

June 11, 1935.

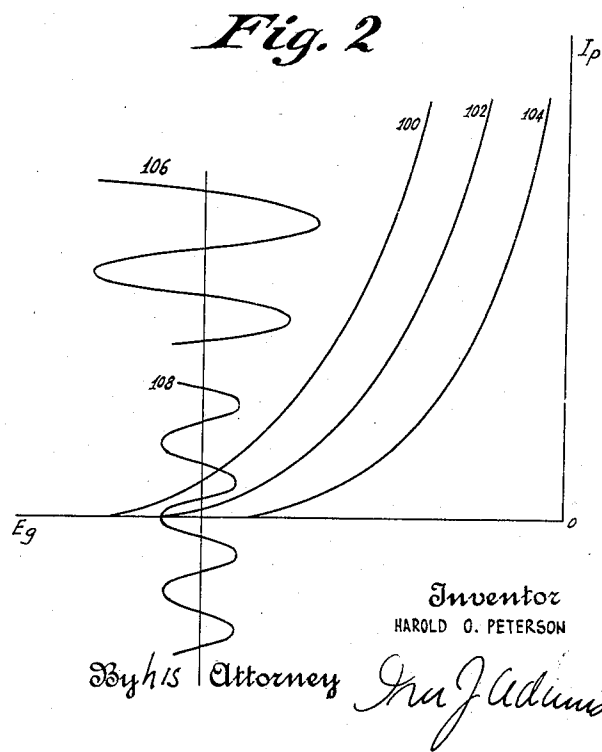
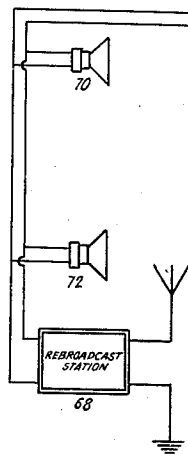
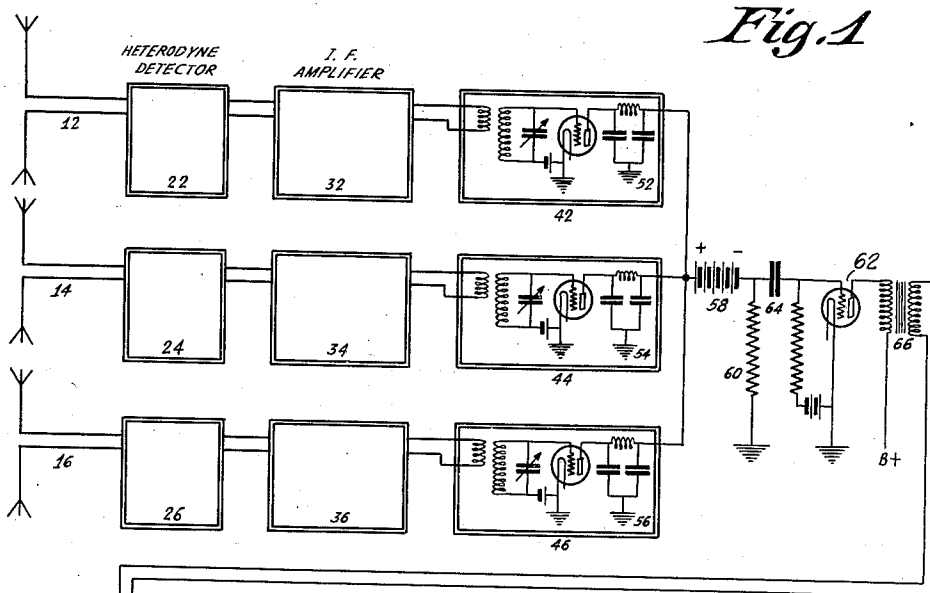
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ANTENNA REGULATOR FOR DIVERSITY RECEPTION

