ELIMINATION OF INTERFERENCE FROM RADIO RECEPTION BY THE DIFFERENTIAL OR BALANCING OUT METHOD

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THESIS

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Recent and marked improvements in the art of radio and particularly radio telephone broadcasting have perfected the transmission of signals to such an extent that about the only room for improvement today is the elimination of interference from the received signals. Work has been done in this connection but no decided results have as yet been attained. Evidence of endeavor along this line is given by numerous and varied patents, files of which have been obtained for reference in connection with this work.

The methods employed for the elimination of static and other interfering impulses as described herein, while entirely original with us, were found, after much of the work had been done, to have been at least partially covered by a patent filed in July, 1920 and issued to Mr. Lester K. Jones of New York City. A brief description of the underlying principles of this method together with the history of its inception may well be given here.

Any separation of one type of object or thing from another or other types of things must of necessity depend upon some fundamental difference of that type. When a child is told to sort out the blue marbles from an assortment which he is given he is able to distinguish them by their color which is common to them alone. When a farmer threshes his grain he takes advantage of the fundamental difference in density of the chaff and the kernels and is thus able to separate the two. Likewise the elimination or separation of static impulses from signal

impulses must take advantage of some difference in the two or some characteristic in the one which does not exist in the other. The static impulses which interfere with a received signal travel via the same medium, are of the same form, have the same wave length and may possibly come from the same direction as the signal impulses with which they interfere. It is true that they are not grouped in such a way as to form intelligible communication but it is also obvious that the only device capable of distinguishing this difference would be the human ear which is not what we are after.

Certain authors, notable Elmer E. Bucher in "PRACTICAL WIRELESS TELEGRAPHY", maintain that at least a portion of the so-called static heard in a radio receiver is caused by the passing to ground, through the circuits of the receiver, of static charges of electricity induced upon the aerial by the potential gradient of the atmosphere. If this were the case the effect of these charges upon the receiver could be eliminated by supplying a grounding circuit for the aerial which would include a radio frequency filter. Such a circuit would carry off the induced aerial charges only but would not affect the reception of signals. The fallacy of the electrostatic origin of interference can, however, be easily proven by merely inserting a set of high resistance telephone receivers or phones in series with an aerial and ground at some time when the interference is known to be bad. If the potential gradient of the atmosphere were changing rapidly enough to cause surges in the aerial circuit sufficient to interfere with received radio signals, they most certainly would affect the phones and cause audible sounds. The most that can ever be heard under such conditions is a slight 60 cycle hum due to potentials induced on the aerial by nearby power lines. It is probably from this outworn conception of the cause of interference that it was termed "static".

Several months ago, before this investigation was started, while listening to two radio receivers, simultaneously, which were tuned to different wave lengths, it was discovered that the static impulses from both were, as near as the ear could detect, identical. This suggested the possibility of eliminating the interference by the use of a differential transformer having three windings; one connected to a receiver detecting both the signal and the interfering impulses, one connected to a receiver detecting the interference alone and the third connected to a reproducing or amplifying device. This, in short, is what we have termed "The Differential Method of Static Elimination", and is the subject of our investigation. Our attempts to put this theory into practice are described herewith.

Rather crude attempts along this line had repeatedly been unavailing before this research was started and, therefore, we tried to formulate reasons for failure and guard against them, even before we started. We have applied certain principles and theories as follows:

The fundamental difference between signal and interfering impulses lies in the fact that the former may be detected with a receiver tuned to but one wave length or frequency while the interference apparently contains waves of several different lengths simultaneously. Thus two receiving mechanisms tuned to intercept two different frequencies will both be actuated by a single interference transient. Further it is believed that the time-intensity contour of the potentials produced in the rectifying circuits of both receivers will be nearly identical.

