Weagant's Anti-Static Invention

Details of a Great Discovery Which Has Revolutionized Long Distance Wireless Communication

An abstract of a paper read before a joint meeting of the New York Electrical Society and the Institute of Radio Engineers at a monthly meeting, Wednesday, March 5, 1919.
In Two Instalments.

PART I

Reported by Elmer E. Bucher
Director of Instruction, Marconi Institute

TO a large and enthusiastic audience composed of radio engineers and scientists of prominence, at a joint meeting of the Institute of Radio Engineers and the New York Electrical Society, held March 5, 1919, Roy A. Weagant, Chief Engineer of the Marconi Wireless Telegraph Co. of America, delivered a paper describing in detail his apparatus for the elimination of the great bug-bear of transoceanic wireless communication—static interference.

So quiet had the details of Weagant's great discovery been kept that few in the audience had the slightest inkling of the fundamental principles upon which the operation of his system is based. And so convincing was the explanation given by the speaker that even the most skeptical were compelled to admit that the discovery was not the result of speculation in theory, but was the outcome of a progressive series of orderly, scientific investigations founded on sound scientific principles.

In the subsequent discussion of the paper, one of the first to laud the inventor was Dr. Michael Ivadorsky Pupin, world famous scientist, who remarked that whatever may be our opinion of the theory advanced supporting a seemingly vertical propagation of static, the outstanding fact remained that Mr. Weagant had demonstrated beyond all doubt that his apparatus was a practical operative proposition and, after all, this was the all-important thing to be considered.

He congratulated the inventor on the success attained and remarked that the discovery was one great stepping stone toward the final solution of the ideal wireless system. He hoped that radio engineers would now give their attention to the development of an amplifier which would permit transoceanic communication with very small powers, for, as he jocularly remarked, the average college professor with his limited pocketbook could not accustom himself to think in terms of 200 kw. radio frequency alternators and enormous receiving aerials such as now are employed! He felt, however, that the commercial success of transoceanic communication is now assured.

David Sarnoff, Commercial Manager of the Marconi Company, brought out the fact that for the first time in the history of electrical communication we are enabled to establish a telephonic service between countries separated by the oceans, noting that in the some 60 years of the practical applications of electrical signaling, no solution of the problem had even been suggested. He also threw an interesting sidelight on the inventor's ideas regarding nature and its laws, declaring that Mr. Weagant once remarked that he could not conceive that Mother Nature, having given to mankind such a priceless boon as wireless communication, would deliberately put into force another unsolvable law which would destroy its usefulness. Mr. Weagant had held to this belief firmly, and his subsequent success would seem to indicate that his discovery had initially more of the nature of an inspiration than had ordinary scientific achievements.

G. H. Clark, Expert Radio Aide, U. S. N., who had been assigned to the U. S. Navy Department to witness the experiments of Weagant, testified to the indefatigableness of the inventor, ascribing his success to stubborn persistence and willingness to abandon a mere theory in favor of an experimentally demonstrated fact. He stated that he was amazed at the results secured in the very earliest experiments, which he was privileged to witness, and that, concerning the ability of the Weagant system to weed out static, there could be no doubt.

F. N. Waterman, who has been closely associated with Weagant from the inception of the invention, praised the inventor for his daring in attacking a problem of such magnitude and declared that it was the ability of Weagant to recognize the fallacies of all previous systems purporting to eliminate static that enabled him to evolve a practical method of wireless reception of wonderful, commercial and scientific value. He recounted in a most interesting manner the results of early experiments, and the many obstacles and discouragements met with and overcome.

He stated that after complete success had been attained, it was almost uncanny to pick up a telephone receiver, at a long distance radio receiving station, in which the crashes of atmospheric electricity were so loud that it was next to impossible to detect the wireless signal, and then to simply throw a switch and note the static disturbances disappear to a degree that required a trained ear to hear them; and simultaneously to note the wireless signal so increased in intensity as to make it easily readable.

E. F. W. Alexanderson, of radio frequency alternator fame, said that when it was first mentioned that a hitherto unknown law of nature had been uncovered, he was somewhat skeptical regarding it, but now it was plainly to be seen that the speaker of the evening had made a discovery which gave practical results.

Previous to the meeting much speculation had existed regarding the newly observed law of nature disclosed by Weagant's experiments, and while the speaker plainly asserted that his theory regarding the origin of a particular type of static may yet call for some revision, the reported results of his researches, in a large measure, justified, in the judgment of those present, the belief that Weagant had observed and made practical use of a hitherto unknown static phenomenon.

Classification of Static or Strays

As a beginning, Mr. Weagant first classified strays after the well known method of Eccles, pointing out from his observations the distinction between the types that represented genuine obstacles to transoceanic communication and those which caused but occasional interference and could therefore be ignored. Static disturbances due to local lightning and snowstorms were ignored, for the reason that these types are of so infrequent occurrence as to be of negligible importance; but there remained the three types, termed, "grinders," "clicks" and "hissing." The last named, which are due to an actual discharge from the aerial to the earth, give no trouble in the ungrounded aerials used in the Weagant system. Of the remaining two types, "grinders" and "clicks," the former were found to constitute the major source of difficulty.

Some Fallacious Ideas Exposed

The success of Weagant's endeavors to eliminate from the receiver the most troublesome forms of atmospheric electricity may be attributed primarily to his clear recognition of the limitations of all so-called static elimination previously evolved.

Take, as an example, the well known receiving circuit in figure 1. His experiments and observations revealed that the static currents induced in the aerial system, A, L-2, L-3, E had the *frequency* and the *damping* of the antenna circuit itself, no matter what frequency of oscillation to which it happened to be adjusted. It therefore became evident that if one were to separate, by any sort of a device, the static currents in the antenna system from the signal currents, he would be confronted with the proposition of separating two currents of the same frequency in the same circuit.

Experimenters, heretofore, had tried to get rid of static interference by detuning the antenna circuit, by differentially combining two radio frequency receiving circuits, by differential connection of two detectors of different characteristics, by differentially combining two audio frequency circuits, as in DeGroot's method, and finally by the use of the Dieckmann shield.

The hoped-for results in detuning the antenna circuit could not be realized because such detuning did not reduce the intensity of the static signal, but simply changed its frequency. The loss, in the transfer of static energy to the secondary circuit when tuned to the frequency of the incoming signal, is exactly the same as the loss in intensity experienced by the signal currents through detuning the antenna. This, of course, does not improve conditions in the slightest, for it reduces the static and the wireless signal in the same ratio.

Some improvement has resulted from the use of loose couplings between the primary and secondary circuits, provided there is a marked difference between the damping of the signal and static currents; but the relief was by no means sufficient to be of any considerable value when working over great distances.

The "interference preventer" next came in for well deserved criticism and was proven by Weagant to be ineffective. As many of our readers are aware, Fessenden coupled, differentially, the two legs of a branched aerial, or the primary circuits of two separate aerials, to a common detector circuit as shown in figure 2. He concluded that if one branch, say A, be tuned to a transmitting station and the other branch, B, be detuned, static currents of equal intensity would be induced in both sides and would be annulled, and that, as the signal in one branch had little or no opposition from the other branch, it would be heard. He assumed the static currents to be forced oscillations and, therefore, that their frequency and intensity were unaffected by an amount of detuning that would *greatly affect* the signal. This, as Weagant clearly pointed out, is an absolute fallacy.

The fact is, that when one branch of the antenna circuit is detuned, the frequency of the static signals changes accordingly, leaving static currents of one frequency in one branch, and of different frequency in the other branch. It is, obviously, not possible to *balance out two opposing E.M.F.'s of different frequency*. Moreover, the detuning of one branch affects the intensity of both the signal and static currents in the secondary circuit in the manner just explained.

It is important to note here that two opposing E.M.F.'s can completely neutralize each other *only* when they have the *same frequency, the same wave form, and opposite phase.* And in the case of damped oscillations, in addition to these requirements, the dampings of the two E.M.F.'s must be identical. The writer feels assured that readers will at once recognize that the steps by which Mr. Weagant eventually arrived at the result attained in his receiving system, constitute one of the most original applications of engineering principles ever made in radio telegraphy.

Continuing, Mr. Weagant said that if any experimenter had secured worth-while results by means of a differential audio frequency circuit, such results have been due to the looseness of coupling involved in the circuits under test. He pointed out also that the effectiveness of balanced detector circuits is due solely to the protection against loud crashes afforded to the ear of the operator. Re-

Points of Interest Disclosed by Weagant's Experiments

The static currents induced in a receiving aerial by static "waves" are of the same frequency and of the same damping as the complete receiving system.

When the oscillation frequency of the antenna circuit is altered by local tuning, the frequency of the static currents changes in accordance.