Filed Nov. 16, 1928

2 Sheets-Sheet 1



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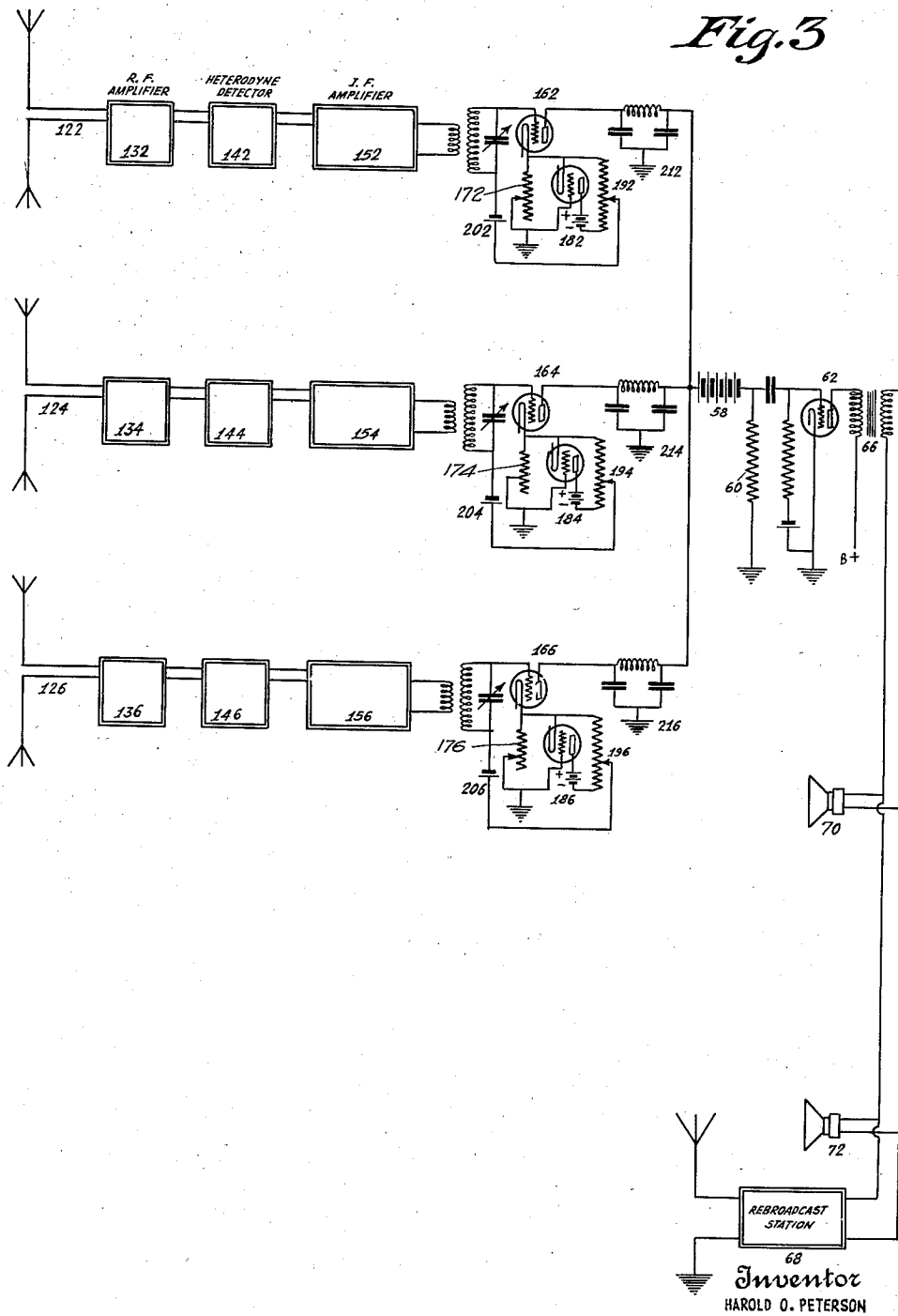
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ANTENNA REGULATOR FOR DIVERSITY RECEPTION

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Fig. 3



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UNITED STATES PATENT OFFICE

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ANTENNA REGULATOR FOR DIVERSITY
RECEPTIONHarold O. Peterson, Riverhead, N. Y., assignor
to Radio Corporation of America, a corpora-
tion of Delaware

Application November 16, 1928, Serial No. 319,938

16 Claims. (Cl. 250—20)

This invention relates to diversity reception, and more particularly to a method and means for advantageously regulating the output from a plurality of antennas.

