps improvised lines of electrical communication by the clever use of wire fences and the steel tracks of a railroad right of way:

* * * * * *

"In compliance with orders from the brigade commander, I reported to the commander of the Brown forces with six men and a light spring wagon equipped with field buzzers, wire, flags, etc., at 7 a. m. July 9th, and accompanied the command to a point near the Junction of the Olympia, Tacoma and Steilacoom Roy roads. Upon arriving at this point I was directed to establish two signal stations, one at each flank, and to connect the same with the reserves, a distance in each case of about 1800 yards. Use was made of all available wire fence, and the main road was crossed by carrying the wires from the fences to the top of the line of telephone poles running along the Olympia-Tacoma road. From the poles the wires were led along the ground, a distance of some 700 yards, to a clump of trees in front of the position of the reserves. Owing to the peculiar dry nature of the soil in this country, it is very difficult to find good 'ground' for the return circuits, and I at first figured on visual signals, but after experimenting it was found that by driving a nail into the root of a young tree, a perfect 'ground' could be established. Each station was therefore placed in a clump of trees, and by attaching the line to one binding-post of the instrument, while to the other was attached a wire leading to the nail driven in the root of a young tree nearby, a perfect 'ground' was obtained. The instrument used in these cases was the field buzzer furnished by the Signal Corps. So perfect was the circuit that we were able to use the telephone for many of the messages, the enunciation being very distinct. Communication was established within eighteen minutes after the order was given by the commander of the forces in the field, and was maintained throughout the exercise. After recall, and the withdrawal of the troops, the wire was recovered by means of a take-up reel mounted upon the light spring wagon referred to above.

* * * * * *

"In compliance with instructions from the brigade commander, a party of signal men, consisting of a sergeant and one private, reported to each of the two troop commanders and accompanied the cavalry during all the operations. The cavalry patrols left camp at 4:30 in the morning, and within one-half hour after their departure communication was established with the station near Huggins Crossing, and each party continued to transmit and receive messages until 9 a. m., when the communications were interrupted by the Blue forces. The instruments used were the Signal Corps field buzzers, and messages were transmitted via wire fences, which were made continuous by bridging across the openings with buzzer wire. The signal party would establish themselves at a given point and transmit the information brought to them by the patrols. As soon as the patrols had advanced beyond a given distance in front of the same, the party would disconnect its instrument and proceed on horses to a point nearer to the advancing troopers, where a new connection would be established. Each man carried three spools of small bronze buzzer wire, while the non-commissioned officer bore, in addition, the field buzzer. As each spool carries about one-half mile of line, it will be understood that each party was provided with six spools or three miles of wire. The party accompanying the troops operating south of the line of lakes utilized the railroad track as far as possible, thus saving a great deal of line construction. About 8:30 a. m. the Blues discovered our line south of the lakes and cut in on it, interrupting communication, and endeavoring to send through false messages. Owing to the fact that a code of signals had been established among our operators the night before, this deception was easily detected. The Blue forces were also using the railroad track for a short time, and we were able to obtain at least one of their messages, from which we learned the near approach of their artillery and its probable destination. In addition to the communications mentioned above, a line was maintained between the brigade commander at Huggins Crossing and his main reserve at Fort Nisqually. A line was also maintained from the brigade commander to the firing line southeast of Huggins Crossing. A signal station was established in a small tree about 350 yards east of Huggins Crossing, and this was connected with the brigade commander by means of buzzer carried to the tree top with the observer. One wire was carried along the ground and up the tree, while the return circuit was established by driving a nail in the tree near its top and attaching the other wire to it. It was found that this plan gave us a sufficiently good circuit to operate the instrument without interruption. This apparent phenomenon is attributed to the fact that sufficient moisture is carried up the tree in the nature of sap to maintain a circuit with the roots of the tree, which of necessity seek the moist earth at a distance of several feet below the surface of the earth. I believe that this discovery of being able to secure a 'ground' in dry countries, by means of utilizing the moisture contained in trees, will prove of great benefit in the future, as heretofore much labor and loss of time has been occasioned by having to either extend long wires to reach moist earth, or of digging to a considerable depth."

* * * * * *

The foregoing facts having come to the knowledge of Major George O. Squier, Signal Corps, were made the basis of much meditation and reasoning, together with experimental observations conducted according to the most approved scientific methods, with the result that this proficient officer has by inductive methods reached an original conclusion to the effect that living vegetable organisms may be used as part of a circuit for electrical oscillations or Hertzian waves, an accomplishment which, it is believed, has not heretofore been demonstrated; and which in turn suggests the possibility of using living trees as substitutes for masts and towers in the operation of wireless telegraphy; a contingency that opens a great scope for the imagination of its future employment in the service of information. Thus, an incident of a maneuver camp, skillfully analyzed by a scientific officer, may result in discoveries of much military utility and of great scientific value.

A letter from Major Squier, together with a memoir enclosed therein, which contains an instructive account of the experiments above referred to, is attached hereto marked "B".

Peace training for field duties, to be of practical benefit, must be conducted on a scale involving an expenditure of money approximating that of actual war, and, as a consequence, questions naturally arise as to the expediency of maintaining such an expensive system of instruction. Conclusive mathematical proof cannot be adduced in behalf of the affirmative of this proposition, but it may be asserted with absolute assurance that an army without some training of this kind must enter the field at a great disadvantage. There are certain duties which are indispensable alike to officers and men which can only be effectively acquired in peace under conditions which exist in maneuver camps.

In continuation of the same line of thought it may be said that the organization, equipment and training of armies are so much alike that a battle of the present day, in most instances, will become an unlimited slaughter, without the possibility of decisive results, unless a new principle or a new invention is developed and applied before one of the opposing forces understands or appreciates the importance thereof. Now, more than ever before, the real business of war begins where the rules leave off; and herein is precisely where lies the great importance of the maneuver camp as offering, (in addition to an opportunity to diffuse conventional military knowledge which cannot be imparted at army posts or in armories of the organized militia), the only possible facilities in time of peace for the development of new and original military ideas, the unexpected infusion of which into field operations is so essential. An army that has not some comprehensive system of peace training is very likely to grope in its own blood for the solution of problems that will confront it in actual war.

It is hoped that the accompanying reports, which seem replete with useful and suggestive information, confirm the wisdom of continuing joint encampments from year to year as a permanent feature of the American military system.

Very respectfully,

ARTHUR MACARTHUR,

Major General, Commanding.

"A".

REPORT OF CHIEF OF STAFF TO THE DIVISION COMMANDER.

HEADQUARTERS PACIFIC DIVISION,
OFFICE OF CHIEF OF STAFF,
SAN FRANCISCO, CALIFORNIA, December 5, 1904.

The Commanding General,
Pacific Division,
San Francisco, Cal.

SIR: Tactical operations of the troops within the division which were concentrated for that purpose at American Lake, Washington, and Camp Atascadero, California, during the months of July and August, last, respectively, form the subject of complete reports recently received from the commanding generals of the departments of the Columbia and California, which I have the honor to submit herewith. They especially exhibit diligent and attentive application to their important functions on the part of the chief umpires of the two encampments and invite commendation for the fidelity with which that particular duty in each case was performed. The reports have been printed in pamphlet form in sufficient numbers to place a copy pertaining to the exercises in which he participated in the hands of each officer, regular and militia, thus bringing them within reach, also, of the enlisted men of both forces—a wise measure, it is believed, greatly overbalancing the nominal cost of publication.

In addition to the maneuvers conducted at Camp Atascadero and American Lake, the organized militia of the territory of Hawaii, consisting of a regiment of nine companies of infantry, with small hospital and signal corps detachments, encamped for five days,—June 8th to 12th, 1904,—near Camp McKinley, H. T., in conjunction with the United States artillery companies at that station. Practical instruction in field work, suited to the small force, was imparted under direction of the regular army officer in command, who reports the territorial troops earnest and tactful, and that the close of the brief season of training showed marked improvement in all participating organizations.

Of the appropriation by Congress of one million dollars to meet expenses incident to the organized militia of the several states, territories and the District of Columbia joining the regular army in camps of field instruction, (Act of April 23, 1904), the following sums were allotted to the Pacific Division:

Pay of officers and enlisted men	$ 60,937.50
Quartermaster's Department funds	121,875.00
Subsistence Department funds	20,312.50
Total	$203,125.00

Subsequently, the amount for pay of officers and enlisted men was increased by $6,000 received from the Atlantic Division; and there was accredited the further sum of $8,000 to cover the cost of blank ammunition to be issued to the militia.

While the grand total of $217,125 that became available for the three camps in this division but little exceeded one-fifth of the whole appropriation, it is gratifying to note that expenditures were kept well within authorized limits, viz.:

Allotment on account of Pay	$ 66,937.50
Disbursed	59,468.16
Balance, covered into Treasury	$ 7,469.34
Allotment, Quartermaster's Department	$121,875.00
Disbursed and estimated outstanding accounts	106,875.00
Balance, covered into Treasury	$ 15,000.00
Allotment, Subsistence Department	$ 20,312.50
Disbursed	16,418.47
Balance	$ 3,894.03
Allotment, Ordnance Department	$ 8,000.00
Cost of blank ammunition issued	6,355.16
Balance	$ 1,644.84

SUMMARY.