For that reason, the differentially connected, branched aerial system proposed by Fessenden is ineffective in reducing static; for when one branch is detuned to the wireless signal, static currents of different frequency exist in the two different branches. Obviously, two currents of opposite phase but of different frequency cannot be made to neutralize one another.

Mr. Weagant's researches prove that all forms of static eliminators utilizing differentially connected audio or radio frequency circuits, are of little or no value for continuous long distance wireless reception.

The dominant type of static waves, called "grinders," apparently is propagated vertically in respect to the earth. Therefore the static "waves" resulting therefrom are at right angles to the wireless waves. By the use of properly disposed aerials advantage can be taken of this phenomenon to separate the static and the signal currents.

Two closed circuit loop antennae, spaced ½ wave length from center to center, the planes of which are in the path of a passing wave, will be acted upon simultaneously by the vertically propagated static waves, but at different times by the horizontally propagated wireless waves.

Hence, when both loops are correctly coupled to a common receiving set, the static currents will be in phase and may be neutralized. The signal waves will be out of phase and will not neutralize, but will add their E.M.F.'s vectorially.

By proper adjustment of the phases of the currents in one loop, in Weagant's antennae system, uni-directional reception is possible, signals of maximum intensity being secured from waves arriving at one end of the loops, while interference from the other end of the loops may be annulled.

Underground or surface-ground aerials act as ordinary closed circuit loops erected above earth. By reason of the capacity effects between the ends of the aerials and the earth, a return path for the induced currents is afforded, which effectively closes the circuit.

The greater the capacity per unit length between the underground or surface-ground aerial and the true underlying earth, the shorter is the maximum length which can be used to advantage. This accounts for the fact that approximately 2500 feet is the maximum length that can be employed for underground aerials placed under brackish water.

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garding the Dieckmann shield and the ability of the combination system to reduce static, as described by DeGroot, the speaker declared that he could see no basis

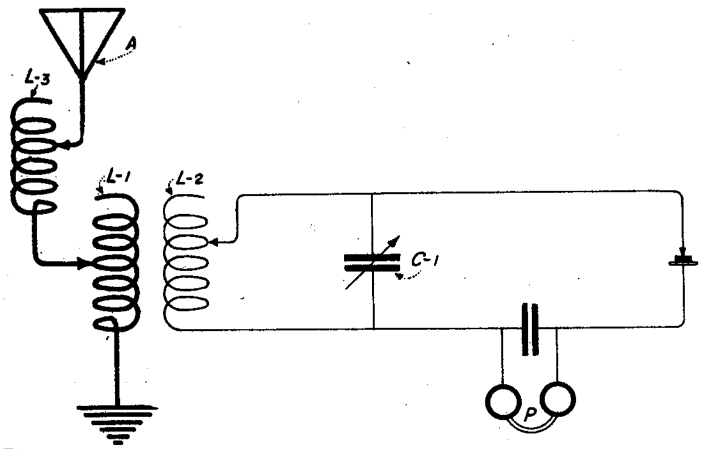

Figure 1—Diagram of an ordinary receiving system in which, as Mr. Weagant points out, the frequency and damping of the static currents are the same as that of the complete receiving system itself. As a consequence, when the oscillation frequency of the antenna circuit is changed by local tuning, the frequency of the static currents change accordingly

therein for differentiating between static and signals, and that investigation had proved that the problem of screening out any electromagnetic wave of any sort, either signal or static, cannot be solved by that method.

For experimental observations Mr. Weagant constructed various forms of aerials, including the horizontal linear—underground and surface-ground aerials. Some of these were found to appreciably reduce static, but the general characteristics of the underground type proved, under experimental investigation, to be entirely different from theories recently advanced. Mr. Weagant's deductions in respect to this aerial will be stated further on.

Some Important Observations Regarding Static

In an effort to determine, by means of the Marconi-Bellini-Tosi direction finder (shown in figure 3), whether or not static was horizontally directed; that is, if it originated from any particular direction at certain hours, Mr. C. H. Taylor, a Marconi engineer, carried out a series of experiments at Belmar, N. J., with apparatus designed for the reception of long waves over great distances. Experiments were also carried on by Mr. Weagant, at Belmar, and simultaneously at another station erected at the Marconi factory at Aldene, N. J.

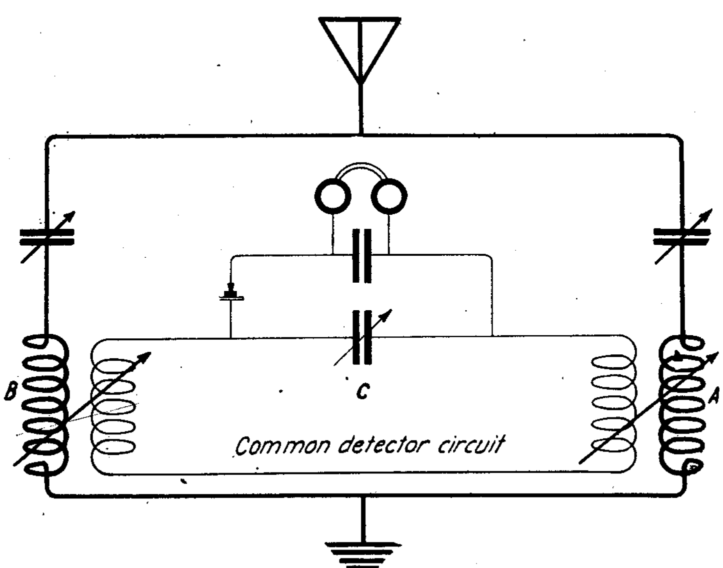

Figure 2—Circuits of the "interference preventer," which Mr. Weagant proves to be ineffective in reducing static. When one branch, say A, is detuned to the wireless signal, the frequency of the static currents change accordingly; hence, static currents of one frequency flow in one branch and of another frequency in the second branch. It is obvious that two currents of different frequencies cannot be made to neutralize each other

These tests seemed to indicate conclusively that the dominant type of static—"grinders"—apparently came from no definite direction, but *gave an equality of disturbances from all points of the compass.*

A further check on this observation was made by rotating a closed circuit loop (see figure 4) connected to a receiving set, about the vertical axis, A. The loop showed equality of disturbances regardless of the direction of the plane of the loop.

These experiments, as Mr. Weagant said, indicated that if static disturbances of the "grinders" type were propagated horizontally, they must come from different directions, and so rapidly that the observer would have no opportunity to manipulate his apparatus with sufficient rapidity enough to determine their direction.

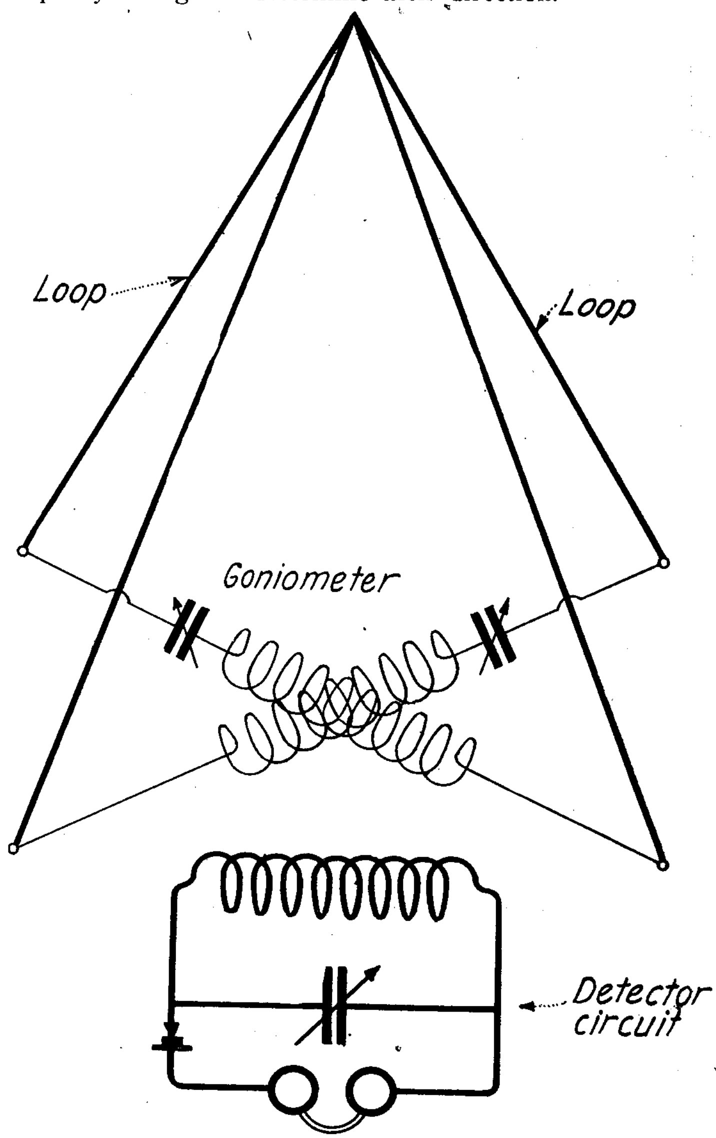

Figure 3—Fundamental circuits of the Marconi-Bellini-Tosi radio goniometer with which experiments were conducted at Belmar, N. J., by C. H. Taylor and R. Weagant to determine whether static signals emanated from any particular direction. The investigation proved that the dominant type of static called "grinders" apparently came from no definite direction but gave an equality of disturbances from all points of the compass