Consider now for a moment the probable origin of an interfering impulse. Let us say a stroke of lightning takes place at a point 100 miles from an observer with two receivers tuned as described above. Modern research workers maintain that a lightning discharge is uni-directional and could not, therefore, of itself produce radio frequency waves. However in the neighborhood of the disturbance there most certainly will be oscillatory surges set up in trees etc., which will be highly damped. These surges might be likened to a rubber ball dropped from a high place onto a smooth surface. If it were dropped from a height of fifty feet its period of bound would at first be about four seconds but as the height to which it bounded grew less and less, the period would grow shorter. Likewise the surges cuased by the electrical discharge as they are damped out emit shorter and shorter waves. Thus it is evident that waves that will affect both of the observers' receivers may be emitted from a single highly damped oscillator which in turn is actuated by a unidirectional electrical discharge. On the other hand, waves emitted by a transmitting device from a free oscillator, with little or no damping, all have practically the same wave length and frequency of succession and can only affect one of the observer's mechanisms- that one which is tuned sharply to the transmitted frequency. It now only remains for the observer to connect the output of the two receivers to two windings of a differential transformer in such a way that equal impulses in both windings produce no effect in a third, at the same time any unbalance in the surges in the two reproduces itself accurately.

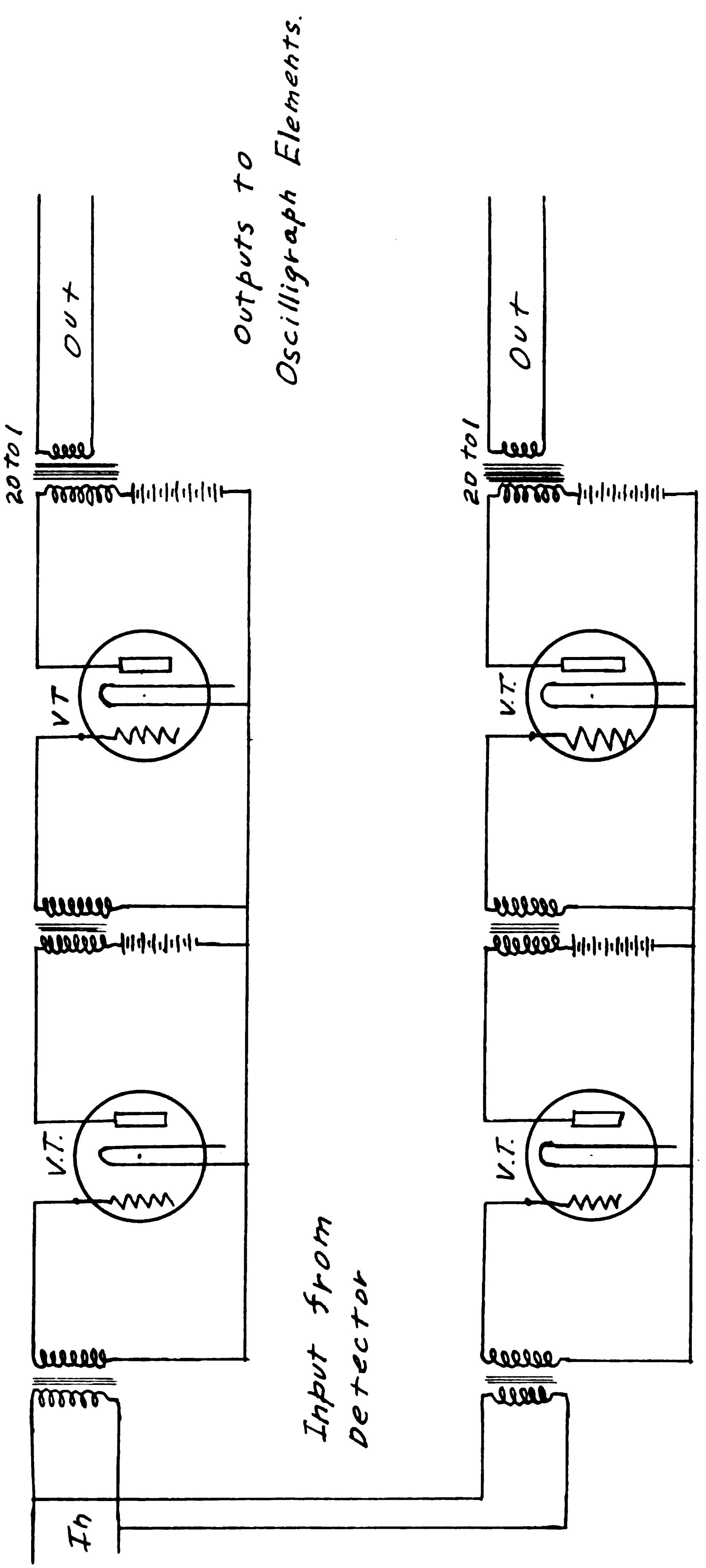
Obviously, for a device of this type to operate successfully the potentials produced in the balanced windings must be identical and must produce flux changes in the core of the transformer exactly 180 degrees out of phase with each other. For this to be the case it is necessary that both receiving mechanisms be identical in their electrical characteristics and that the transients affect both simultaneously. Return for a moment to the analogy of the rubber ball. It is obvious that the shorter periods of vibration follow the longer ones by a certain definite interval of time, depending on the difference in period length and the damping of the oscillations. The greater the difference in period length, the greater the time interval and the greater the damping the less the time interval.

