

Feb. 28, 1928.

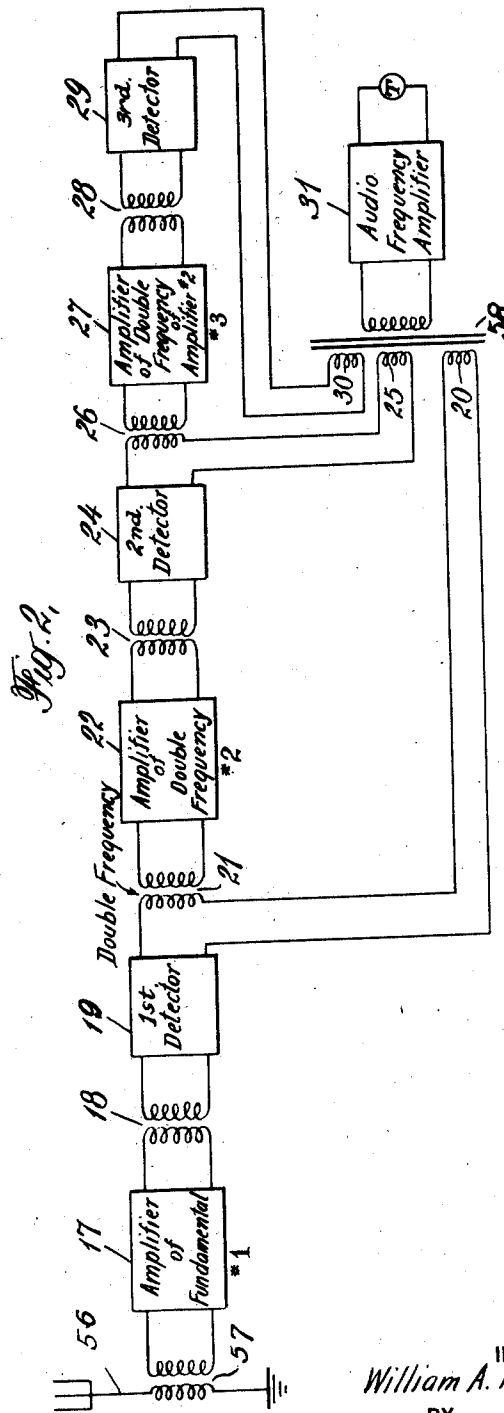
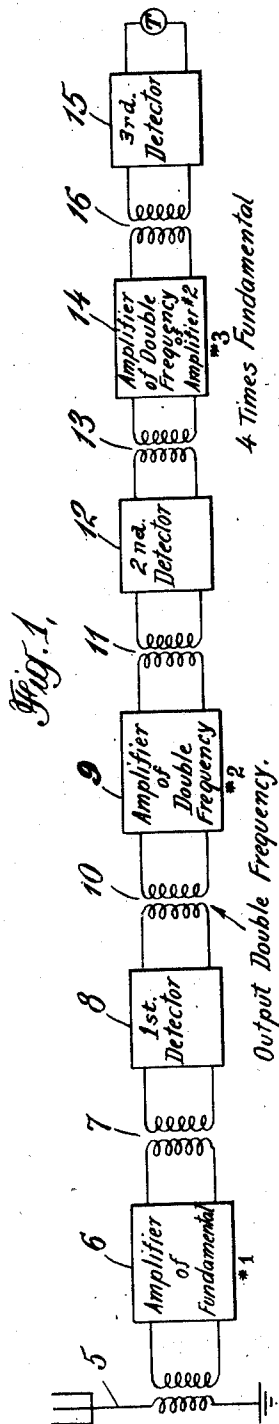
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RECEIVING SYSTEM