Weagant's Great Discovery

It then occurred to Mr. Weagant that these static disturbances might be propagated *vertically,* instead of horizontally, and if so the *direction of propagation would be at right angles to the direction of the advancing wireless wave.* If that could be definitely proven, then advantage might be taken of the difference in direction to separate the static from the signal currents flowing in the antenna

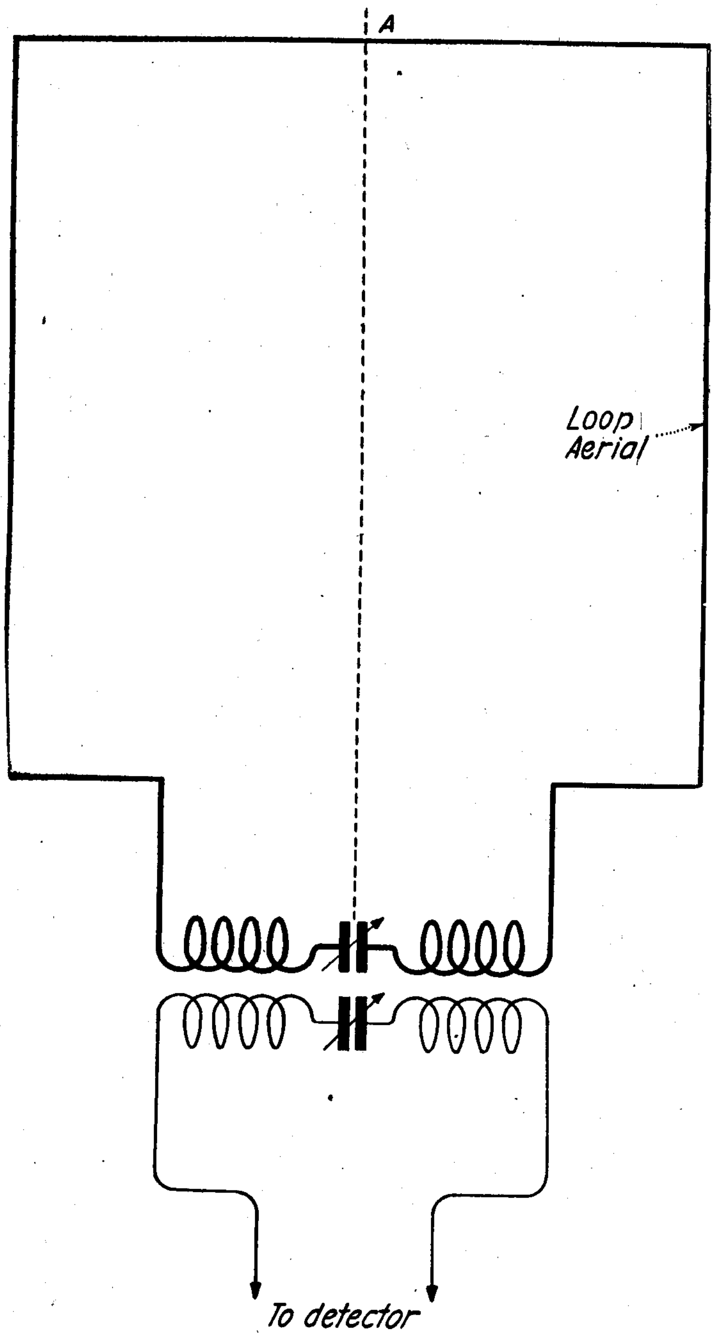

Figure 4—Loop aerial used by Weagant to check up the observations made with the apparatus in figure 3. The loop was rotated on the axis A to determine the line of direction of the static waves. The experiment proved that these waves came from no definite direction

circuit. This was the fundamental working hypothesis on which the Weagant system is based.

A series of experiments to verify the hypothesis then followed.

Observations on Two Loops, the Planes of Which Are Perpendicular

For one thing it was found that when two loops, the planes of which were perpendicular, were connected to a common receiving apparatus, as in figure 5, the static currents *could not be balanced out.* The experiment justified the assumption that *electromagnetic waves responsible for static currents are heterogeneously polarized;* that is, the axes of the oscillators producing them assumed all possible angles in space; and the highly damped waves resulting therefrom are propagated in a direction perpendicular to the earth's surface.

In other words, to the unscientific mind, these static waves may be described as an electric shower which acts upon an aerial, perpendicularly to the earth.

An Early Form of Weagant's Static Eliminator

To determine the correctness of the hypothesis that static is propagated vertically and to ascertain if it were possible on this assumption to devise a system whereby the static currents could be balanced out while the signal was retained, Mr. Weagant erected at Belmar, N. J., the aerials and apparatus shown in figure 6. Two closed loops A and B, each consisting of a single turn of wire 400 feet high with a base line of 1,000 feet, were spaced 5,000 feet from center to center. Two wires, brought from each loop to a receiving station located at the center, were supported on ten-foot poles, 6 feet apart. These leads were connected to the primary coils of a goniometer of the type used in direction finders; the secondary coil was connected to a sensitive oscillation detector. It was this apparatus that permitted the reception of transatlantic signals through static interference of great intensity, whereas without it, it was impossible to distinguish the wireless signal.

The connections to the receiving tuner and detector are shown in figure 6, where loop A has the loading coils L-1 and L-2, the resistances R-1 and R-2, and the coil,

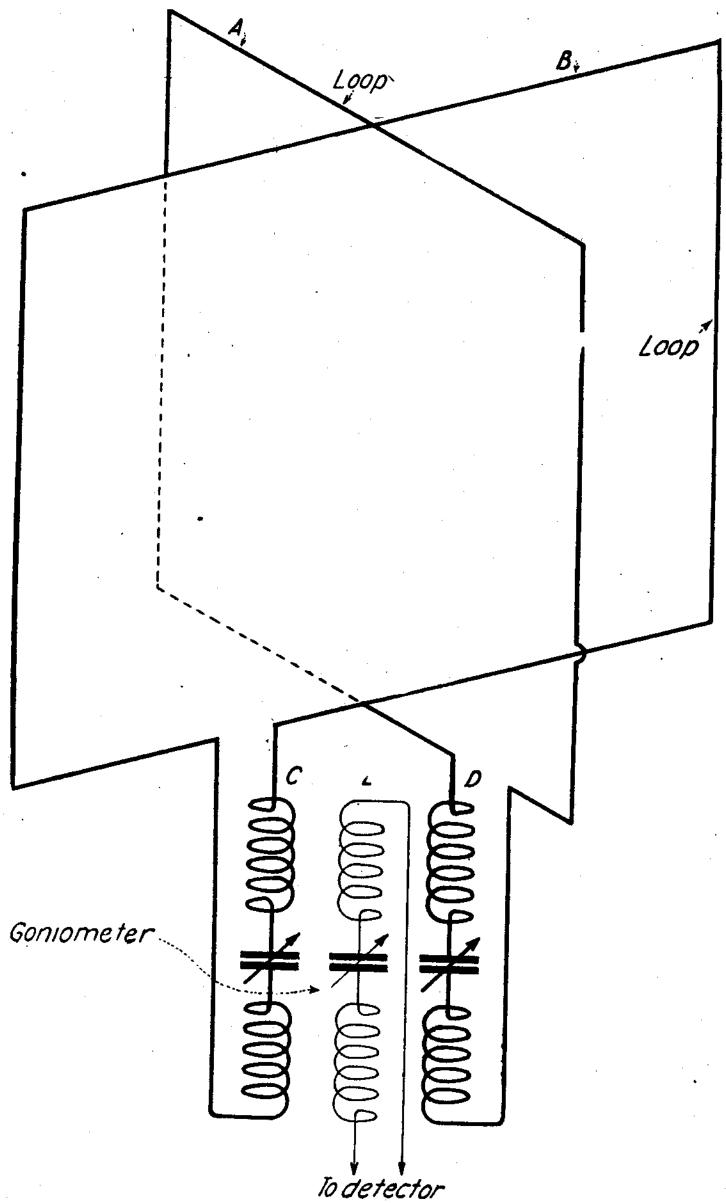

Figure 5—Fundamental circuits of an experiment involving the use of two loop antennae, connected to a receiving set to determine if the static currents could be balanced out while the signaling currents were retained. The test proved fruitless and served to indicate that the electromagnetic waves responsible for static currents are heterogeneously polarized; that is, the axes of the oscillators producing them assume all possible angles in space and the highly damped waves resulting therefrom are propagated perpendicularly to the earth's surface