Short wave signals are subject to fading which varies both in frequency and degree in an unpredictable manner. Inasmuch as the fading at any instant may differ very widely at geographically spaced points, or in different planes of polarization, it has been suggested that a receiving station be equipped with a number of antennas having different fading characteristics, the energies collected by which are fed to a single signal responsive means.

Experience has shown that high frequency energy fluctuates not only in intensity but also in phase, and that there may be considerable relative phase fluctuation at the several antennas. This phenomenon makes it impossible to directly combine the radio frequency energies, for the energies may as often be in phase opposition as in like phase. To overcome this difficulty it has been suggested to equip each of the antennas with a separate receiver, and to combine the energies after rectification, and this, in the case of code signals, has proven an apt solution.

However, I have found that in the case of speech telephony, or other speech-simulating signals, where the transmission energy is radiated in the form of a carrier and side bands, there may be a relative difference in the phase fluctuations of closely adjacent frequencies, such as side band and carrier frequencies, even at one antenna, just as there is between carriers of like frequency at different antennas. This causes similar phase fluctuations in the beat of the carrier and side bands, for if of two beating waves one is kept constant in phase, while the other is shifted in phase, their beat is equally shifted in phase. It consequently follows that although the carrier and side band energies experience only radio frequency differences in phase, these differences are transferred to the detected or audio frequency energies, so that it is as impossible to combine the detected energies as it is to directly combine the originally collected radio frequency energies.

With the usual type of diversity system, even if applied merely to code signals, the received energy is apt to vary between the extremes of almost complete fading at all of the antennas to no fading at any of the antennas. To overcome this it has been suggested to employ a volume control with each antenna for varying the gain in the amplifier coupled thereto. Such an arrangement suffers from the disadvantage that the in-

creased gain given an amplifier of an antenna at which fading is prevalent increases the noise level in the output of that amplifier, and therefore in the combined output of the entire system. Furthermore, in the case of speech-simulating signals, in the event of fading of the carrier and not of the side bands at an antenna its amplifier is given increased gain, as a result of which the beat between the side bands is unduly amplified before being combined with the output from the other antennas, thereby creating augmented distortion.

In order to overcome the foregoing difficulties I propose to select from among the several antennas that antenna at which the received signal is the strongest, and to greatly magnify the initial signal strength differential, so that the energy from the selected antenna will greatly predominate over the other. In this way there is little conflict due to relative phase fluctuations at the different antennas, and a considerable amount of volume control is provided merely in using substantially only one antenna at a time. Furthermore, an antenna receiving speech-simulating signals at which the carrier alone has faded is given diminished output, and therefore has but little effect on the receiver, which reduces distortion.

In order to effect remarkably smooth operation, and to simplify the necessary apparatus, I do not physically disconnect all of the antennas but one, but rather permit them to remain in circuit, and regulate their outputs. In terms of a method, my invention includes simultaneously making a plurality of separate energy collections of relatively different fading characteristics, preferably by collecting the energy on a plurality of geographically spaced antennas, utilizing the energy from each of the antennas for reducing the strength of signal from the other of the antennas in such a manner that the weaker signals are further weakened more than proportionally, so that the strong signals are relatively strengthened while the weaker signals are relatively weakened, and thereafter or simultaneously combining the energies and utilizing the combined energy, so that energy is fed to the utilization means predominately from the antenna having the strongest signal. In a preferred and an exceedingly simple modification I employ separate electron emission tube detectors for each of the antennas, and I couple the anode circuits of the detectors together and to a source of anode potential and a common anode impedance, so that the anode current of each of the detectors tends to reduce the anode potential applied to