Total funds allotted	$217,125.00
Total disbursements and estimated outstanding accounts	189,116.79
Unexpended balance	$ 28,008.21

Further analysis of the above mentioned item, $189,116.79, representing the total charge within the Pacific Division against the specific appropriation for maneuver purposes, 1904, gives the cost, separately, of the three camps as follows:

ATASCADERO.

Pay of organized militia	$ 33,241.19
Lease of land, transportation and other expenses of Quartermaster's Department, outstanding accounts estimated	55,693.45
Subsistence	10,678.33
Blank ammunition	2,892.16
Total	$102,505.13

AMERICAN LAKE.

Pay of organized militia	$ 24,132.35
Lease of land, transportation and other expenses of Quartermaster's Department, outstanding accounts estimated	50,250.00
Subsistence	5,228.27
Blank ammunition	3,463.00
Total	$ 83,073.62

HONOLULU.

Pay of organized militia	$ 2,094.62
Transportation	931.55
Subsistence	511.87
Total	$ 3,538.04

Settlement of accounts for railway transportation, freight and passenger, is made by disbursing officers not subject to your control. Inasmuch as only partial returns have been received of payments made under that classification, the foregoing financial statements are necessarily, in that respect, approximate; but the reasonable assurance that these outstanding accounts would not exceed nor vary greatly in total sum from the funds reserved to meet them appeared to warrant covering into the Treasury $15,000 of the appropriation for the Quartermaster's Department.

Taking into consideration the whole number of troops under instruction, together with the duration and expense of the several camps, it is found that this extra tuition of its soldiery within the Pacific Division cost the United States daily about one dollar and twenty-five cents per capita, or, say, twenty dollars for each officer and soldier participating. Were these regiments of regulars and militia to be called upon to-day to take the field against a real adversary, I venture to assert they would justify the wisdom of the outlay for their special training.

Very respectfully,

S. P. Jocelyn,
Colonel, General Staff,
Chief of Staff.

On the Absorption of Electromagnetic Waves by Living Vegetable Organisms.

BY

GEORGE O. SQUIER, Ph. D.,
MAJOR, SIGNAL CORPS, U. S. A.

"B".

HEADQUARTERS DEPARTMENT OF CALIFORNIA,
OFFICE OF THE CHIEF SIGNAL OFFICER,
SAN FRANCISCO, CAL., December 3, 1904.

Major General Arthur MacArthur,
United States Army,
San Francisco, California.

SIR: In compliance with your request, I respectfully submit herewith, for your personal information, and for such use as you may think expedient, a report of an exceedingly interesting incident which occurred at the recent joint encampment of regular troops and organized militia, at American Lake, Washington, in connection with the signal service; together with an account of some of the consequences that may result therefrom.

I first learned of this incident from yourself, in August, 1904, at the time of reporting to you for duty as Chief Signal Officer of the Provisional Division comprising regular troops and organized militia at the joint maneuvers, Camp Atascadero, California.

The experiments described have been carried out in this Department during the past three months, with apparatus constructed here, and no attempt has been made thus far to determine to what ultimate distances this method of wireless signaling may be employed, since there are not available here for test, at present, any of the types of sensitive electromagnetic wave detectors which have been recently developed in different parts of the world, and which are principal features of the various systems of wireless telegraphy now in commercial use.

In space telegraphy with a particular type of apparatus, signaling distance is principally dependent upon the power of the emitter, and the delicacy of the detector.

In the paper enclosed, entitled, "ON THE ABSORPTION OF ELECTROMAGNETIC WAVES BY LIVING VEGETABLE ORGANISMS," some account of other physical phenomena, suggested by regarding the vegetable kingdom as a conductor for electromagnetic oscillations, is included, as indicating possible fields for useful research in living vegetation, attacked more especially from a physical viewpoint.

Very respectfully,

GEORGE O. SQUIER,
Major, Signal Corps, U. S. A.

CONTENTS.

ON THE ABSORPTION OF ELECTROMAGNETIC WAVES BY LIVING VEGETABLE ORGANISMS.

I.

INTRODUCTION.

The difficulty of transmitting electromagnetic waves over land as compared to that over seawater, has been well established, and this difficulty is attributed in a large measure to the general absorption of intervening hills, vegetation, buildings and conductors through which the wave trains must pass in reaching the receiving apparatus.

However closely we may approximate in theory to the actual mechanism of electromagnetic wave transmission, as used in wireless telegraph practice at present, it is now reasonably certain that both the earth itself and the space above the earth are essentially involved in the phenomena.

Repeated experiment has shown the importance of good earth connections for both the transmitting and receiving antennæ, and several letters patent, such as those of Lodge, Muirhead, Fessenden, and Stone, provide, in addition, for special conducting metallic nets, or strips, at the foot of the antennæ, extending therefrom to a distance of a quarter wave length or more, whereby the efficiency is increased.

The influence of the general condition of the earth around the foot of the antennæ as to moisture, temperature, and ingredients, has also been noted, and the effects of the capacity of the aerial itself, its height, and of elevated capacity areas placed at or near the end of the vertical wire, have been investigated in connection with the recent great advance in syntonized systems.

For best results, it has been observed in general that the vertical wire or net should be carefully insulated from all supporting poles, guys, or indeed any electrical conductor connected to the earth, the object being, to form an open vertical receiving circuit, insulated in the air.

We may therefore, with advantage, as Fleming and others have done, regard the general function of the vertical receiving wire and its accessories, as serving to unite electrically the earth and space effects above mentioned, by which, through the agency of one of the forms of wave detectors, a sufficient amount of the energy of the radiating waves is localized to operate a suitable receiving device.

It was from a general survey of the above established facts regarding the receiving conditions for successful wireless transmission of intelligence, that the writer was led recently to consider how far these conditions may be fulfilled by growing vegetation, particularly in the form of high trees covered with green leaves.

My attention was first attracted by learning from Major General Arthur MacArthur, U. S. Army, of a successful experiment made in July, 1904, at the military maneuvers of the Department of the Columbia, at American Lake, Washington, by Lieutenant William M. Goodale of the U. S. Signal Corps, in which he found that in laying rapid telephone lines in a wooded country, for the field exercises of the Army, a much better ground could be obtained by attaching the earth side of the instrument to an iron nail driven into the trunk of a tree or shrub, than by the ordinary and more laborious method of burying a conducting plate, or by driving an iron spike into the earth itself.

At the subsequent joint military maneuvers of the Department of California at Camp Atascadero, California, in August, 1904, opportunity was afforded the writer to test the efficiency of this simple means of earthing telephone and "buzzer" telegraph circuits in a country where, due to the extremely dry condition of the soil to considerable depths at that season, it was found very difficult, if not impossible, to use the ordinary single wire grounded circuit even when great care was taken in making the "ground". By using a tree, however, for a ground connection, a telephone or telegraph station could be established in a few moments, with excellent results.

It is found that the conductivity of a growing tree in a healthy state, for telephonic currents, is such that the earth contact nail need not be at the root of the tree, but may be carried to a height up the tree of 30 feet or more, and the telephone used from that elevation with satisfactory results. Indeed, experiment shows that good communication can be maintained from one tree top to another with the trunks of both trees in the circuit. When the operator holds the ground wire in the hand, and completes the circuit to earth by merely touching a live twig or leaf, the transmission of speech is good. This permits the military scout to use the vantage point of the tree elevation for observing the enemy, while being screened from view by its foliage, and at the same time, to transmit by telephone to the distant station, the information thus obtained.

II.

VEGETABLE ANTENNÆ FOR WIRELESS TELEGRAPHY.

The experiments described below were conducted principally at Fort Mason, San Francisco, California, where the U. S. Signal Corps has a wireless telegraph station, and between this point and Alcatraz Island, San Francisco Bay, another wireless station of the Signal Corps, at a distance of about 1½ miles.

Later, the Naval Wireless Station at Yerba Buena Island, at a distance of 3¼ miles, was also used as a transmitting station, through the courtesy of Admiral Whiting, U. S. Navy.

A grove of eucalyptus trees on the lawn in front of Major General Arthur MacArthur's quarters at Fort Mason, was utilized as a receiving station.

Apparatus and Method of Experiment.

The experiments thus far have been mainly qualitative, and the apparatus used, of marked simplicity.

In testing the effects of different arrangements of receiving circuit, and of capacities and inductances in its branches, it was more convenient to use the station at Fort Mason for transmitting, which is about 320 yards distant from the trees utilized as receiving antennæ.

The transmitting apparatus at Fort Mason consists of a small Apps induction coil of about 4-inch spark, and a vertical antenna wire suspended from a 75-foot pole situated on a bluff about 80 feet above sea level. This was one of the first wireless stations installed in the United States.