Filed Oct. 8, 1925

3 Sheets-Sheet 1



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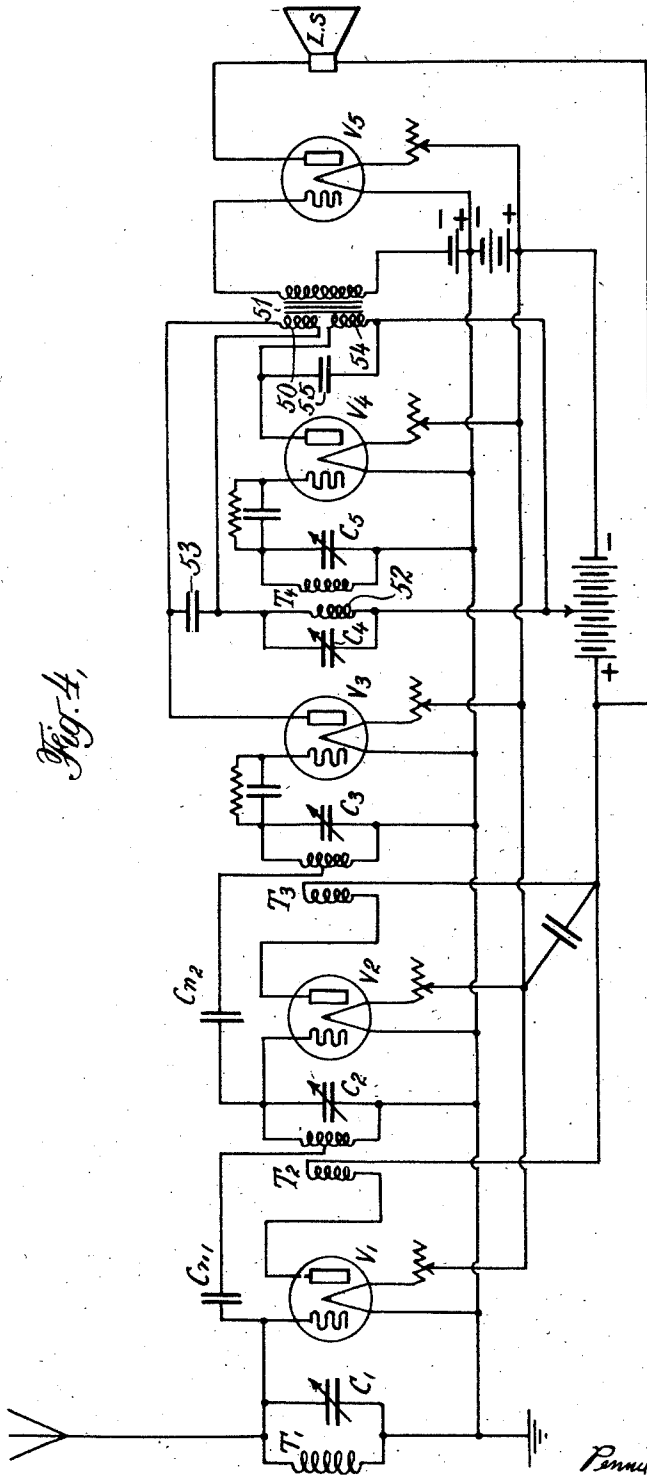
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UNITED STATES PATENT OFFICE.

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RECEIVING SYSTEM.

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This invention relates to methods and arrangements for utilizing the harmonic frequencies appearing in the output circuit of a detector or rectifier of a radio receiver for increasing the amplification of received signals and for increasing the selectivity of the receiver.

It is well known that a rectified alternating current contains a certain portion of the fundamental frequency which has escaped rectification, together with various harmonic frequencies of the fundamental, the amplitude of the series of harmonics decreasing in proportion as the harmonic series progresses.

In modern radio reception, rectification or detection of some form is required to render the incoming radio-frequency signal waves audible. It was customary in past practice to utilize only the audio-frequency component developed from the rectified portion of the incoming or fundamental radio frequency, and to short-circuit, remove or neglect the harmonics or higher multiple radio frequencies appearing in the output circuit of the detector. A single exception to this practice occurs wherein the fundamental radio-frequency energy appearing in the output circuit of the detector is returned to the input circuit thereof and redetected. This action is known as regeneration, and is the subject-matter of Armstrong U. S. Patent No. 1,113,149.

In the present arrangement, it is proposed to utilize the harmonic radio frequencies with the object of amplifying them to a desired value, rectifying them and then employing them directly, or in conjunction with other rectified high frequencies, to increase the amplification, in audible form, of the received signals.

It has been recognized that there is a certain limit to the amplification which it is possible to obtain in a multistage radio-frequency amplifier, because of the difficulty in controlling oscillations which not only render the radio receiver unstable, but tend to generate influences which mask the desired signals. By utilization of the present invention it is possible to realize the maximum amplification possible at the fundamental radio frequency, and then, by properly arranging the output circuit of the detector or rectifying means, such as a vacuum tube, to utilize the first harmonic

or double frequency of the fundamental. This harmonic frequency is then preferably amplified as much as is practicable without producing disturbing oscillations. The amplified first harmonic frequency, when rectified, can be combined with the audio-frequency component of the fundamental to give increased signal strength. It is thus possible, by amplifying individual signals of different harmonic frequencies, to obtain greatly increased amplification without producing undesirable oscillations.