the other of the detectors. Owing to the asymmetric characteristic of the detector tubes this results in magnifying any initial signal strength differential. I may further employ individual
 5 regulator tubes for varying the control electrode potential of each of the detector tubes in response to its anode current, and this again, because of the asymmetry of the tube characteristic, results in magnifying the initial signal inequality.
 10 The invention is described more in detail in the following specification, which is accompanied by drawings in which Figure 1 is a wiring diagram for a form of my invention employing common regulation by variation of anode potential;
 15 Figure 2 is a diagram explanatory of the operation of the arrangement shown in Figure 1; and Figure 3 is a modified arrangement employing individual regulation by variation of control electrode potential.
 20 Referring to Figure 1 there are a plurality of antennas 2, 4, and 6, which are given different fading characteristics in any suitable manner, such as by being geographically spaced, or positioned in different planes of polarization, and any
 25 desired number may be used. They are coupled by transmission lines 12, 14 and 16 to autodyne heterodyning means 22, 24, 26. It will be understood that separated local oscillators and heterodyne detectors may be employed, the autodyne circuit differing merely in that the same tube
 30 which acts as an oscillator tube also acts as a detector tube for combining the received and locally generated energies. The resulting energies of intermediate frequency are fed to intermediate frequency amplifiers 32, 34 and 36, to
 35 which are coupled the electron emission tube detectors 42, 44 and 46, across the output circuits of which there preferably are connected a suitable number of filter sections 52, 54 and 56, for
 40 bypassing the radio frequency components of the detected energy. The anodes of the detector tubes are then connected together, as shown, and to a common source of anode potential 58, and a common anode impedance 60, the lower terminal
 45 of which is grounded to complete the anode to cathode circuit.
 In operation the flow of anode current through the impedance 60 causes a reduction in anode potential. Assuming one of the signals to be
 50 stronger than the others the resulting reduction in anode potential weakens the weaker signals still further, often to the point of complete cut off, while the strong signal is not so greatly affected because that decrease in anode potential
 55 which is due to the anode current of the other tubes is not sufficient to overcome its initially greater input voltage. Of course, the operation of the system is predicated upon the assumption of a differential or inequality in the received signal strengths, and in practice it is found that
 60 this assumption is safe. If the signal strengths happen to differ even very slightly the difference is immediately magnified owing to the operation of the detector tubes according to an asymmetric characteristic, usually a square law.
 65 The operation of the invention may be more clearly explained in connection with Figure 2, in which the anode current I_p , of a detector tube, is plotted as a function of the input voltage, E_g . The characteristic curve is different at different
 70 anode potentials, this being indicated by the curves 100, 102, and 104, corresponding to decreasing potentials, say 80 volts, 60 volts, and 40 volts, respectively. If it be supposed that the
 75 resultant anode current flow, due to some strong

signal 106, as well as one or more weak signals 108, is sufficient to bring the anode potential down to 40 volts, the resulting characteristic curve will be the curve 104, and, noticing the intercept of this curve with the zero line of anode current,
 5 it will be seen that as a result the signal 106 will, and the signal 108 will not, produce an output. The normal potential values have been so chosen, in this illustration, that there is no output at all
 10 from the weaker signal, which is a very desirable condition, but it should be understood that the operation may be carried out anywhere else along the characteristic curves, and owing to the fact
 15 that they follow a square law characteristic, there will always result a relative weakening of the weaker signals, and a magnified predominance of the stronger signal.

To obtain the combined energy for utilization the potential drop across the common anode impedance 60 (Fig. 1) is applied to the control electrode of an amplifier tube 62, through a grid bias
 20 blocking condenser 64, and the output from the amplifier may be applied through a transformer 66 to any suitable utilization means, such as a re-broadcasting station 68. Monitoring translating
 25 devices 70 and 72 may be provided at the receiving station and at the re-broadcasting station.

The paramount factors of this arrangement are merely a plurality of antennas, a plurality of detector tubes, and a common anode impedance
 30 through which the polarizing energy for exciting the anodes of the detector tubes flows. The use of superheterodyne receivers with intermediate frequency amplifiers is optional, and if used, they may be connected directly to the antennas, as
 35 shown, or be provided with radio frequency amplifiers.

Attention is now directed to Figure 3, in which there are a plurality of antennas 112, 114, and 116, which are coupled by transmission lines 122,
 40 124, and 126, to radio frequency amplifiers 132, 134, and 136. The amplified outputs are reduced to an intermediate frequency by autodyne heterodyne detectors 142, 144, and 146, the outputs from
 45 which are amplified in intermediate frequency amplifiers 152, 154, and 156. The intermediate frequency energies are then detected by detector tubes 162, 164, and 166.