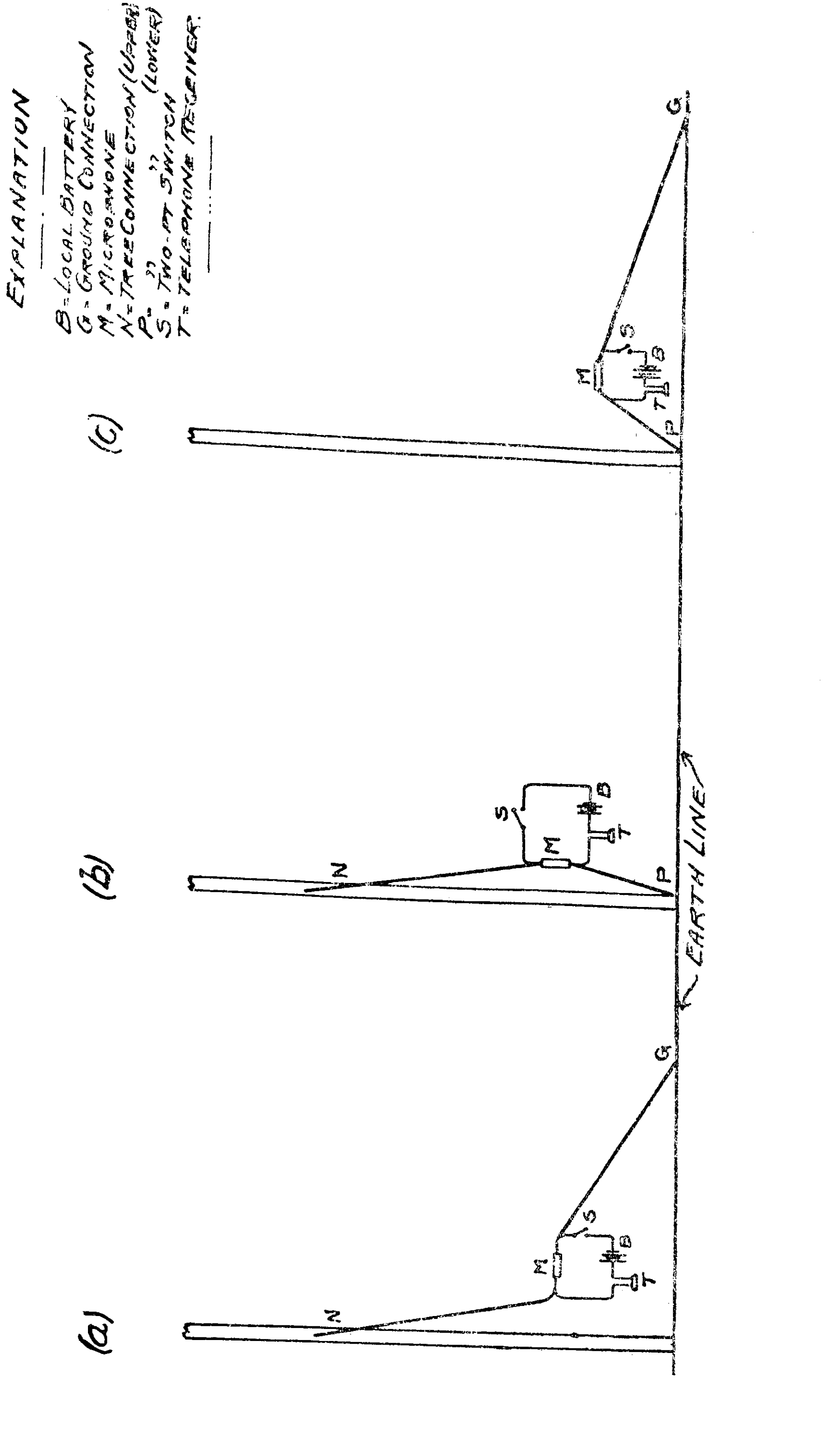
The detector used consists of a simple microphone made by partially filling a small ebonite tube with the regular sized spherical carbon granules used in telephone transmitters, and by imbedding therein two steel needles as electrodes so that they nearly touch each other at the central part of the tube.

This apparatus, which serves to give roughly quantitative results, decoheres itself readily, an occasional slight tapping with the hand being all that is required to keep it sensitive.

A head telephone was used to interpret the signals.

No attempt has been made thus far to determine to what ultimate distances this method may be employed for wireless signaling, since

FIG. 1.


EXPLANATION
B = LOCAL BATTERY
G = GROUND CONNECTION
M = MICROPHONE
N = TREE CONNECTION (UPPER)
P = " " (LOWER)
S = TWO-PT SWITCH
T = TELEPHONE RECEIVER
(a)
(b)
(c)
EARTH LINE

this is dependent upon many things, notably high power in the sending apparatus, and extreme sensitiveness in the receiver.

The experiments described have reference to the general features of the phenomena observed. The wave length employed in most of the tests was about 300 feet, corresponding to a frequency in free space of 3.27×10^6 per second.

In figure 1 are shown three typical arrangements of receiving circuits, which have been found efficient in practice. In this figure, a growing tree is represented by the double line.

In figure 1 (a), N represents a point of electrical contact with the tree, made in any convenient manner, such as by driving an ordinary iron nail or pin into the tree, preferably through the outer, living part thereof.

The point G represents a conducting contact with the earth, made by driving a metallic pin therein. M is a microphone; T, a telephone; and B, a source of electromotive force. In figure 1, (b) and (c), the corresponding letters represent similar apparatus.

The first experiments tried were with an arrangement of circuits indicated in figure 1, (b).

The electrical contact with the tree at the point P, was made by driving a nail into the tree itself an inch or two above the earth line, so that the contact would be distinctly with the tree, and not with the earth. The whole apparatus used for these preliminary experiments was extremely simple, consisting of a few feet of flexible lamp cord, a microphone, with three small dry cells, and a head telephone receiver, suitably mounted on a small board about 10″x12″.

With the electrical contact at the point P remaining stationary, the upper point N was shifted up and down the tree, the effects being noted. In this experiment, the transmitting station remained unaltered as far as possible, sending a simple signal, such as the letter S. It was found that as soon as the distance PN became more than 3 or 4 feet, faint signals were heard, which in general increased in loudness with the distance between P and N, along the trunk or stem of the tree, up to the general region where the first branches began to diverge, beyond which a further increase could not be certainly noted.

In order to insure that the effects observed were actually due to electromagnetic waves from the tree itself, and not to the short antenna wire represented by MN, in (a) and (b), figure 1, a careful exploration of the tree was made, using lead-covered insulated wire for the connections PM and MN, the lead covering of this short antenna being carefully grounded, so that the actual wire used was incased throughout in an earth connected metallic conductor, which would effectually screen the electromagnetic waves from affecting the wire inside. With such a wire, with the point P remaining stationary, experiments were made, showing that as soon as the distance PN became more than about 3 feet for the particular distance and apparatus used, faint signals began to be heard. Upon removing the terminal an inch or two away from the tree, still keeping it at the same height above the earth, the signals disappeared entirely, returning again when electrical contact was restored. These effects increased in general, as the distance PN became greater.

Metallic net screens of fine mesh were also used to protect the whole receiving apparatus, and were placed close to the tree on the side toward the receiving station, and above the height of the point N for a considerable distance.

A tree selected behind a masonary embankment 8 feet high, and growing close up against the wall and on the side directly opposite the sending station, was also used for receiving purposes, so that the whole receiving apparatus, including the upper contact was considerably below the surface of the ground sustained by the retaining wall. These conditions did not perceptibly interfere in receiving signals through the tree.

The method employed in these experiments has the disadvantage of requiring the results to be interpreted by relative intensities of sound to the human ear, which method is well known to be unreliable in general, as compared with any method involving an instrument, for instance, where deflections may be read by the eye, yet the effects were so pronounced and unmistakable that they were readily confirmed by repeated tests.

It was found that the upper contact point N could be made either to a metallic nail or pin, driven into the tree trunk, its smaller branches, or by pressing the wire against its leaves, buds, or flowers.

Since a vertical wire, earthed at its lower extremity, possesses a potential node, and a current anti-node for electromagnetic waves at approximately the point where the wire intersects the earth line, it was thought that a growing tree, which can be regarded as a vertical conducting cylinder, earthed at its lower end through its root system, would possess a more or less well defined potential node region at or near the intersection of the earth line with the trunk or stem of the tree. Experiment confirmed this, and the point P, at the base of the tree was therefore used, in general, as one of the advantageous points of connection throughout the experiments, and comparisons usually made from this point to others, both up and down the tree itself on the one hand, and in exploring the ground surrounding and adjacent to the tree on the other.

Electromagnetic Effects in the Surface of the Ground Immediately Surrounding the Base of the Tree.

In figure 1 (c), is shown an arrangement for receiving electromagnetic effects from the surface of the ground itself immediately surrounding the growing tree. Here, as in (b), the point P was a metallic nail in the tree at its base, whereas the point G was at various radial horizontal distances up to and somewhat beyond $\lambda/4$. With this arrangement it was then an object, using P as one terminal, to explore horizontally along the surface of the ground with the other terminal.