It would thus seem that if our hypothesis concerning the origin of interfering transients was correct there would always be a certain phase displacement between the potentials they produced in the rectifying circuits of the two receivers, those in the circuit tuned to the lower frequencies taking the lead. Our results showed that this condition was not serious enough to cause trouble. It is conceivable that enough periodic circuits of a natural origin in the neighborhood could be set in oscillation so that waves of almost any frequency would be emitted simultaneously with the discharge.

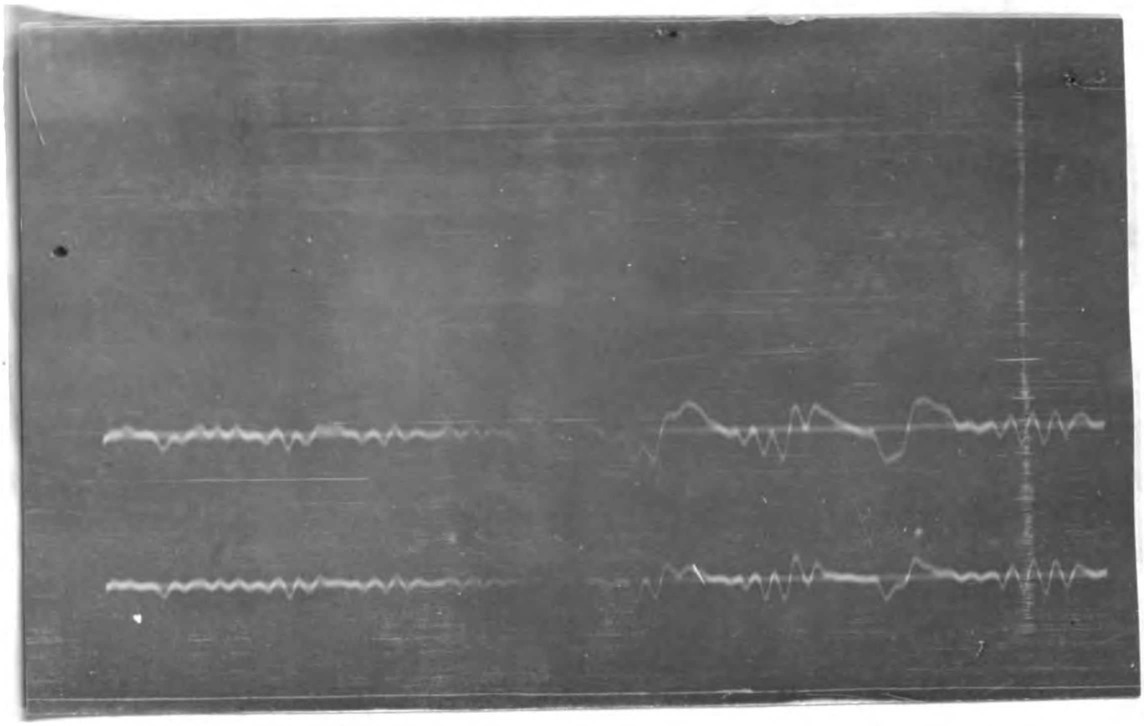
Our first laboratory experiment was to determine how nearly the same two separate and identical amplifying devices could be made to reproduce in amplified form the same applied impulse.