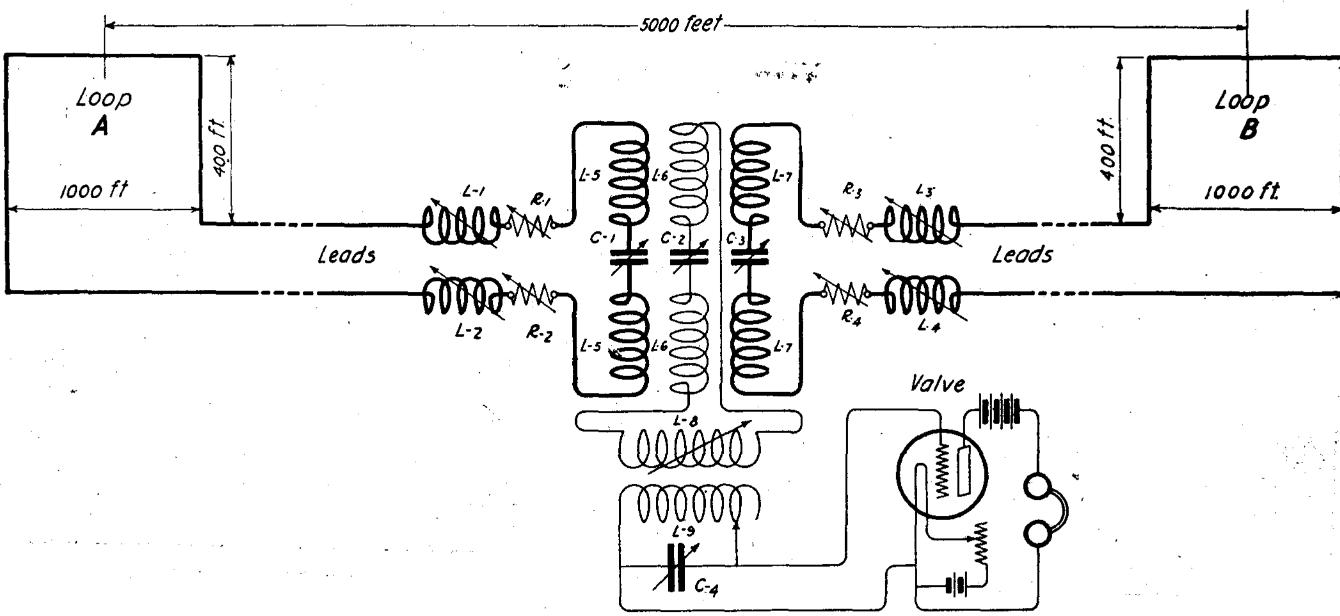

Figure 6—An early form of Weagant's system for eliminating static interference showing two single turn loop antennae spaced 5,000 feet apart. Each loop was 1,000 feet long at the base and 400 feet high. The leads from each loop were connected to the primary coils, L-5 and L-7, of the radio goniometer which were coupled to the secondary coil L-6. By rotating L-6, a position was found where the static currents neutralized and the signal currents were retained. This apparatus and antennae permitted the reception of signals from stations in Europe under conditions of static interference which with ordinary receiving apparatus and antennae would render reception impossible.

L-5, broken at the center point for connection to the variable condenser C-1. The coil L-7 connected to the loop B is similarly connected. Both L-5 and L-7 are coupled to the secondary coil L-6 which is broken at its center to include the variable condenser C-2.

The arrangement of the three coils at the receiving station was similar to that employed in the Bellini-Tosi goniometer shown in figure 7, wherein the rectangular frames L-5 and L-7 are stationary and the rotating frame L-6 is mounted on a vertical axis so that it can be rotated within the resulting magnetic field.

It may be well to describe here the preliminary procedure of adjustment: The coil L-6 is first placed in inductive relation with L-5 of loop A and the incoming signal tuned to maximum intensity. Next, coil L-6 is placed in inductive relation with L-7 of loop B, which circuit is also tuned to maximum signal intensity. Both loops are then connected in and coupled to the coil L-6 which is turned on its axis to receive the maximum induction from both L-5 and L-7. The two primary coils produce a resultant magnetic field which acts upon the rotating coil somewhat after the principle of the radio goniometer.

HOW THE STATIC ELIMINATOR WORKS

An explanatory diagram of the system of figure 6 appears in figure 8. Here the two closed circuit loops of figure 6 shown as A′ and B′ are coupled to a common secondary coil L-3 of the receiving apparatus which is installed in a station placed between the loops. The vertically propagated static waves are indicated by the *downward arrows* above the loops and the advancing signal waves which, in this diagram, are assumed to pass from left to right, are represented by the arrows A, A, A, A.

If static waves are propagated vertically, it is clear that they act upon loops A′ and B′ simultaneously and consequently electro-motive forces of equal intensity are generated in both loops and the static currents resulting therefrom flow in the same direction in each loop, as indicated by the single pointed arrows. For purposes of illustration, we have assumed that the static currents flow clockwise in the two loops as shown in the diagram. The current in loop A′ flows downward through the coil L-1 and that in loop B′ upward, through the coil L-2. The two currents will therefore neutralize and consequently none of the static current will flow in the coil L-3.

It now remains to be seen how a useful part of the energy of the signal wave is retained. From figure 8 it is evident that the signal wave acts upon the loop A′ before arriving at the loop B′; and we may assume, for the purposes of illustration, that the arrows A represent the progressive movement of the advancing wave. As the wave motion progresses and the positive half acts upon the loop B′, the negative half of the wave is acting upon loop A′. We will assume that, at a particular moment, its polarity is such that in loop A′ the static current and the signal current pass in the same direction through the coil L-1. The signal and static currents must therefore flow in opposite directions in the loop B′; and inasmuch as coils L-1 and L-2 are coupled to L-3 in such a way that the static currents oppose and neutralize, the signal

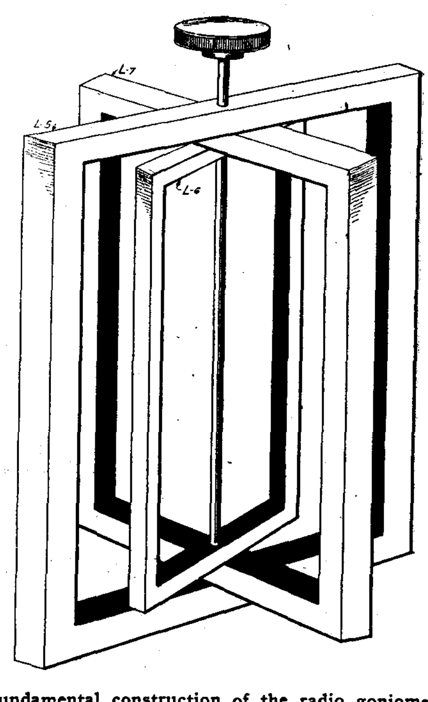

Figure 7—Fundamental construction of the radio goniometer used in the Weagant receiving system. Coils L-5 and L-7 are mounted at a right angle and the coil L-6 may be rotated in the resultant magnetic field

currents must build up in phase and accordingly affect the oscillation detector connected to the terminals of the coil L-3. The principle, of course, holds good when the negative half of the signal wave acts upon B′, and the positive half on A′.

The foregoing may be stated in another way by saying that the static waves arrive at the two aerials at the same time, while the signals arrive at the two aerials at different times. Therefore the static currents in the two loops at any instant are in phase and the signal currents are out of phase by an amount depending upon the effective spacing of the two loops in respect to the wave length being received.