It was found that a marked difference in effects could be obtained by changing the point G, relative to the base of the tree, at times even as little as a foot or two, provided however, it was in a zone beyond 6 or 8 feet distance from P. This minimum distance, however, is a matter of the sensitiveness of the instruments, as well as of the power used at the transmitting station. No law has been observed, thus far, relative to the position of the point G from P, since the local effects produced are quite likely due to the unsymmetrical distribution of the root system immediately beneath the surface, which root system readily conducts electromagnetic waves, and may therefore be considered as an extension of the antenna into the earth.

When the wire at P was entirely removed from the nail at the base of the tree, and inserted in the ground itself immediately adjacent thereto, but not actually touching the tree at all, the signals were heard. Here, then, we are receiving electromagnetic effects without any actual contact with any form of antenna, but directly from the earth itself immediately surrounding the foot of the antenna, and under its electrical influence.

In figure 1 (a), which is a combination of (b) and (c), is represented a third type of receiving circuit which gave slightly stronger results than either (b) or (c) independently.

With the three typical circuits diagrammatically indicated in figure 1, a number of experiments were tried, with the following results: Inserting impedance in MN, figure 1, (a) and (b), invariably cut down the intensity of the signals, whereas, impedance inserted in

MP, (b) and (c), had little or no effect. A large choke coil with an iron core, inserted at the lower contact P of the circuits, made practically no difference, whereas, the reducing influence of a hundred ohms in the branch MN, (a) and (b), was decidedly noticeable. A small air core coil, made by winding a few turns of small wire, and inserted in this branch of the circuit, cut down the effects perceptibly, while seven or eight thousand ohms would cut off all signals. With the arrangement figure 1 (a), short circuiting from a point at the base of the tree to either side of the microphone, alternately, made no appreciable change in intensity of signals. The detector in use being a microphone, operated by potential difference, and not by energy or current, attempts to increase the effect in the microphone by a number of parallel branches MN, made to several separate metallic pins in the tree around its circumference at the height N, and joining each to the same terminal of the microphone, produced no perceptible increase in intensity, as was expected. The same may be said, of course, with respect to substituting for the single metallic electrode P at the base of the tree, several such points connected in parallel to the microphone.

Several trees of a large grove were connected in parallel by joining the upper terminals thereof to one terminal of the microphone, the other terminal of the microphone being to earth. Here, again, slight increases were shown upon cutting in different trees in succession, singly, and in combination. The slight differences noticed were probably due to differences in size and character of the trees, the resultant effect upon the microphone being merely that of the most efficient tree of the number being used at any one time.

In an effort to determine means for increasing and concentrating a greater proportion of the electromagnetic waves absorbed by the whole tree system, and for localizing the effect at the proper point in the receiving circuit, the following significant experiment was made.

With the arrangement, figure 1 (b), several other contacts were prepared around the circumference of the tree at N, and also at P, and these short circuited by wires direct, affording metallic paths for the waves to reach the earth other than the one actually containing the microphone. Not the slightest diminution of the signals could be noticed upon connecting such short circuit wires, either singly or in combination, provided only of course, the short circuit was not between the actual nails used in the receiving circuit, but was confined to other terminals in the tree, even when very close thereto.

This experiment shows that the electromagnetic effects utilized in the single circuit, shown in figure 1 (b), are but a very small proportion of the total effect absorbed by the whole tree system. This indicates that if we use a wave detector which operates by electrical energy, instead of potential difference, we can easily magnify the effects. Manifestly, this can be done by surrounding the tree, at the selected upper point, by a conducting ring or collar, containing many metallic contacts with the tree itself, thereby multiplying and concentrating at the detector almost at will, the proportion of the energy of the electromagnetic waves absorbed by the tree system as a whole.

In similar manner, the point P, at the base of the tree, may become a conducting ring or collar, with many actual contacts with the tree itself.

If a wire is attached to the same upper tree contact which is being used for receiving, and its other terminal touched in succession to other contacts along the tree nearer and nearer to the lower contact point P of the microphone, then a perceptible decrease in intensity of the signals is noticed as the lower contact P is approached; this operation causes the signals to almost entirely disappear when this wire is touched to the tree within a few inches of the point P. In the latter case, a lower impedance path to earth than that through the microphone is offered the electromagnetic waves.

The point G in figure 1, (a) and (c), can be made by metallic strips or nets laid upon the ground, or by driving metallic nails or pins into the projecting root system, at sufficient distances from the base of the tree.

The position in azimuth of the contact point N relative to the distant sending station, had no effect upon the received signals, the intensity being the same, even with the points P, N, in an element of the cylinder of the trunk of the tree, on the side directly opposite the sending station.

In figure 2, (a), is shown an arrangement of transmitting antenna which, however, has been used only over very short distances up to the present time, as the experiments thus far have been principally confined to receiving.

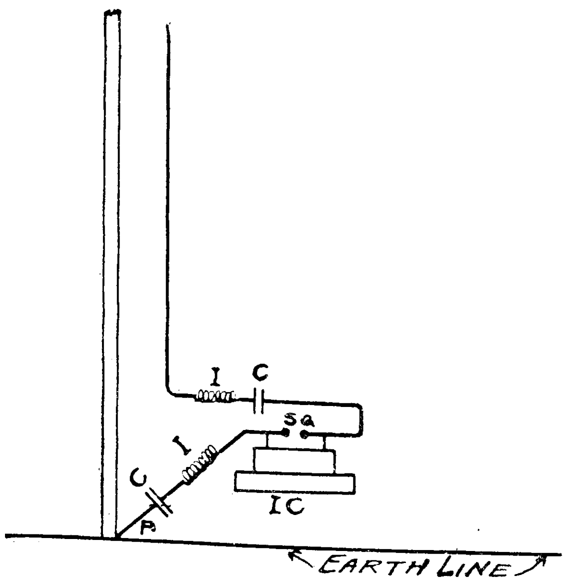
In the figure, the earth or ground is made through the root system of the growing tree, and the aerial is merely suspended, using the tree itself as a supporting mast.

Since the capacity of a vertical wire is increased by the presence near it of a conductor parallel thereto, the efficiency of the arrangement can be changed by varying the distance of the vertical wire from the trunk of the tree.

Attempts were made to note if there is any screening effect from neighboring trees in line with the receiving station; in other words, if electromagnetic shadows are cast. With the wave lengths used, and the distances involved, the results seemed equally good from even smaller trees immediately behind a bank of larger ones in line with the transmitting station.

FIG. 2.

(a)



Short circuiting the trunks of trees by direct wires from contacts at a point where the main branches diverge, to a terminal at the base of each, had no appreciable influence upon the signals being received from neighboring trees. A direct current sent through the tree by a hundred volts of battery, when thrown on, off and reversed, showed no perceptible effects upon the signals being received through the microphone.

No difference in receiving was noticed, resulting from the different wave lengths used in transmitting, whether from the Fort Mason

Station, Alcatraz Island Station, or the Naval Station at Yerba Buena Island.

No effects were observed with a telephone in series with a source of electromotive force, and connected directly to two small needle electrodes inserted in the smooth living surface of the inner bark of the tree. This result was expected, but the experiment should be more hopeful if the waves were made to traverse a portion of a minute living hair root, as we would then be dealing with an electrolytic detector built up of vegetable cells.

As indicating the order of magnitude of the ohmic resistance involved in these experiments, it may be stated that in a eucalyptus tree about 15 inches in diameter, the resistance between two nails 15 feet apart, was about 5,500 ohms.

In the cases measured, the resistance circumferentially, was greater than that measured over the same distance vertically, or with the grain of the wood.

In trees possessing a well defined heartwood, the effect of girdling is pronounced, since in such a tree the only living portion is a comparatively thin outer layer, the central portion of heartwood being practically dead and free from sap.

In cases of rapid growth, especially in this climate, the whole tree is practically alive, and the effect of girdling, even to a considerable depth, has comparatively little influence on the measured ohmic resistance.

As an example:

In a young eucalyptus tree at the Presidio, San Francisco, 18 inches in diameter, and about 50 feet high, the resistance was measured between two points on the tree trunk 15 feet apart, and was found to be 5,450 ohms. After completely girdling the tree to a depth of 1½ inches for a distance of about 2 feet between the electrodes, another measurement was taken over the same distance, and the resistance was found to be but 6,150 ohms.

The efficiency of an elevated capacity area attached to an antenna is not wholly dependent upon the extent of such area, but also upon its general configuration, or in other words, upon its capacity. In like manner, the efficiency of an artificial earth for grounding an antenna does not wholly depend upon the area of the plate buried in the earth, but also upon the shape and disposition of such surface, it having been observed that a given area of earth plate is more efficient in the form of strips, radiating out from a common point, at the foot of the antenna, than in the form of a single circular plate. It appears possible, therefore, that the manifold and varied forms and shapes given by nature to the leaf surfaces of vegetation, adapt them for absorbing electromagnetic radiation; while the general configuration of the root systems of trees, consisting of large radial root trunks, proceeding out from a common stem, and supplemented by innumerable branches and microscopic hair roots and rootlets filled with conducting fluids, is not ill-suited for the conduction of electromagnetic waves into the earth.

Again, the strength required in towers and masts for supporting antennæ wires, is provided in the antennæ here suggested, since a great tree with its natural buttresses, and its root system often extending deep into the earth, is well designed to resist the elements.