For this experiment two identical two-step vacuum tube amplifiers were built. The wiring and the position of the instruments were duplicated exactly and the corresponding vacuum tubes in the two were of as near the same characteristics as could be obtained. The input for both amplifiers was supplied from a vacuum tube detector which in turn received its energy from an outside antenna and one-step of vacuum tube radio frequency amplification. The primary windings of the two first-step amplifying transformers were connected in parallel rather than in series to secure a more exact duplication, a series connection resulting in the capacitance of one amplifying transformer winding being shunted across the other.

For this test signals were picked up from Station WKAR, the local College Broadcasting station. The filament temperature on the radio frequency amplifying vacuum tube was decreased to a point such that the detector and amplifier tubes would not be overloaded. The output of each amplifier was impressed on an element of a Westinghouse Portable Oscillograph. Step-down transformers with a ratio of 20 to 1 were used between the plate circuits of the amplifiers and the oxcillograph elements. It is interesting to note here that at the time this experiment was run, station WKAR was broadcasting a talk from the college gymnasium by Edgar Guest,



Duplicate Amplifyer.



Oscillogram recording the output of the two duplicate amplifiers.

Michigan's well known poet, and the oscillograms on page 8 are of his voice.

A pair of telephone receivers connected to the output of either amplifier indicated, as near as the ear could detect, equal amplitude and equal clarity and no difference in tonal qualities was apparent and yet an examination of the two traces shows decided differences in wave form; so much so, in fact, that it is hard to conceive of the ear as interpreting them alike. A close examination shows a preponderance of the lower frequencies in the upper trace. A difference of this kind could only be due to a difference in the inductance and capacity balances in the two amplifiers and probably came about through slight differences in the several transformers. Attempts to counteract the differences by the addition of either inductance or capacity at the output of either transformer only made matters worse. The error would probably have to be corrected at its source.

The fact that two amplifiers gave such dissimiliar results after having been constructed as near alike as we possibly knew how, discouraged further attempts at neutralization after the impulses had been amplified. The elements of the oscillograph were not sensitive enough to register the output of the detectors without amplification and it was therefore hoped that the amplifiers could be used so that the process of neutralization could be recorded on an oscillogram, one element recording the potentials in each of the three windings of the differential transformer. Such an oscillogram would have registered any difference in the phase relationship of the static impulses on the two different

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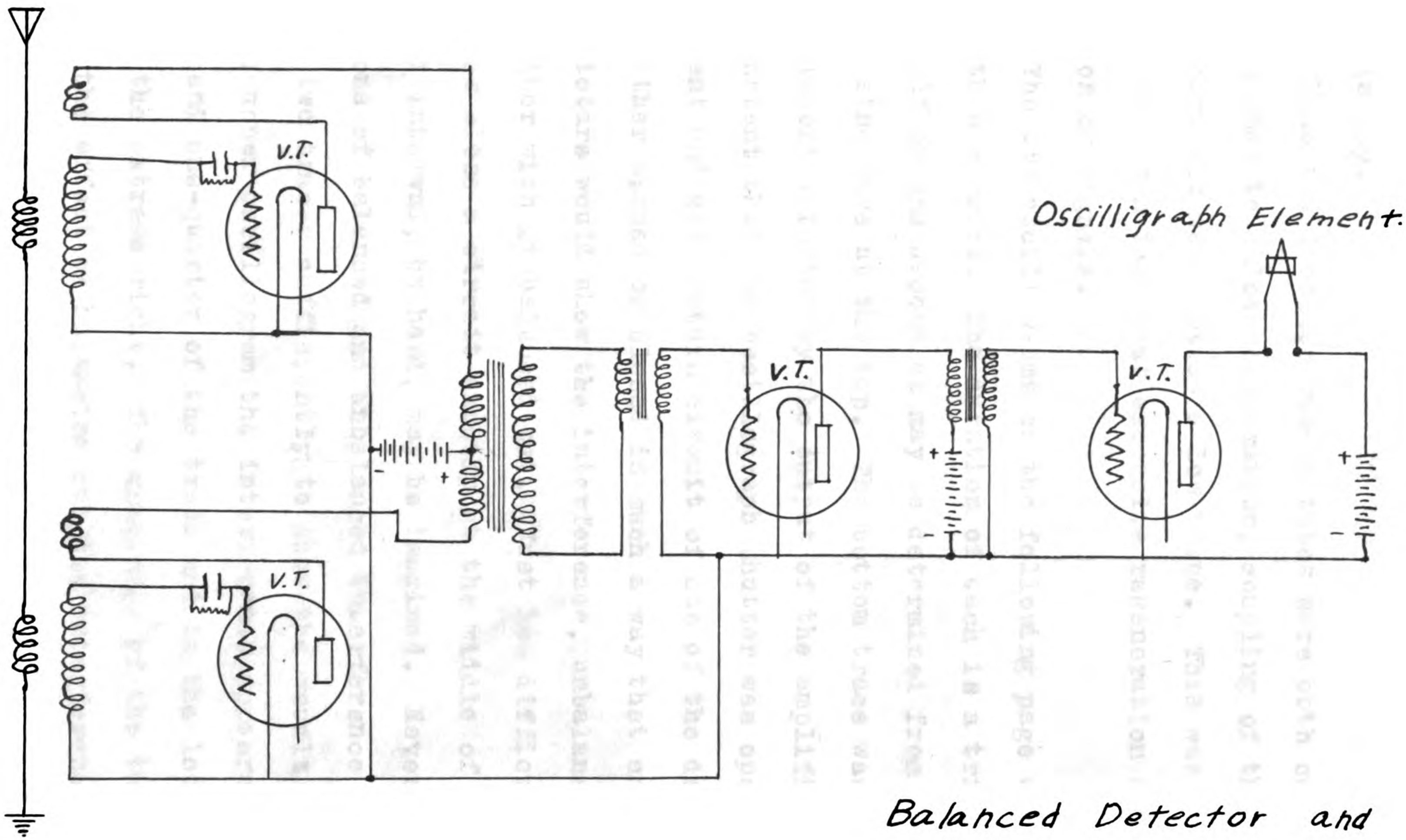
wave lengths. However, since this method proved so unreliable it had to be abandoned with the hope that some time, with more accurate equipment it might still be successful.