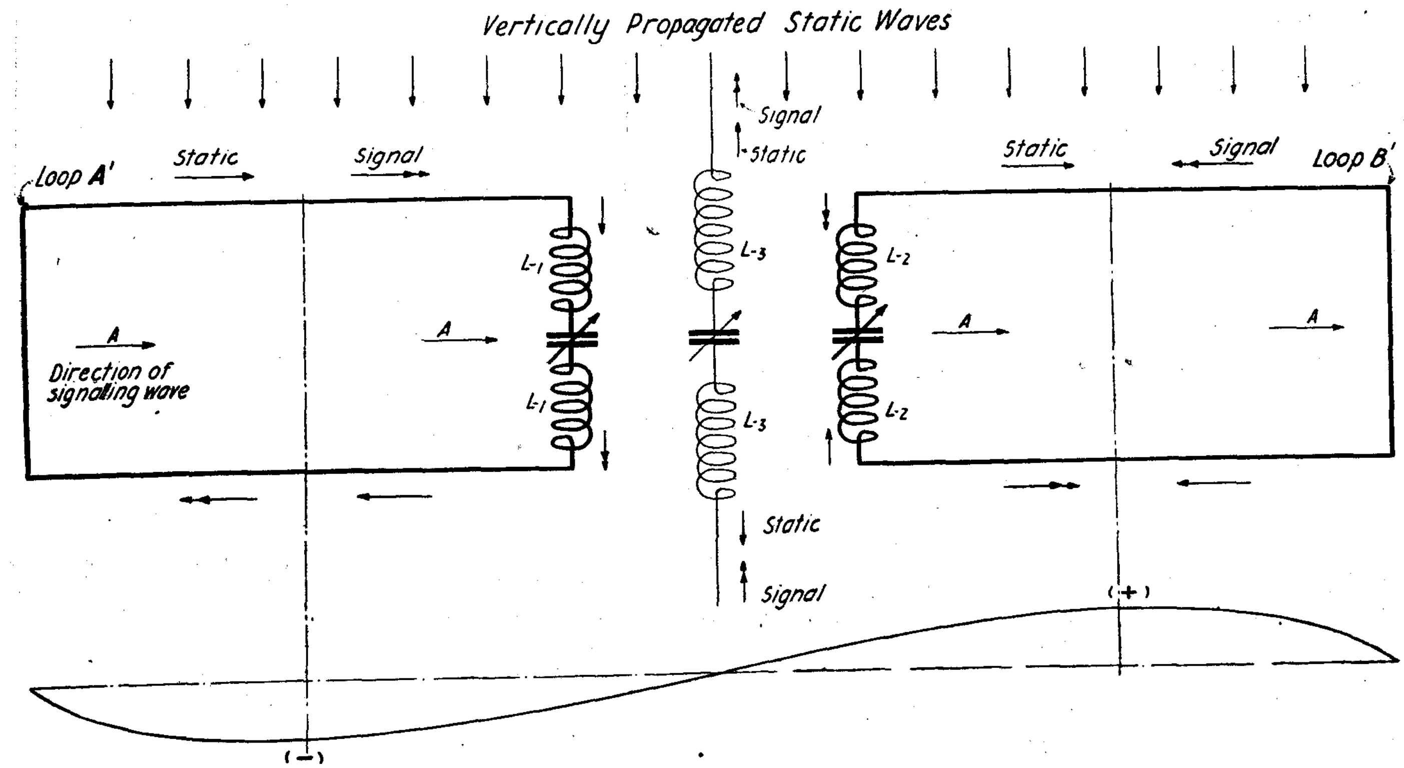

Figure 8—Explanatory diagram of the Weagant static eliminator. Loop A′ is connected to the primary coil L-1 of the goniometer; loop B′, to the second primary coil L-2. Both primaries act upon coil L-3 which rotates in the resultant magnetic field. The vertically propagated static waves act upon both loops simultaneously and the resulting static currents, as shown by the single pointed arrows flow in the same direction in both loops. The static currents flowing in the coils L-1 and L-2 may be made to act oppositely on the coil L-3 and therefore neutralize. On the other hand, the positive half of the signaling wave is assumed to act upon loop B′ and the negative half on loop A′. In loop A′, the signal current and the static current flow in the same direction, but in loop B′ they flow in opposite directions

Since coil L-3 is coupled to L-2 and L-1 in such a way that static currents neutralize it follows that the signal currents must combine. If the two antennae are spaced one-half wave length from center to center, the E.M.F.'s generated in the coil L-3 by the signal currents, will be in phase and the resultant will be the arithmetical sum of these two E.M.F.'s. If the loop separation is equal to one-quarter wave length then the E.M.F.'s will be 90 degrees apart and the resultant E.M.F. will be 1.4 times that of the individual E.M.F.'s; that is, they combine in quadrature. It is not essential that the effective spacing of the loops be one-half wave length; for one antenna can be employed for a considerable range of wave lengths provided one is willing to sacrifice some of the signal current at wave lengths other than that for which the loops give one-half wave length separation. It is evident that the Weagant system can be used in connection with any type of oscillation detector so far devised, and that the operation of the system as a whole is based on a fundamental principle never before utilized in radio communication

The magnitude of the E.M.F.'s generated by the signal waves will always give a resultant depending upon the effective separation of the loops; that is, the distance from center to center of the loops. If this separation is one-half wave length, the E.M.F.'s generated in the coil L-3 by the signal currents from loops A′ and B′ will be in phase and the resultant is therefore equal to the arithmetical sum of these two E.M.F.'s. If the loop separation is equal to one-quarter wave length, then the E.M.F.'s acting on the coil L-3 will be 90 degrees apart and the

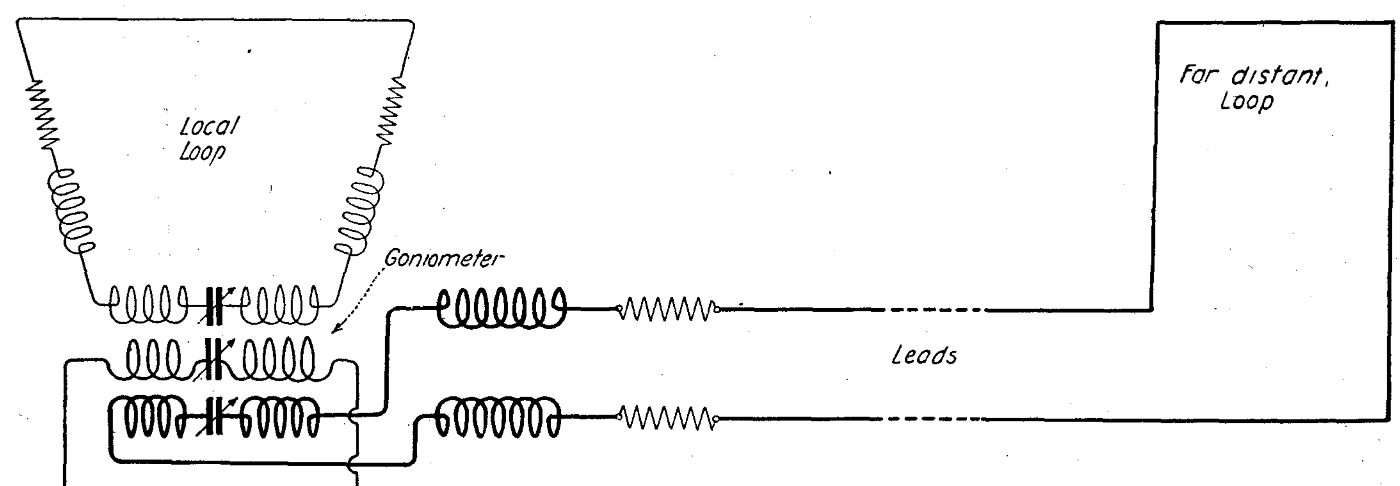

Figure 9—Circuits used in one of the early experiments conducted by Weagant wherein a small closed circuit loop was balanced against a far distant loop. This experiment at first gave a better static balance with a loss of signals and helped uncover the fact that the long low leads extending from the distant loop to the receiving station acted as an antenna, picking up both static and signals which under some circumstances were found to flow in opposite directions. This circuit was abandoned in favor of that shown in figure 6

resultant would be equal to 1.4 times that of the individual E.M.F.'s; that is, they combine in quadrature.

It is clear that the most effective separation for maximum signals is one-half wave length, and, therefore, from any particular wave length, the effective spacing of the loops should be selected to meet the above mentioned conditions. This, however, is not strictly essential in practice. One antenna can be employed for a considerable range of wave lengths provided one is willing to sacrifice some of the signal current at wave lengths other than that for which the loops give one-half wave length separation. This, therefore, is not an objection to the commercial application of this discovery.