III.

WIRELESS TELEGRAPHY FOR MILITARY FIELD OPERATIONS.

There is little doubt at present that wireless telegraphy will be used in the military field operations of the future. The maintenance of a wire line has always presented a serious obstacle to reliability and efficiency, and when this line is in the military terrain, the problem is doubly difficult.

A principal objection to field wireless telegraph equipments has been the necessity of transporting some form of mast, captive balloon or kite, to sustain the vertical aerial. These balloons or kites, in addition to being difficult to manage, also disclose to the enemy the positions of the signal stations.

Realizing the ideal character of some form of space telegraphy for transmitting information in the field, the armies of Europe as well as the Signal Corps, U. S. Army, have been vigorously investigating this subject.

One of the best military field outfits at present in use is that furnished by the "Gesellschaft für Drahtlose Telegraphie" of Berlin, designed by Messrs. Braun, Slaby and Arco. This system has been tested by the Signal Corps, and there are in operation at present about forty of these equipments in the armies of the various countries of Europe.

The prime requisites for any field telegraph system are simplicity and reliability.

In the field wireless system above mentioned, there are included a power car, an apparatus car, and an implement car. Balloons or kites are used to raise the aerial wires.

The implement car is provided with a gas reservoir, the necessary tools, and a reserve benzine reservoir for the power car.

The power car is equipped with an alternating current dynamo, having a capacity of one kw, and a direct current exciting dynamo coupled to a four-horse power benzine motor. This small engine is cooled by a circulation of water, forced from a reservoir around the cylinder of the engine.

Storage batteries are automatically charged by the continuous current dynamo which supplies current for exciting the alternating current generator.

To the power car is attached the cable drum for hauling in the balloon.

A wire netting or metallic cylinder at a fixed horizontal distance from the earth is used, instead of directly earthing the aerial, in order to give more uniform results for syntonizing.

This general type of apparatus has been furnished the Russian Army, and is said to have given good results in the recent maneuvers of the German Army. It is also reported to have been adopted by Austria.

The above indicates the comparatively complex apparatus required for field wireless telegraph stations at present.

For short distances, which alone have been thus far attempted for reasons already stated, the field apparatus which was used in some of these experiments, is shown in the photographs herewith attached, indicating how simple the outfit for short distances may become, when the necessity for supporting masts, balloons or kites is removed.

In order to test other kinds of trees than those available at Fort Mason, California, a telegraph auto-car recently purchased for the Signal Corps of the Army, was temporarily fitted with the necessary transmitting apparatus, and a tour made through Santa Clara and Alameda counties, California, installing and operating field sending and receiving stations at various points along the route.

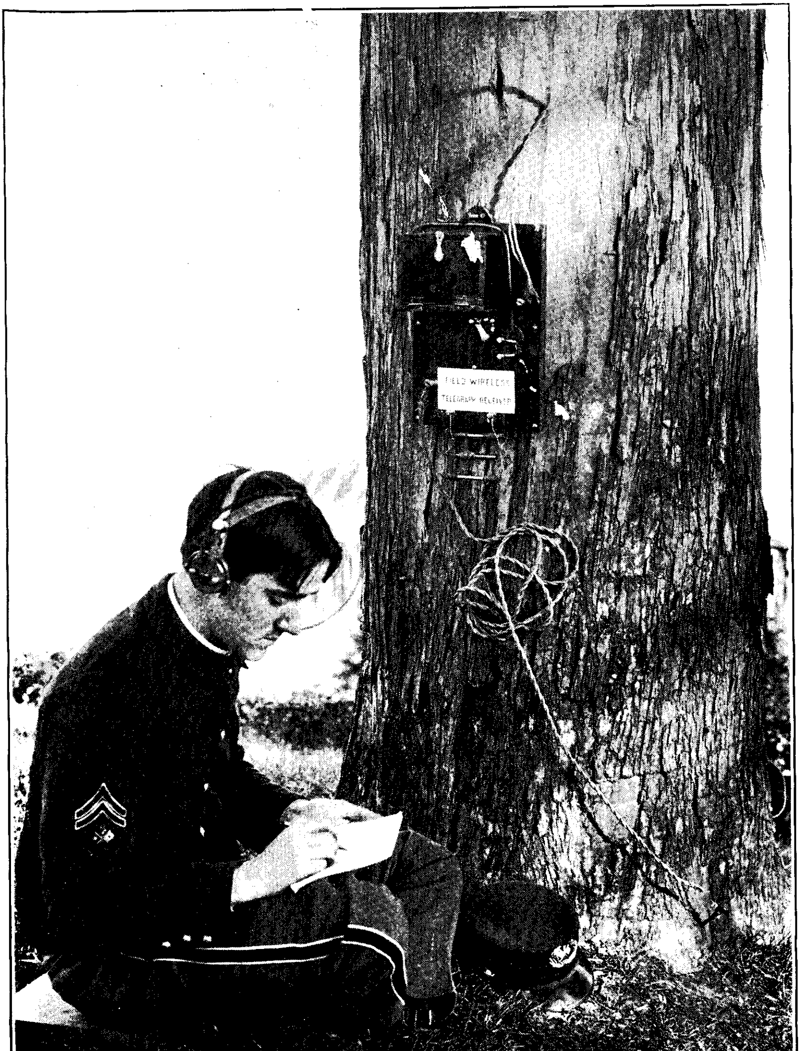
The electric power required was in the form of two small portable storage batteries of ten volts each, which were used to excite a large Apps coil.

When a tree was used to support the sending aerial, the "earthing" was accomplished through the root system of the tree itself, by attaching a wire to one or more iron nails driven into its base. The tree stem was utilized to support the aerial, the only electrical connection therewith being at its base.

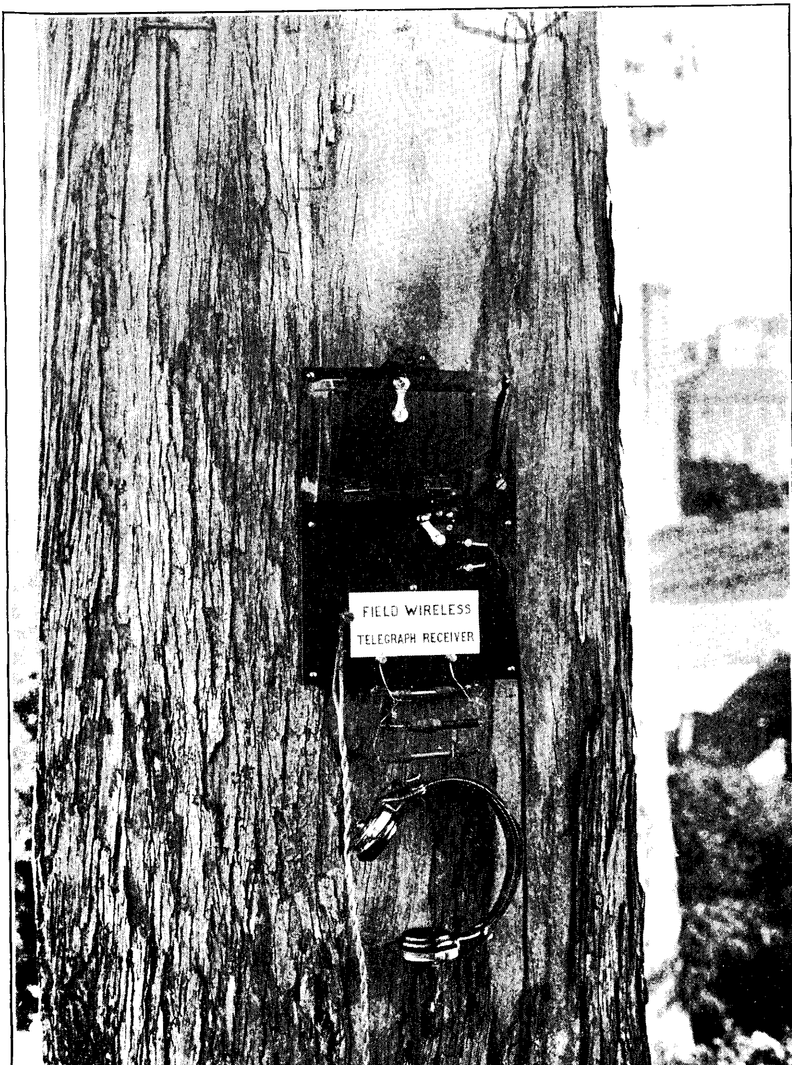
For receiving, the apparatus used was that already described and shown in detail in the photographs.

Several kinds of trees of various sizes were used for receiving, such as willow, pine, spruce, oak, etc., and a marked difference in efficiency observed. A tree with little leaf surface, and generally dry and unhealthy, is difficult to use at all, even for very short distances, while a tree perfectly dead behaves as an insulator.