Our next experiment was with the circuit shown on the following page. Two identical detector tubes were connected so as to receive their energy from the same antenna at different wave lengths. The output of each tube was connected to one winding of a differential transformer as shown and the output of the transformer amplified by a two-step vacuum tube amplifier. Here, again, there was a chance that the impulses might be distorted by the detector tubes in such a way that they would not be similar in the windings of the transformer even though they were alike before they entered the detector circuit. However, there was less chance for dis-similar distortion here than in the two amplifiers. It was hoped that if phase displacement existed it might be possible to correct it, in a measure, by inserting the proper value of resistance in one of the plate circuits to act as a phase shifter in combination with the inductance of the transformer.

Several types of transformers were used and the results compared quantitatively by means of a pair of head phones connected at the output of the amplifier. A Western Electric Repeater Coil such as is used in phantom telephone circuits seemed to give the best results. Static elimination was never absolute,however, and, furthermore, the interval of time required to change from one transformer to another made it difficult to remember about what the avarage intensity of interference was. If the static had been constant in



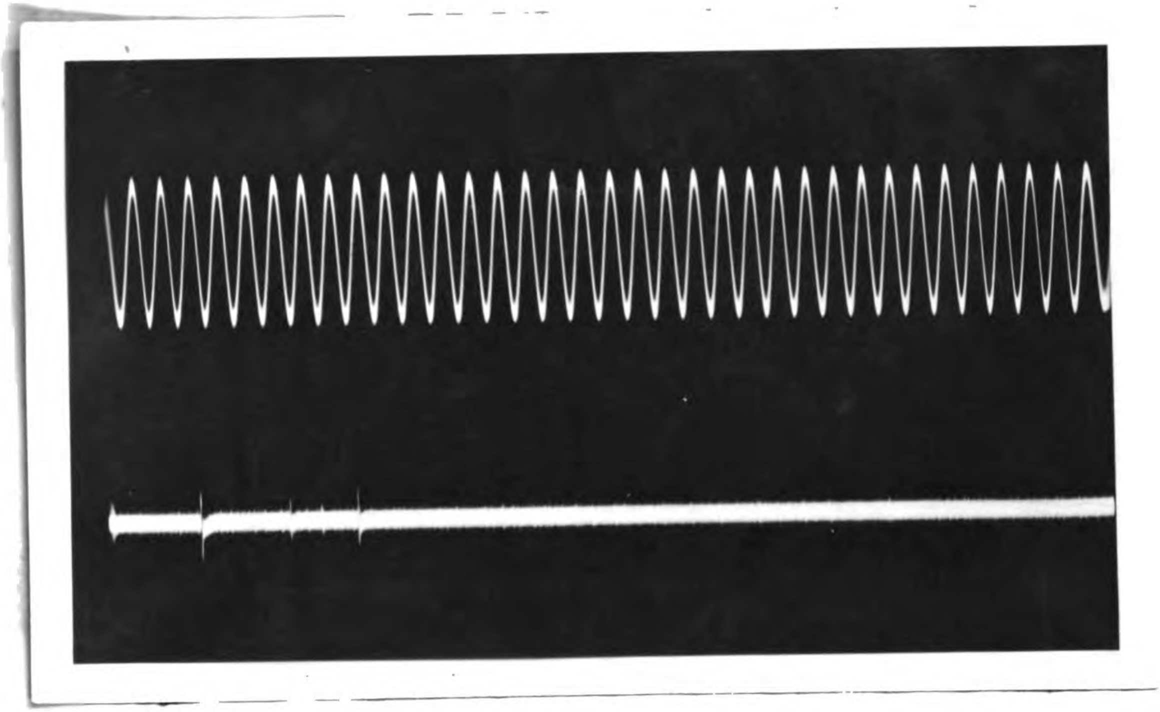
Balanced Detector and Amplifyer for Oscilligraph Element.

intensity and continuous it could have been measured on the ground glass of the oscillograph and comparison made in this way.

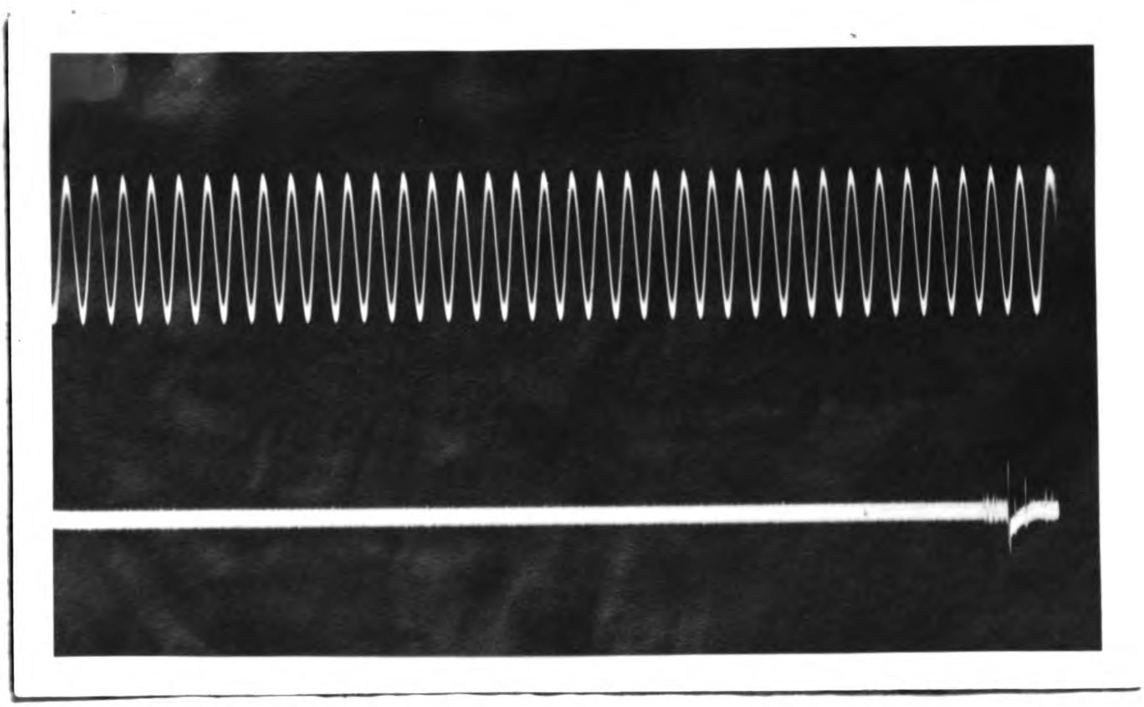
While the detector vacuum tubes were both connected in a manner to allow regeneration, coupling of the plate and grid circuits was kept at a low value. This was because of the well known fact that excessive regeneration causes distortion of signals.