Each of these detector tubes is individually regulated by variation of its grid bias potential. To
 50 this end there are included in the cathode to anode circuits, and preferably in series between the cathodes and ground, the resistances 172, 174, and 176, which determine the control electrode potential of the regulator tubes 182, 184, and 186.
 55 The anode circuits of the regulator tubes include resistances 192, 194, and 196, the potentials across all or a portion of each of which are used to determine the control electrode bias of the detector tubes 162, 164, and 166, respectively. Batteries
 60 202, 204, and 206 may be used to fix the normal detector bias at a desired value. In operation, an increase in signal strength causes an increased current flow through resistances 172, 174, and 176, which increases the positive potentials on
 65 the cathodes of the regulator tubes 182, 184, and 186, thereby decreasing the anode current flow through the resistances 192, 194, and 196, which decreases the negative potential applied to the control electrodes of the detector tubes 162, 164,
 70 166, thereby increasing the detector outputs. However, as before, owing to the asymmetric characteristic of the detector tubes, the increases in output are not proportional, but are greater in the case of those tubes having stronger signals, 75

so that the output from the tube having the stronger signal is relatively strengthened and predominant.

The anode circuits of the detector tubes 162, 164, and 166, include low pass filter sections 212, 214, and 218, to shunt the radio frequency components of the rectified energy, while the signal components are combined in any suitable manner, here exemplified by connection to a common anode battery 58 and anode impedance 60, just as was disclosed in Figure 1, which results in increased regulation in the desired direction, that is, magnification of initial signal strength differential, owing to the effect of the common anode impedance 60 on the anode potentials of the detector tubes 162, 164, and 166. As before, the output may be amplified in an amplifier tube 62, and fed through a transformer 66 to a rebroadcasting station 68, or other suitable utilization means, as for example the monitoring speakers 70 and 72.

I claim:

1. The method of reception which includes collecting signal energy on a plurality of antennas, rectifying the signal energies, using the rectified energy from each of the antennas for reducing the strength of signal from the other of the antennas in such a manner that the weaker signals are further weakened more than proportionally, combining the rectified energies, and feeding the combined rectified energy to utilizing means.

2. The method of reception which includes collecting signal energy on a plurality of antennas, rectifying the signal energies in electron emission tube detectors, using the rectified energy from each of the detectors for reducing the anode potential applied to the other of the detectors, in order to magnify any initial signal strength differential, combining the rectified energies, and feeding the combined rectified energy to utilizing means.

3. The method of reception which includes collecting signal energy on a plurality of antennas, rectifying the collected energies in electron emission tube detectors, feeding the rectified energies from the detectors and the anode polarizing direct energy to the detectors through a common impedance, whereby the rectified energy from each of the detectors tends to reduce the polarizing potential applied to the anodes of the other of the detectors, and feeding the combined rectified energy to utilizing means.

4. The method of reception which includes simultaneously making a plurality of separate energy collections of relatively different fading characteristics, separately rectifying the collected energies in electron emission tube detectors, using the rectified energy from the detectors for making the potentials on the control electrodes of the detectors more negative, whereby the weaker signals are further weakened more than proportionally, combining the rectified energies, and feeding the combined rectified energy to utilizing means.

5. The method of reception which includes simultaneously making a plurality of separate energy collections of relatively different fading characteristics, separately rectifying the collected energies in electron emission tube detectors, using the rectified energy from the detectors for making more negative the potentials applied to both the control electrodes and the anodes of the detector tubes, whereby the weaker signals are further weakened more than proportionally, combining the rectified energies, and feeding the combined rectified energy to utilizing means.

6. A receiving system comprising a plurality of antennas having different fading characteristics, a plurality of electron emission tube detectors coupled thereto, means coupling the anode circuits of the detectors together and to a source of anode potential and a common anode impedance, whereby the anode current of each of the detectors tends to reduce the anode potential applied to the other of the detectors, and utilization means responsive to the combined detector current.