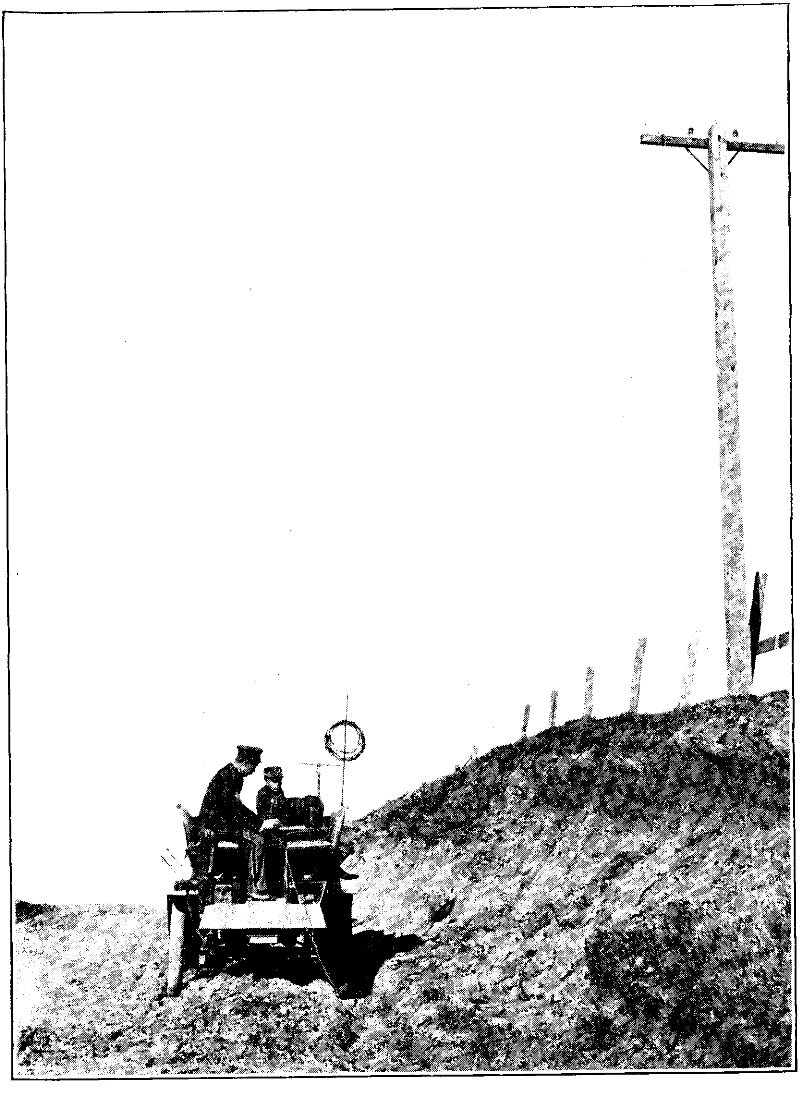
After a little practice, two men, a sergeant and corporal of the Signal Corps, one a good lineman, and the other the chauffeur of the machine, who also acted as telegraph operator, could install a sending station in ten to fifteen minutes. A receiving station is even



RECEIVING WIRELESS MESSAGES AT FORT MASON, CALIFORNIA,
FROM YERBA BUENA NAVAL STATION, 3¼ MILES DISTANT.
EUCALYPTUS TREE AS ANTENNA.



DETAILS OF FIELD WIRELESS TELEGRAPH RECEIVER, FORT MASON, CALIFORNIA, NOVEMBER, 1904.



TEMPORARY FIELD WIRELESS TRANSMITTING STATION,
NOVEMBER, 1904.

TEMPORARY FIELD WIRELESS TELEGRAPH AUTO-CAR, NOVEMBER, 1904.

less trouble to install, since there is nothing to transport except what can be carried in the hands.

The best field system of wireless telegraphy for the army will result only after careful, tedious and exhaustive experiments, and tests under the exacting conditions of actual war, for the extravagant and enthusiastic claims of inventors have nowhere to be received with more caution than in practical wireless telegraphy.

IV.

ELECTROMOTIVE FORCES IN GROWING TREES.

In the course of these experiments it was desired to measure with a Wheatstone Bridge, the electrical resistance of living vegetable cells, such as between metallic electrodes inserted in the trunk of a tree.

In attempting such measurements, it became evident that there are electromotive forces present in growing vegetation, which are exhibited in this case by the great difficulty experienced in making any accurate measurements of resistance at all, due to the continued unbalancing of the Bridge by these electromotive forces.

The phenomenon is complicated, and considerable experimental care, and many observations upon different kinds of trees, in various locations, and in different kinds of weather, would be needed to clear up the matter satisfactorily.

For instance, unless platinum or other non-oxidizable electrodes are employed, there would be voltaic effects caused by the vegetable acids of the sap of the tree in contact with the metallic electrodes imbedded therein, and also, unless modified by the tree itself, we would expect a difference of potential between an electrode at the base of a tree and one higher up the tree, since the upper atmosphere is positive with respect to the earth. Again, it has been shown that a living tree serves as an earthed conductor, and is sensitive to electrical disturbances outside of itself. The resistance measured evidently depends, also, upon the size and shape of the electrodes used, etc.

A suitable electrometer was not at hand, so that in order to determine roughly the general character of these phenomena, some observations were taken with a Weston Laboratory Standard Milli-Voltmeter, with a diagonal scale capable of indicating electromotive forces as small as .00002 of a volt.

Several curves were taken, but sufficient regularity was not observed to enable any adequate theory to be advanced at present. An electrostatic instrument, whose readings are independent of the ohmic resistance between the electrodes, should be used for such experiments.

The curve, figure 3, exhibits the volt-time variations observed between two points in the trunk of a eucalyptus tree, one, at the base of the tree, and the other at 25 feet elevation. The electrical contacts were made by inserting metallic pins in the tree itself, no earth connections being used.

The resistance of the tree between the electrodes was about 6,150 ohms, which was large in comparison with that of the voltmeter, and the readings, therefore, do not represent actual values of the voltages, but serve merely to note general diurnal variations in a particular case.

From this curve it is observed that the upper contact is positive with respect to the one at the base of the tree, although slight reversals of very small value, and comparatively sudden changes, evidently due to causes outside the tree itself, were noticed several times. These, however, were too small and too sudden to be read on this scale. The observations for this curve were obtained by half-hour readings over a period of 24 hours, during a great portion of which a severe rain storm was raging. The day in general was extremely cloudy, with little sun.

It appears from the curve, that from 9 o'clock in the evening until 6:30 o'clock in the morning, the electromotive force was too small to be recorded by the instrument, and that the principal changes occurred between 6:30 and 9 o'clock in the evening, and between 6:30 and 9 o'clock in the morning, with another rise between 1:30 and 4 o'clock p. m.

Variations of the electromotive force between the lower tree terminal and the earth itself, are comparatively large and indefinite in manner, as has been observed frequently before, due to earth currents proper.

In examining the curve in figure 3, it is interesting to note that two of the maximum changes occurred, one in the early evening, and another in the early morning, about twelve hours apart, or at about the periods when the general influence of the sun during the day is withdrawn for the night, and again when it reappears in the morning after a long period of darkness.

In other cases, the readings between electrodes a short distance apart indicated as much as 8 milli-volts, and at times the terminal at the base was positive, instead of negative.