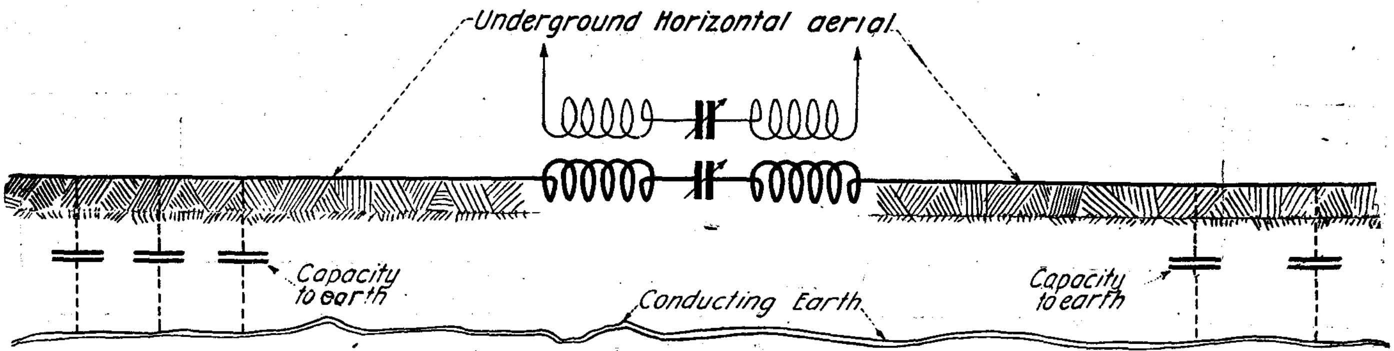

Figure 10—Explanatory sketch of the action of underground aerials showing that because of the capacity of the horizontal wires in respect to the earth, these antennae act as the closed circuit loops of the Weagant system

Now, if the theory advanced by Mr. Weagant concerning the vertical propagation of static waves were not correct, the results described could not be secured; for, if the apparatus in the receiving station was adjusted so that the signal currents combined vectorially and in accordance with the effective aerial separation, then the static currents would combine similarly, and therefore, the entire system would show the same signal to static ratio as a single loop. Since the experiments proved that the static currents do not combine but are annulled, while the signal is retained, the theory of vertical propagation of static waves is well sustained. However, as Mr. Weagant remarked, if this theory is not correct, it is at least certain that the static waves operate on a sufficient area of both loops, simultaneously, to produce the desired balance described.

In accordance with the principle of the invention, the two loops should preferably be symmetrical in every respect. Controlling appliances permitting proper adjustments to be obtained are shown in figure 6. They consist of the loading inductances, condensers and variable resistances therein indicated.

Some practical results obtained with the system portrayed in figure 6 were reported as follows: Signals were received at Belmar, N. J., from Nauen, Germany, 6,000 and 12,000 meters; Clifton, Ireland, 5,600 meters; Carnarvon, Wales, 14,000 meters; Elivese, Germany, 9,600 meters; and Glace Bay, Nova Scotia, 7,600 meters.

Mr. Weagant observed that whenever the circuits were so adusted that static disturbances were cancelled or reduced to a minimum, the signals received on the two loops combined, as might be expected from the spacing between them and the wave length of the incoming signal.

It is evident that the spacing between the loops in the diagram of figure 6 is slightly over one-quarter wave length for the wave of 6,000 meters used by Nauen, Germany, during some of the tests. In the case of the 6,000 meter wave, the resultant signal was approximately 40% greater than that due to either aerial alone, while in the case of Carnarvon, at 14,200 meters, the spacing was equal to only 1/9 of the wave length and the resultant signal was materially less than that due to either loop, which was to be expected. The system shown in figure 6 permitted reception from Nauen, Germany, throughout the months of July and August and during the worst static periods of the day. Grinders, of such intensity as to render the signals unintelligible by ordinary receiving apparatus and antennae, were eliminated to such a degree that continuous reception from foreign stations was possible. Other observations, through continued use of the circuits of figure 6, established the fact that the heavier the static disturbances were, the more perfect was the balance that could be secured; with a consequent greater improvement in static reduction to signal ratio. This, as students of wireless telegraphy will agree, is a very desirable characteristic.

A very interesting but erstwhile elusive phenomenon met with in the system of figure 6, was the fact that the long low horizontal leads picked up static and signals as well as the far distant loops, and until this feature was thoroughly worked out, the results obtained seemed to indicate that the farther apart the loops, the less perfectly

Marconi Company's Horizontal Antennae

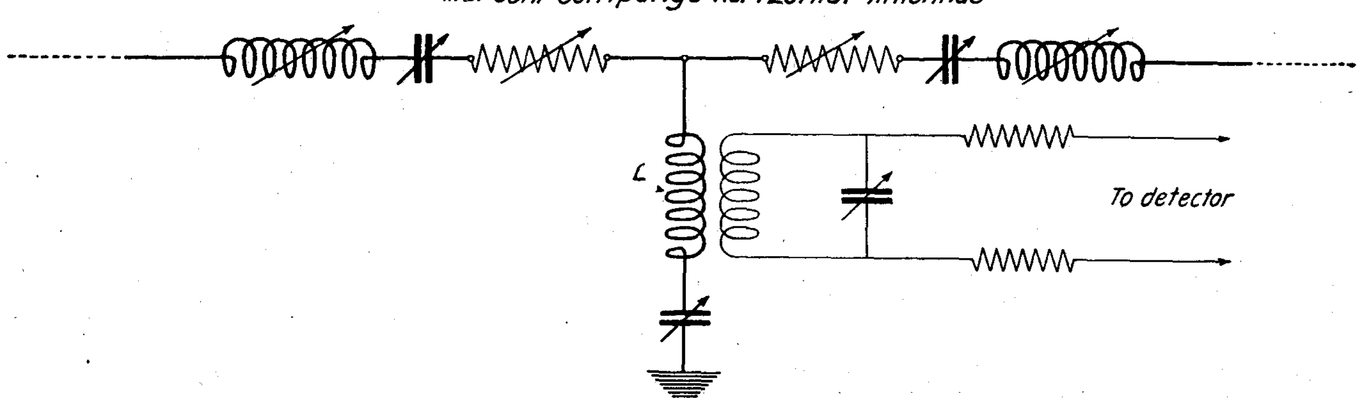

Figure 11—An early experiment conducted by Weagant in which two horizontal aerials were coupled to a detector circuit through a tuning transformer to determine if a reduction of static interference was possible. This and the circuits in figures 12, 13, 14 and 15 following, were found to give an appreciable reduction in static, but not of sufficient magnitude to permit continuous long distance wireless reception

could the static currents be balanced, and also, the converse.

One experiment, seemingly supporting this erroneous belief, made use of a far distant loop, connected to the receiving apparatus through long low horizontal leads, and another loop with short leads erected at the receiving station, as in figure 9. This arrangement was found for the time being to give somewhat better results than that in figure 6, and the improvement was found to result from the more perfect balance thus secured, in spite of the loss of signal.

However, as mentioned above, it was discovered later that the horizontal leads of the two loops as in figure 6, picked up some of the static and signal energy and, as a result, the static currents in a set of leads and in the loop tended to flow in the same or opposite direction. Adjustments that were made in the circuit shown in figure 6, to balance out static currents in the loop, before this fact was recognized, caused the static currents in the leads under some circumstances to add; but the simple expedient of placing reversing switches in the circuits solved the problem.

The results thereafter obtained with the Weagant system were found to be better with the use of greater rather than less effective separation, by an amount proportional to the separation.

It was observed that, in all arrangements employing two closed circuit loops connected to a central receiving station by long horizontal leads, local tuning of each loop was necessary. This was not a very convenient procedure with aerials 3 miles apart, for it became necessary to station an operator at each loop and to inform him, by telephone, what adjustments were to be made.

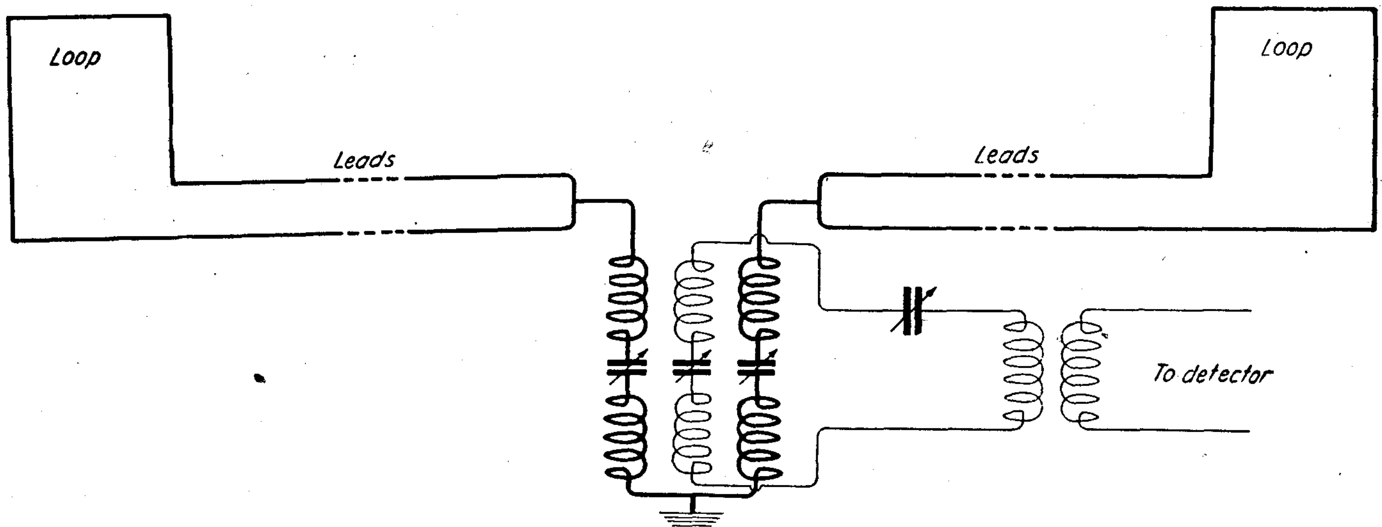

Figure 12—One of Weagant's early experiments in which the leads of two closed circuit loops were connected together, both aerials being coupled to a common detector circuit

Underground and Surface-Ground Horizontal Aerials

The low horizontal aerial for radio reception was first used by Marconi. An antenna of the same type employed by Weagant in the spring of 1914, at New Orleans, gave a distinctly better signal to static ratio, than the large earthed aerial. Later comparisons with a loop aerial showed the two to be substantially identical in that respect.