The two oscillograms on the following page were made with this circuit. The duration of each is a trifle over one-half of one second as may be determined from the 60 cycle sine wave at the top. The bottom trace was made by the element actuated by the output of the amplifier. During the instant that the oscillograph shutter was open the filament and grid return circuit of one of the detectors was either opened or closed in such a way that one part of the picture would show the interference, unbalanced, and the other with it balanced out. Just how difficult it is to open or close a circuit exactly at the middle of a one-half second interval, by hand, may be imagined. Never-the-less, portions of balanced and unbalanced interference appear on these two traces sufficiently to show the results obtained. In the upper oscillogram the interference appears on the left hand one-quarter of the trace and in the lower one it is at the extreme right. The remainder of the two traces shows the effect of balancing out the interference. We can truthfully say that our efforts in this experiment were as successful as could possibly be hoped for.

The two oscillograms on the following page were made



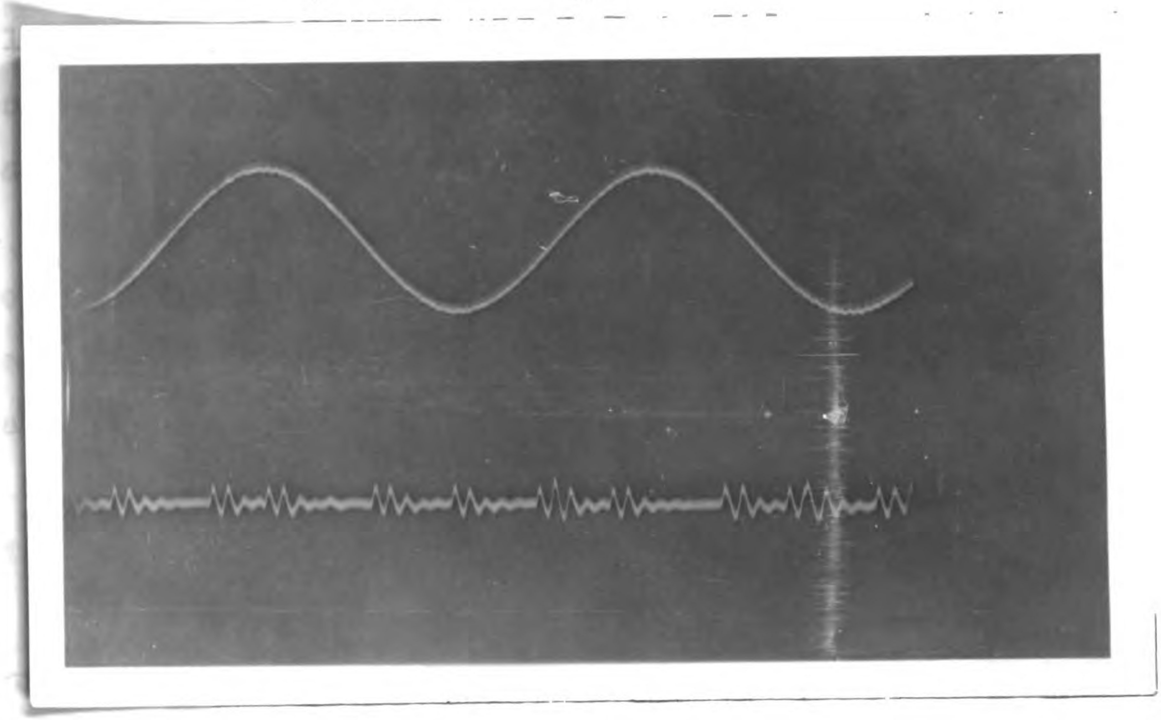
Oscillograms with part of trace recording interference unbalanced and part with neutralization taking place.