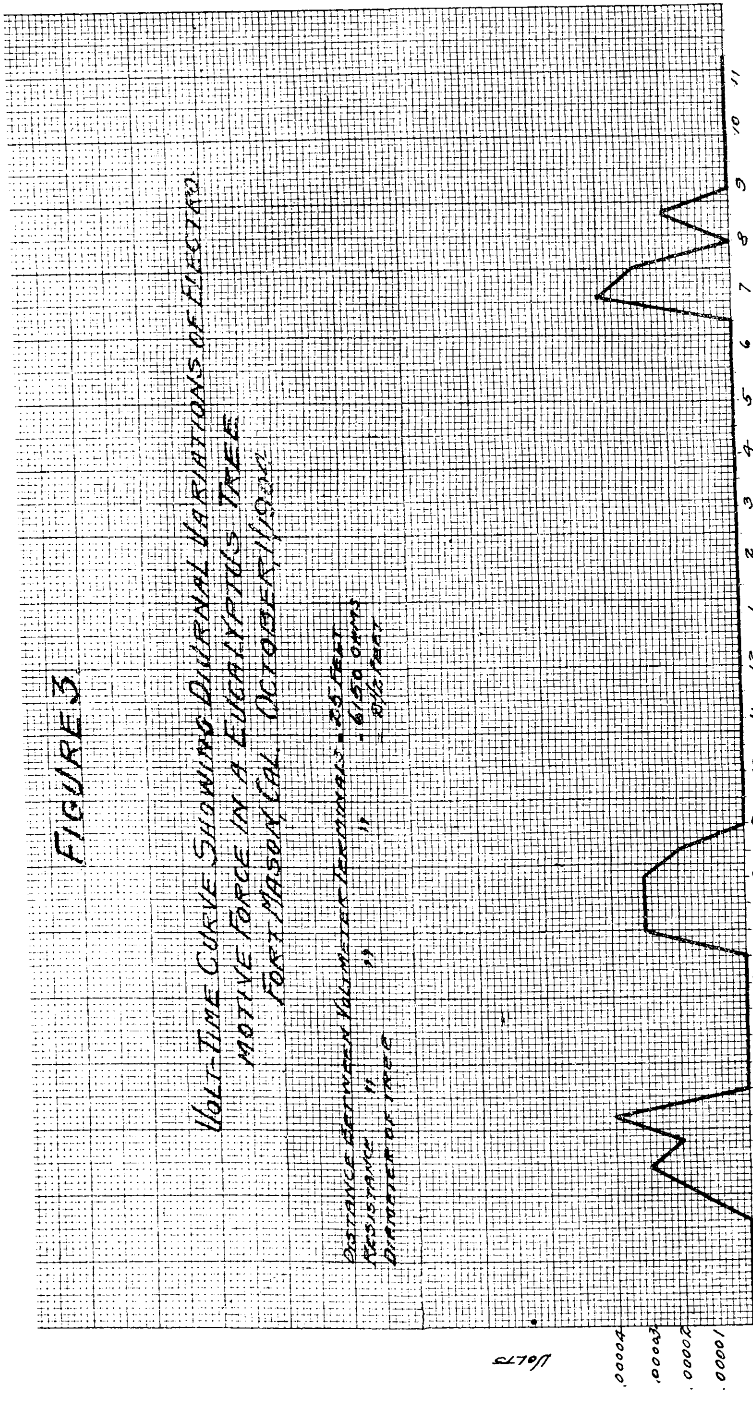


FIGURE 3
VOLT-TIME CURVE SHOWING DIURNAL VARIATIONS OF ELECTRO MOTIVE FORCE IN A EUCALYPTUS TREE
FORT MASON, CAL. OCTOBER
DISTANCE BETWEEN VOLTMETER TERMINALS = 25 FEET
RESISTANCE " " = 6150 OHMS
DIAMETER OF TREE
12 NOON 1 2 3 4 5 6 7 8 9 10 11 12 MID 1 2 3 4 5 6 7 8 9 10 11
TIME
.00004 .00003 .00002 .00001
VOLTS

Resistances were more easily measured at night than in the day time, as the balancing of the Bridge was then more readily obtained.

According to present theory, during daylight the air is filled with electrons, carrying positive and negative charges of electricity which are more or less recombined during the night.

In this connection, it is interesting to note that it is stated by Sir Oliver Lodge, in a footnote to his Royal Society lecture of 1894, that he found that leaves of geraniums discharge positive electrification five times as quickly as negative, under the action of an arc light.

Evidently, these phenomena require careful investigation.

V.

ON THE ABSORPTION OF ELECTROMAGNETIC OSCILLATIONS OF LOW FREQUENCY.

There are three modes by which an electrical disturbance may be transmitted through space, namely:—by electromagnetic induction, by electrostatic induction, and by electromagnetic radiation.

The first of these was the basis of an early system of wireless telegraphy, as used by Sir William Preece and others. The second comprises a method proposed by Professor Dolbear,* Edison, and others.

In general, the effects of both electromagnetic induction and electrostatic induction decrease with the cube of the distance from the source, so that these methods have not proved efficient as a means of transmitting intelligence through space where considerable distances are involved.

Since Hertzian waves are readily absorbed by vegetation, it was desirable to determine to what extent electromagnetic oscillations of low frequency are also absorbed. The following experiment was therefore tried:

Near Lorin Station, along the route of the long distance transmission line of the California Gas and Electric Corporation of San Francisco, the vegetation was examined for inductive effects. This line transmits power from Yuba County, California, at a voltage of 56,000, with a frequency of 60 cycles per second, three-phase.

From previous experiments, it was thought that the vegetation in the vicinity of this transmission line would be sufficiently affected, so that a note corresponding to this frequency would be heard in a telephone receiver.

Upon connecting the telephone between two nails driven in any growing tree along the route of this line, and at a reasonable distance therefrom, the telephone responded to this note with great clearness, and when the distance was not more than 100 feet, the sound was very loud. For this experiment, no microphone need be used, nor any source of electromotive force other than that induced in the tree itself, the telephone being connected directly between two nails driven into the tree.

* U. S. Letters Patent No. 350,299, dated October 5, 1886.

Since the trunk or stem of the tree, being perpendicular to the surface of the earth, is normal to the direction of the transmitting wire, the effects of electromagnetic induction should be a maximum between points of the tree on a line parallel to the wire, and a minimum between points on a vertical line. Since, however, the large leaf surface at the top of the tree presents in reality an extensive conducting area, it may be regarded as having a resultant surface which acts as a capacity plate parallel to the earth, and connected therewith by a vertical cylindrical conductor represented by the stem or trunk of the tree. The details of the experiment follow:

In a tree 18″ in diameter, between points in the circumference at the same level above the surface of the earth, and parallel to the wire, the effects were nil in the telephone, whereas, the effects in a vertical line along the trunk of the tree increased in general with the distance between the electrodes. It appears, as stated above, that, although the stem of the tree is normal to the power line, the general leaf surface spreads out horizontally, and receives electrostatic charges from the alternating current in the line, causing a corresponding alternating current to flow in the trunk of the tree, which current is indicated in the telephone.

Opposite the transmission line, in an open meadow free from vegetation, an examination of the surface of the ground with the same apparatus exhibited marked effects, and with one terminal stationary, and the other terminal exploring in azimuth, the location of the equipotential lines, normal to the direction of the wire, and of the lines of current flow, parallel thereto, could be readily and accurately traced at any reasonable distances from the wire, the effects, however, rapidly dying away as the lateral distance increased.

The points of no sound in the telephone could be located within two or three feet, at a distance of one hundred feet from the transmission line, and with no source of electromotive force other than that induced in the surface of the earth. This simple experiment is very realistic, and is a repetition on a large scale of the familiar laboratory experiment of tracing the lines of current flow on the surface of a conducting liquid, by means of a telephone and "buzzer," except that in the latter case, we are concerned with electric conduction instead of electromagnetic induction.

Several kinds of trees of various sizes and forms were examined along this power transmission line, and all were found to be singing, with a loud voice, the fundamental note characteristic of the frequency of the line current. Indeed, the strip of vegetation along this line has thus been singing continuously, day and night, for several years, since the operation of the line began, it needing only the electromagnetic ear to make the sound apparent.

The general appearance of vegetation along this route is certainly vigorous, showing that the continuous presence of actual electric currents of an oscillating character, flowing throughout the living portion of the vegetation, does not apparently interfere with normal growth—indeed, if any effect is noticeable, it is rather that of increased luxuriance of growth in the immediate vicinity of this line, although this point would require careful observation by skilled specialists. The fact remains, that from a botanical standpoint, we have here an experiment on a huge scale, of vegetation growing over an extended period of time under the influence of induced electrical oscillations of low frequency flowing through its living parts.

This transmission line, at the point examined, is strung on wooden poles about 45 feet in height, with special porcelain insulators for the execessive voltages used. The insulation is so effective that an examination of one of the supporting poles of this line, in the same vicinity, and with the same apparatus, failed to give any indication in the telephone, although the pole itself was vibrating mechanically, due to the stretched wires being supported on it. In fact, dead vegetable matter, thoroughly dry and free from sap, is an efficient insulator for electrical oscillations.

The conductivity of a substance for electrical oscillations of high frequency is dependent upon the amount of surface area, rather than upon the volume, since the result is a " skin " effect, which decreases in thickness as the period of oscillation increases. The amount of conducting area presented in the innumerable chains of vegetable cells filled with conducting fluids, which go to make up the living portion of the trunk of an ordinary tree, is very great compared to that offered by wires.

VI.

FLORAL SPECTRA.

Spectrum analysis has been of inestimable value in making known to the world the manifold beauty and variety of radiation, and it stands at present as the most powerful means at the disposal of the physicist and chemist for qualitative analysis.

This method has revealed the existence of many until recently so-called elements of nature, such as caesium, rubidium, thallium, indium, gallium, etc., and is able to detect, under proper conditions, the presence of such a very minute quantity of a substance as one ten-millionth of a milligram of calcium, and a one hundred-millionth of a milligram of strontium, in the high temperatures of the electric discharge. Heretofore, spectrum analysis has not been available for studying vegetable matter.

If in the place of the usual metal electrodes of a moderately powerful induction coil, suitable vegetable electrodes be substituted, most of the phenomena of the electrical discharge in air can be observed. An instructive experiment is the following:

Place upon a glass table two ordinary house plants in earthen jars, preferably plants of large leaf area, such as those of the palm family. Separate the regular secondary terminals of the coil beyond the sparkling distance, and connect the two growing plants each to a secondary terminal by simply inserting a fine wire in the damp soil in the jar, without actual contact with any part of the plant itself. Darken the room and excite the coil. By placing the jars near together, and then separating them by sliding them along the table, interesting phenomena are observed. When the nearest leaf surfaces of the two vegetable electrodes are beyond the disruptive sparking distance, the brush discharge effect outlining the edges of the various leaves is beautiful, and exhibits the effect of points and edges in streamlets of purple and lavender discharge. As the jars are moved nearer together, the usual disruptive spark takes place, and at a distance so nearly equal to the regular sparking distance between metal electrodes, that the living leaves of the plants may be said to behave electrically, for these highly oscillating currents, as though they were sheets of metal of the shapes and dimensions of the leaves themselves.