7. A diversity receiving system comprising a plurality of geographically spaced antennas, a plurality of electron emission tube detectors coupled thereto, a common source of anode potential, a common anode impedance, means coupling the anodes of all of the detectors to the common source and impedance, whereby the anode current of each of the detector tubes tends to reduce the anode potential applied to the other of the detector tubes, and a utilization circuit coupled to the common anode impedance.

8. A diversity receiving system comprising a plurality of antennas having relatively different fading characteristics, a plurality of electron emission tube detectors coupled thereto, means responsive to the anode currents of the detector tubes for varying the control electrode biasing potentials thereof in order to magnify any initial signal strength differential, a common utilization circuit, and means coupling the anode circuits of the tubes to the utilization circuit.

9. A diversity receiving system comprising a plurality of antennas having different fading characteristics, a plurality of electron emission tube detectors coupled thereto, an impedance in the anode to cathode circuits of each of the detector tubes, a regulator tube coupled to each of the impedances, an impedance in the anode circuits of each of said regulator tubes, a bias lead connected from each of the latter impedances to the control electrode of the respective detector tube, a common utilization circuit, and means coupling the anode circuits of the detector tubes to the utilization circuit.

10. A diversity receiving system comprising a plurality of antennas having different fading characteristics, a plurality of electron emission tube detectors coupled thereto, an impedance in the anode to cathode circuit of each of the detector tubes, a regulator electron emission tube coupled to each of the impedances, an impedance in the anode circuits of each of said regulator tubes, a bias lead connected from each of the latter impedances to the control electrode of the respective detector tube, a common source of anode potential for the detector tubes, a common anode impedance, means coupling the anodes of all of the detectors to the common source and impedance, whereby the anode current of each of the tubes tends to reduce the control electrode and anode potentials applied to each of the detector tubes, and a utilization circuit coupled to the common anode impedance.

11. A radio receiving system comprising in combination, a first receiver, an antenna therefor said antenna being located at one point, a second receiver, a second antenna therefor located at a second point so separated from said first point that fading effects vary differently at said separated points, each receiver tuned to the same frequency, common means connected to both said receivers to indicate the signals received thereby, and means to govern the operation of one of said

receivers in accordance with the strength of the signal received at the other of said receivers.

12. A radio receiving system comprising in combination, a first receiver located at one point, 5 a second receiver located at a second point, said receivers receiving signals of like frequency but being so placed as to be subjected to different fading effects from a single transmitting source, and producing outputs substantially identical in 10 frequency, and means to govern the operation of one of said receivers in accordance with the strength of the signal received at the other of said receivers.

13. The method of reception which includes 15 collecting signal energies on a plurality of antennæ amplifying each of the collected energies, rectifying each of the amplified energies for controlling the degree of the amplification of said other energies in such manner that the weaker 20 signal energies are further weakened by the predominant amplified energy, combining the rectified energies, and feeding the combined energy to utilization means.

14. A receiving system comprising a plurality 25 of antennæ having relatively different fading characteristics, a tube having a rectifying characteristic coupled to each of said antennæ, a common utilization circuit having its input energized from said tubes, and an impedance in said input and adapted to be traversed with current

passing through said tubes for magnifying any initial signal strength differential, whereby energy is transmitted to said utilization circuit predominantly from that tube at which the rectified energy is a maximum.

15. The method of operating a radio receiving system having a plurality of antennæ and an electric discharge device coupled to each antenna, which comprises producing a unidirectional potential which is a function of the amplitude of 10 the wave of largest amplitude received at any instant in any of said devices, and utilizing said potential to so affect the discharge devices in which the received waves are of substantially smaller amplitude that they are rendered substantially 15 inoperative for the transmission of waves of said small amplitude.

16. The method of radio reception which comprises receiving at a plurality of separate points waves carrying the same signal, changing the 20 frequency of the received waves, detecting the waves of changed frequency, producing from the detected waves a unidirectional potential, and controlling in accordance with said potential, the transmission of the received waves to substantially 25 suppress all but that one of the received waves having at any instant the largest amplitude.

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