One important deduction resulting from these tests was the fact that the long horizontal aerials laid under ground, on the surface of the ground, or suspended above the ground, may act as a loop aerial. Because of the capacity to earth (as shown diagrammatically in figure 10) a return path for the currents exists between the ends, which effectively completes the circuit.

It has been noted particularly that, as the distance between the ground and the horizontal aerial is increased, its action becomes more nearly that of an ordinary antenna; and that, because it is then not in the most effective position relative to the incoming signal to collect the maximum of energy, the signals are less in strength than would be secured with less spacing.

Quoting Mr. Weagant:

"The usually accepted explanation of the working of the horizontal aerial is that the wave front of the signal wave is tilted forward and that consequently there is a component of electric force in the direction of its length. It is to be noted, however, that under some circumstances such an aerial may be acting equally well as a loop. An aerial of this type is shown, in figure 10, lying on the surface of the ground and it is evident that by virtue of its capacity to the true conducting earth, a return path between its ends exists and, therefore, it is a form of loop; which method of consideration will account for many of the observed facts, such as its directivity, in a satisfactory way. It will also account for one observed fact which the usual methods of explanation do not account for, namely, that when an aerial of this type is laid on the ground, or buried underneath it, its effectiveness as an aerial does not increase indefinitely with length, but rapidly reaches an optimum value dependent on the circumstances obtaining. This can readily be accounted for under the present hypothesis by the fact that as the length

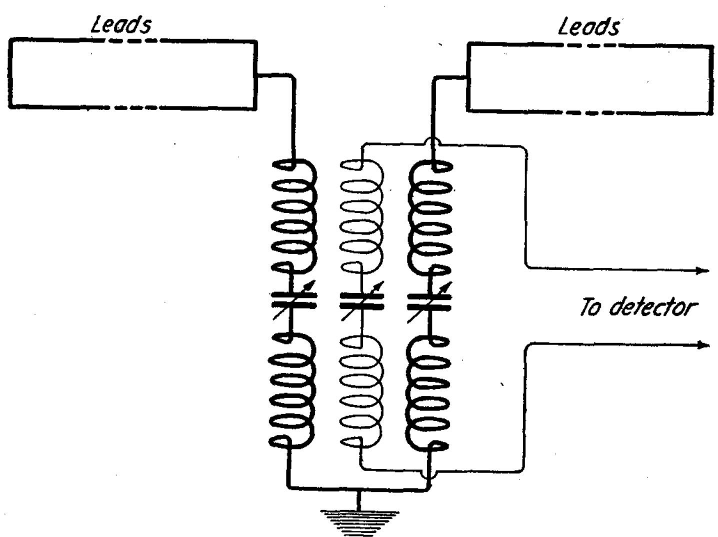

Figure 13—Circuits of an experiment wherein the leads of the Weagant loop antennae were employed as low horizontal aerials, both being coupled to a common detector circuit through a goniometer

increases its capacity to earth increases and at some point becomes sufficient to close the loop.

"As this capacity increases, however, the currents originating in this increased length have various paths in which to flow, one of which includes the receiving apparatus but others are through the capacity to earth between the conductor and the receiving apparatus, and the larger this gets the greater is the proportion of the currents originating in the ends of this aerial, which are diverted and do not flow through the receiving apparatus. This method of considering such an aerial is further supported by the fact that the greater the capacity per unit of length which exists between the conductor and the true underlying earth, the shorter is the maximum length which can be used to advantage. This capacity is a maximum, of course, when the aerial is actually buried in the ground or under water, becoming less when the wire is run on the surface of the earth and still less when the wire is suspended at some height above the earth, tests having shown that wires suspended some 10 feet above ground can be used up to some six miles in length, the signal increasing with length; that a length about one-half of this is effective when the wire is laid on the ground and of approximately 2,500 feet when the wire is placed under brackish water.

"I have also found that as the distance of such an aerial above ground is increased, its action becomes more nearly that of an ordinary antenna, and that therefore on account of its position relative to the incoming signal, it becomes less effective in collecting this signal energy."

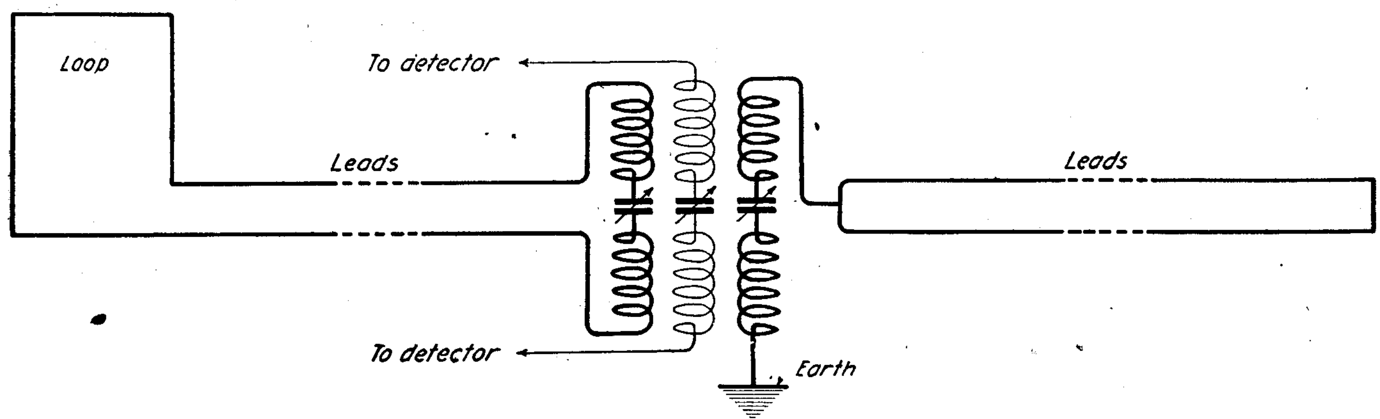

Figure 14—The circuits of an experiment wherein the horizontal leads of one loop were balanced against a second loop used in the regular way but not connected to earth

length to the height is unusually large. It follows that the aerial which is pointed in a direction away from the transmitting station is a much better receiver of the signal energy than the aerial which runs in a direction toward the transmitting station. Both aerials, however, pick up the same amount of static. The two aerials, therefore, may have a very marked difference in their signal to static ratio, and this effect will add to the effect resulting from their phase separation when this separation is small. At times, this constitutes a factor in the results obtained. While figures 11 and 12 show direct coupling at the coil L, any of the well known methods such as electrostatic, inductive or resistance couplings may be employed.

Mr. Weagant finds that this principle operates in all of the arrangements shown in figures 12, 13, 14 and 15. Figure 12 shows the connections used in an experiment in which the loop leads were connected together and each loop converted into an ordinary aerial tuned to earth. In figure 13, the leads were disconnected from the loops and their ends joined, thus making them horizontal aerials tuned to earth. In figure 14, one loop is used in the normal way and balanced against leads of the other loop tuned to earth. In figure 15, one loop is connected in its normal way while the other one is arranged as an earthed aerial. In all methods where an aerial tuned to earth is employed, it was found that the counterpoise aerials gave the best all-around results, although fair results were obtained with all the foregoing arrangements.

In addition to the foregoing connections, other variations in the circuits were also tried.