Under proper conditions, from a normal 8-inch spark coil, a 6-inch disruptive spark of deep purple is readily obtained between vegetable electrodes.

Upon closing the primary circuit of the coil, a decided movement of the leaves and stems of each electrode is observed, depending upon the stiffness of the leaves themselves, or their resistance to mechanical stress. The individual leaf surfaces of the same electrode suffer a mutual repulsion, while the leaves of opposite electrodes are strongly attracted, and may move up toward each other an inch or more at the moments of disruptive discharge.

These comparatively large leaf areas act as charged condenser plates of metal, those whose charges are of the same sign repelling each other, while those of opposite sign attract. The general effect of the electrical oscillations upon the plant life itself is interesting, and should be investigated quantitatively. When the discharge is a powerful one from a large coil, and the plant surface is small, the leaves between which the disruptive discharge takes place, seem to dry up and die within a day or two after such an experience, whereas other stems of the same electrode, on the side away from the disruptive discharge, remain seemingly unaffected, and continue to grow apace.

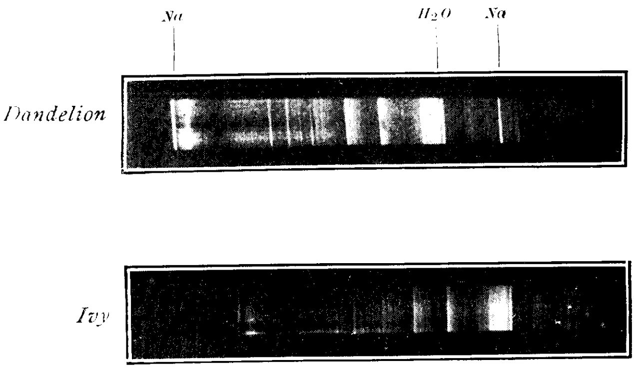
The heat of the discharge, and the volatilization of the water in the plant, undoubtedly play an important part, but what effect these rapid electrical oscillations may have on the living protoplasm of the plant cell, is an important question. The above indicates that in plant life, as in living animal cells, weak electrical oscillations may stimulate without harm, while sufficiently strong ones may produce "electrocution."

Since it is known that the red end of the solar spectrum contains the more efficient electromagnetic waves involved in plant growth, may not much longer electromagnetic waves, even such as those being here considered, which we have some reason to believe are also radiated by the sun, be capable of influencing plant life under suitable conditions?

For spectroscopic work, the discharge should be one of considerable energy, and for this purpose one or two Leyden jars in parallel with the spark gap, can be used to advantage, by which means the character of the spark may be changed from a thin non-luminous one, to a short, thick spark of greater brilliancy.

The general shape of a leaf surface causes the discharge to take place from its points and edges, thus dissipating the effect, but this can be partially overcome by "forming" the vegetable electrodes

FLORAL SPECTRA.



All lines and bands other than sodium lines appear to be due to nitrogen, and carbon compounds, and water vapor.

FIG. 4.

in suitable insulating and adjustable dies, such as by forcing several leaves, unattached from their growing stems, into glass tubes, so that their inner ends, to which the discharge is thus confined, will present vegetable surfaces of definite form. Comparatively large electrical power is needed for success in such experiments.

In figure 4, are shown photographic spectra recently taken at the University of California, at Berkeley, California, between dandelion and ivy electrodes, respectively. These were kindly furnished by Professor Percival Lewis of the Department of Physics of the University, a well known authority on spectroscopy.

VII.

CONCLUSION.

Until recently, the vegetable kingdom has been regarded as practically non-electric, but due to exhaustive researches* into the nature of the discharge of electricity through gases, the discoveries following that of radium, and the general phenomena of radio-activity, etc., a new electric theory of matter has been formulated, which serves to bring all forms of gross matter within its comprehensive embrace.

It would seem that living vegetation may play a more important part in electrical phenomena than has been generally supposed. We have seen that living vegetable organisms absorb and conduct electromagnetic oscillations over a wide range of the electromagnetic spectrum, beginning with sunlight, whose electrical action in the plant cell is at present little understood, and extending to waves of identical character, but of immensely greater lengths, such as Hertzian radiation, telephonic waves, and oscillations of the ordinary low frequencies used in commercial electric transmission lines. Disruptive discharges between vegetable electrodes, and electrostatic effects between vegetable surfaces are easily produced.

The paucity of scientific literature upon this general subject is remarkable.

Recently, Professor S. Lemström† of Helsingfors, Finland, published an account of some interesting experiments upon vegetable growth in northern latitudes.

It is noted by Professor Lemström that there is a rich development of plants in the Polar regions, as compared with corresponding conditions in countries further south, which he attributes to peculiar electrical conditions of the atmosphere causing the phenomena of "aurora borealis."

It is also noted that the flora of the Temperate and Polar regions, such as the pine and fir, have by nature sharp pointed foliage and pointed projections, suitable for the conduction of electromagnetic waves accompanying "aurora borealis."

May not here exist either a cause of, or in part, a reason for, such floral forms?

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* "*Conduction of Electricity through Gases,*" J. J. THOMSON.

† "*Electricity in Agriculture and Horticulture,*" by PROFESSOR S. LEMSTRÖM, London.

Plowman* has studied the growth of seedlings in water through which an electric current is made to flow, and records the general effect of the anode in causing the root tips to turn towards it. He attributes this reaction to the effect of positive electrons rather than to mere chemical effects of the atoms themselves, and states his conclusion that "negative charges stimulate, and positive charges paralyze the embryonic protoplasm of plants."

Since it is easy to induce into plant cells electromagnetic oscillations over a wide range of frequency, without mechanically disturbing the natural position of the plant in soil, researches to determine the possible influence of such oscillations upon plant life should be undertaken.

According to present theory, all electrical conduction is really electrolytic in character, accompanied by dissociation of electrons and recombination, so that actual oscillatory currents maintained throughout the living organisms of vegetation may effect changes in a growth whose very existence is now known to vitally depend upon other electromagnetic waves of sunlight.

Heald† has examined, for the determination of relative electrical conductivity, the juices of plants, expressed from the leaves, stems, roots, etc. He finds such juices comparatively good conductors, due principally to dissolved mineral substances, while organic compounds play a minor part.

Jonesco‡ has given elaborate study to the underlying causes of the seeming preference of lightning for certain kinds of trees, and states that woods rich in fatty materials are not as good conductors as those containing a greater proportion of starchy matter.

The element of imagination is a dangerous one in physical research, yet without it, often in a bold form, the more important advancements in physical science would not have been made.

However, in view of what has been accomplished in space-telegraphy within the last seven or eight years, it is difficult to predict to what extent this means of communication may be ultimately developed. If, as indicated above in these experiments, the earth's surface is already generously provided with efficient antennæ, which we have but to utilize for such communication, even over short dis-

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* "*Electrotropism of Roots*," by AMON B. PLOWMAN, Phanerogamic Laboratories, Harvard University, American Journal of Science, August, 1904, ibid XIV p. 131. August, 1902.

† "*The Electrical Conductivity of Plant Juices*," FREDERIC DE FORREST HEALD. Science, Vol. 15, p. 457.

‡ "*Ursachen der Blitzschläge in Bäume*," DIMITRIE JONESCO, Stuttgart, 1892.

tances, it is a fascinating thought to dwell upon in connection with the future development of the transmission of intelligence.

Since a transmitting station is a central point for electromagnetic waves sent out in all directions over the surface of the earth, a large class of information, such as meteorological reports, crop reports, and general news items of interest to all, may in time be sent from central points, to be received at many places within the radius of influence of the signal station, and this, too, by the simplest forms of apparatus.

Again, it is seen that a growing tree, covered with foliage, is influenced inductively by electrical disturbances outside of itself, and in fact becomes generally responsive to induced electrical oscillations. It should offer, therefore, a promising means of studying meteorological effects of an electrical character, particularly those of lightning discharges, and electricity of the air. One of the first practical rules for the preservation of life against lightning is to avoid the vicinity of a tree.

Our great forest areas may exercise an influence in maintaining a general equilibrium between the electrical charges of the upper atmosphere and the earth, which has not been fully realized. On this point, comparisons between observations from the interior of great desert areas devoid of any vegetation, with those from other portions of the earth's surface well covered with forests, would be instructive.

Notwithstanding the accumulated data since the famous kite experiment of Franklin in 1752, much has yet to be done towards an electrical survey of the earth's atmosphere.

From this viewpoint, the general surface of the earth may be considered as supplied by nature with innumerable meteorological observation towers, which possibly may be employed by means of apparatus involving principles already well known to science.

In conclusion, it is believed that vegetation should be studied more systematically from a distinctly physical standpoint than has been done in the past. Physics has been said to be the mother of all the sciences, and more and more the physical method of studying all science is proving to be the true one, as is evidenced by the great advance in recent years, in comparatively new branches of scientific work, such as Astrophysics and Physical Chemistry. Has not the time arrived for a more systematic study of Physical Botany, in the light of the new electric theory of matter?

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Phelan Building, San Francisco, Cal.,
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