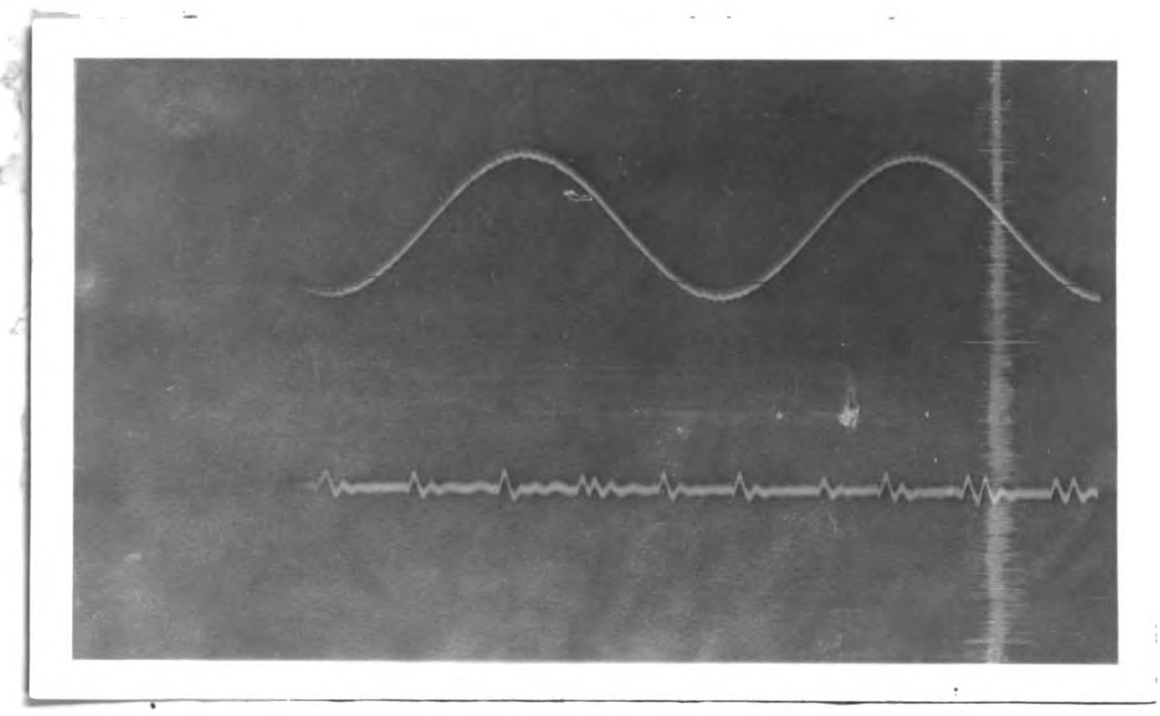
with the same circuit out at a much greater speed. The 60 cycle sine wave shows about two complete cycles or one thirtieth of a second. Artificial interference was set up by means of a small induction coil and battery. The upper trace shows the interference unbalanced while the lower trace was taken with the balancing mechanism in operation. Careful examination of the upper trace shows that the vibrator rate was about 300 per second and that the natural spark tone rate was about 1400 cycles per second. The latter is probably the natural period of the secondary winding of the induction coil.

These two traces do not clearly illustrate the marked difference noticed in the amount of interference when listening with head phones both with it balanced and unbalanced. It is possible that when these traces were taken the filament rheostat of one of the tubes had been disturbed slightly and neutralization was not as complete as it might have been. Never-the-less, the lower trace shows quite a decided decrease in interference over the upper trace.

In summing up; first with regard to the theory of static elimination. We believe it to be fundamentally a problem in the separation of two very nearly identical things. It appears that there is but one basic difference in these two on which to work and that is the difference in damping or decrement of the useful and interfering wave trains. Granting this, there is but one way to be rid of static and that is by detecting it on a slightly different wave length than that used for communication, and applying it in the form of opposing potentials, either directly or through the medium of magnetic



Oscillogram of artificial interference.



Oscillogram with artificial interference partially neutralized.

flux in the core of a transformer, to counteract those potentials due to static which were detected on the communication frequency.

We have found that it is advantageous and even imperative, when modern commercial apparatus is used, to produce neutralization in the first circuits in which it could possibly take place in order to avoid distortion of the impulses. This will be the power circuit of the rectifying or detecting device in most connections.

Our results have shown that this method of eliminating interference is entirely practical and is not in the least complicated.

Previous failures have undoubtedly been due to lack of absolute balance in the duplicate circuits or to too much complication about them. The latter is an affliction of Mr. Jones' patent (No. 1,471,165) which was mentioned above.