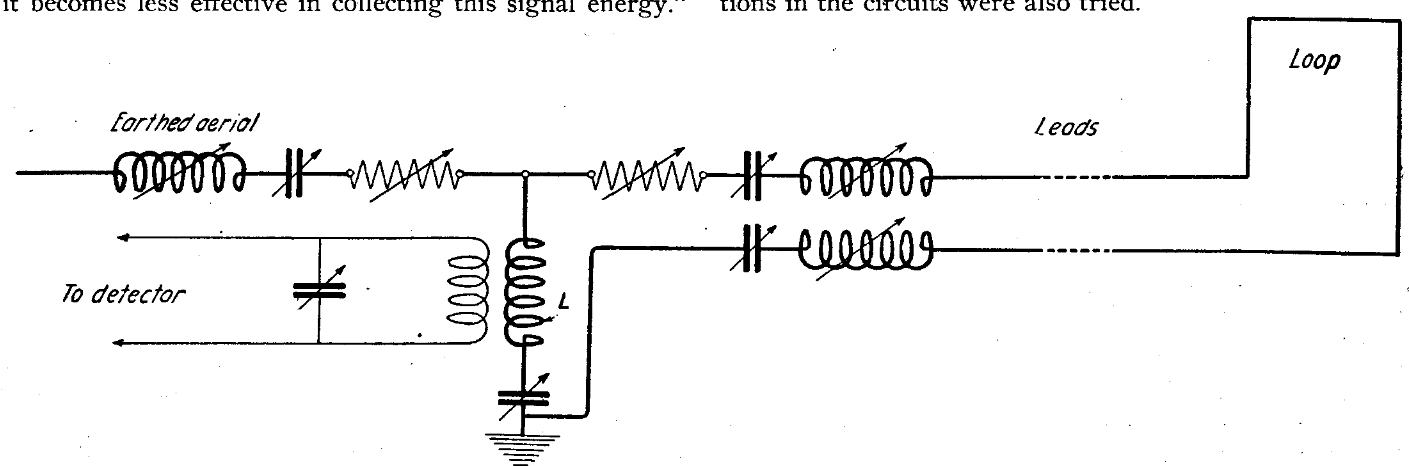

Figure 15—The circuits of an experiment wherein one of the loops in Weagant's system was connected in the regular way and balanced against an aerial tuned to earth

At an early date, at the Marconi station at Belmar, N. J., additional experiments were made by Weagant with the antenna shown in figure 11 and other combinations. It will be noted that the arrangement shown in figure 11 consists of two Marconi aerials of which the ratio of the

Elimination of Interference by the Weagant System

A discovery of vital importance in connection with the looped antenna of the Weagant system was the fact that it constitutes, as a whole, a uni-directional receiving antenna; that is, signals arriving from one end of the loop can be tuned in, while an interfering signal from the opposite end can, by proper phase adjustments, be tuned out.

When the looped antenna system is adjusted to annul static of the "grinders" type, the system has a reception curve of the form shown in figure 16; its equation, is, $v = V$ cosine², while that of the single loop is the cosine curve. The directional effect in this case is materially greater than with the single loop.

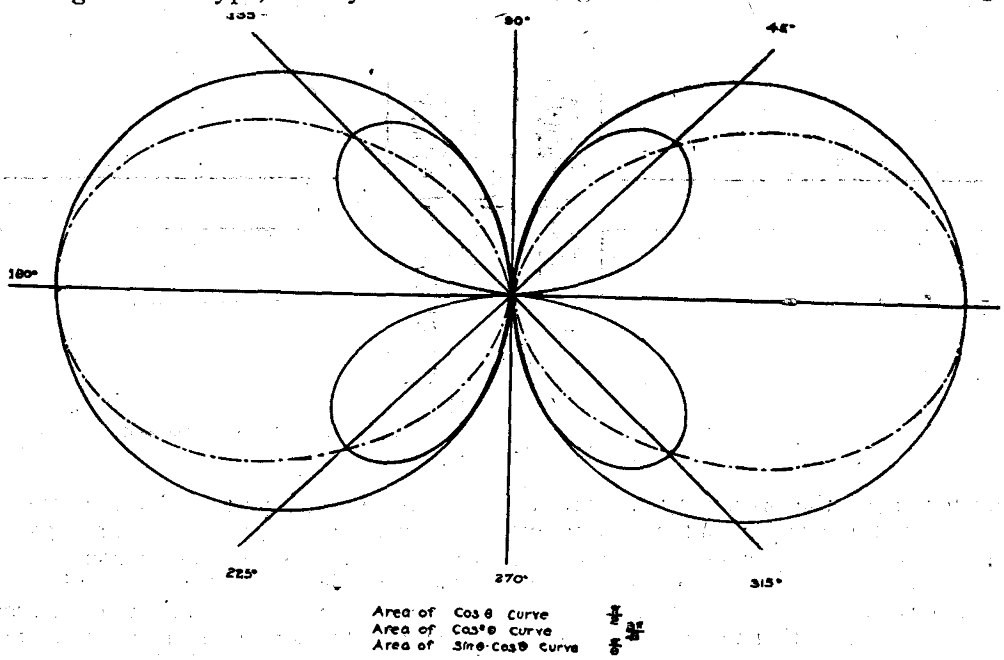

Figure 16—Reception curve of the Weagant system utilizing two-loop antennae

By shifting the phases of the currents in the loop antennae, the reception curve becomes that of figure 17. Between $\theta = 0$ and $\theta = \Pi$, the curve is a cosine² curve while between the angles $\theta = \Pi$ and $\theta = 2\Pi$ the curve is a sine-cosine curve, when the loops are ¼ wave length apart. This curve indicates maximum reception in one direction and zero reception in the opposite direction, with a considerable reduction of signals in the third and fourth quadrants. The line of zero reception can be swung at will through the third and fourth quadrants by alteration of the phases of the currents in the two loops, so that interference from any station arriving in either quadrant can be annulled, while reception is maintained from signals arriving in the first and second quadrants.

Mr. Weagant pointed out that advantage can be taken of this property to eliminate static interference if the static waves happen to come from a direction other than that from which the signal arrives. This is of considerable help when a thunderstorm is gathering in the vicinity of the station. Although the most effective spacing of the loop to obtain this uni-directional characteristic is one-quarter length, a general order of the result is obtainable with any spacing between the loops. The process of adjustment for obtaining one-way reception is quoted from Mr. Weagant's paper as follows:

"Suppose that the two loops of the system are one-quarter wave length apart and that the desired signal arrives from right to left; then the currents in the left-hand loop are 90 degrees behind those of the right-hand loop, if the circuits are accurately tuned, and they will add in quadrature. Next, suppose a signal arrives from left to right; then the currents due to this signal in the left-hand loop are 90 degrees ahead of those in the right-hand loop and therefore also combine in quadrature. Then currents due to both signals exist in the common receiving circuit.

"Suppose now, the phases of all currents in the left-hand loop are shifted forward 90 degrees; then the currents due to the desired signal in this loop are shifted around until they are in phase with those from the right-hand loop, while the phase of the currents due to the interfering signal in this loop, and which were previously 90 degrees ahead of those due to the right-hand loop, are now 180 degrees ahead of those in the right-hand loop, so that they oppose and neutralize. Because of the unusual characteristics of the aerial used, this shift in phase is readily accomplished by a small adjustment of the condenser in the loop circuit. If the interfering signal is not in line the right amount of phase shifting can be made to take care of it, and this general order of result is obtainable to some extent with any spacing between the loops, although one-quarter wave length is best. The reception of Carnarvon's signal, 14,200 meters, through the powerful interference of the 200 kw. Alexanderson alternator at New Brunswick, only 25 miles away, working at 13,600 meters, has been an everyday performance of the system, while at the same time preserving a good static balance. All forms of the arrangement described have capabilities of reception through interference, these capabilities varying with the type of aerial employed, the loop aerials and the horizontal aerials giving similar curves."

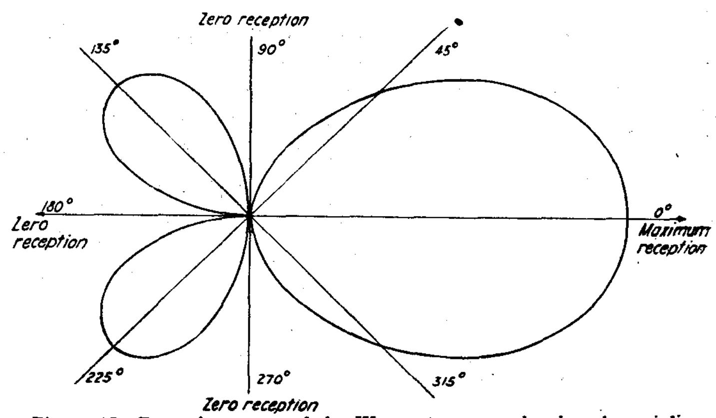

Figure 17—Reception curve of the Weagant system showing the uni-directional characteristic which may be obtained by proper adjustment of the phases of the currents in one loop. Maximum reception is obtained in directions extending through part of the first and second quadrants and minimum reception in the third and fourth quadrants. The line of zero reception may be swung through the third and fourth quadrants at will, by proper phase shifting

(To be continued)