A further advantage of the invention is that of greatly increased selectivity. It will readily be understood that signals of a frequency other than the fundamental, no matter how strong they may be, cannot force themselves through the series of tuned amplifiers, because each successive amplifier is tuned to a frequency which differs widely from the others. In other words, the only radio energy which can interfere with the signals received upon apparatus arranged according to this invention is the radio energy of a frequency identical with that which it is desired to receive.

For a further understanding of the invention, reference is made to the accompanying drawings, wherein:

Fig. 1 shows a schematic arrangement of the present invention in which the audio-frequency component of the fundamental radio frequency thereof is disregarded, and in which only the double frequency of the first harmonic is utilized to obtain an audible signal;

Fig. 2 represents a schematic showing of a modification of the present invention in which the audio-frequency components of the fundamental radio frequency, the first harmonic thereof, and the first harmonic of the latter are combined and introduced into the input circuit of an audio-frequency amplifier;

Fig. 3 is a third modification of the invention in which the first and second harmonics appearing in the output circuit of the first detector are amplified and rectified, and thereafter combined with the audio-frequency component of the fundamental frequency, and subsequently introduced into the input circuit of an audio-frequency amplifier; and

Fig. 4 represents one form of a diagrammatic circuit arrangement incorporating the

present invention in a radio receiver, from which it will be possible to understand more clearly the circuits suitable for radio-frequency amplification and detection in the schematic illustrations shown in Figs. 1, 2 and 3.

Referring especially to Fig. 1, 5 indicates an antenna, which may be of any well-known form, coupled to the input circuit of a radio-frequency amplifier 6 capable of amplifying the received fundamental radio-frequency signal. It will be understood that this amplifier may consist of one or more stages of radio-frequency amplification, each stage of which includes at least one vacuum tube. It will further be understood that the input circuits of these stages are preferably tuned to the fundamental radio frequency of the incoming signal, although this invention is not limited to such tuned circuits. The output circuit of the radio-frequency amplifier 6 is coupled by means of a transformer 7 to the input circuit of the usual detector or rectifier 8, which is preferably of the vacuum tube type. As is well known, such a detector, or rectifier, serves to rectify the radio-frequency signals amplified by amplifier 6, so that the rectified signals are rendered capable of operating suitable audio-frequency amplifying apparatus. It is also well known that, due to the rectifying action of the detector, there are present in the output circuit thereof the harmonic frequencies of the fundamental which occur in the simple harmonic series.

In the output circuit of the first detector 8, therefore, appears the rectified or audio-frequency component of the fundamental radio frequency, and also the first, second, third and higher harmonics of that fundamental frequency. It will be understood that the first harmonic is usually the strongest of the series, and that the succeeding harmonics progressively decrease in amplitude throughout the series. In the arrangement of Fig. 1, under consideration, the audio-frequency component of the fundamental radio frequency is disregarded, but the first harmonic radio frequency is introduced into the input circuit of an amplifier 9 by means of a transformer 10. Amplifier 9 may consist of one or more tuned stages, each stage including at least one vacuum tube for the purpose of amplifying the first harmonic radio frequency. The output circuit of the last stage of amplifier 9 is coupled, by means of a transformer 11, to the input circuit of a second detector 12, while the transformer 13 serves to introduce an harmonic radio frequency, double that amplified by the second amplifier 9, into the input circuit of a third amplifier 14, the output circuit of which is coupled to a third detector 15 by means of transformer 16. The output circuit of this detector includes an audio-frequency

indicating device such as a telephone, or loud speaker, T. It should be noted that the third amplifier 14 is tuned to a frequency double that to which the second amplifier 9 is tuned. In other words, amplifier 14 is tuned to the first harmonic of the frequency amplified by the second amplifier. While this frequency is necessarily four times that of the fundamental frequency, it cannot properly be considered as the third harmonic of the fundamental frequency, because all harmonics except the first are neglected by the second amplifier 9. The net result of this arrangement is that the indicating device T is operated only by the audio-frequency component of a frequency corresponding to the fourth harmonic of the fundamental radio frequency, i. e., the first harmonic of the first harmonic of the fundamental frequency. Such an arrangement provides an extremely high degree of selectivity, because interfering signals cannot pass the series of harmonic filter systems unless those signals be of a frequency identical with the fundamental radio frequency. The degree of amplification finally attainable is also greater than could be obtained by a straight multistage radio-frequency amplifier, because each amplifier, namely, 6, 9 and 14, may include within itself as many component amplification stages as are practicable at the frequency to which that amplifier is tuned.

Referring to Fig. 2, there is indicated an antenna 56 coupled by means of a transformer 57 to the input circuit of a radio-frequency amplifier 17. This amplifier, which may include one or more tuned or untuned stages of vacuum tube amplification, amplifies the fundamental radio-frequency signals intercepted by antenna 56. The output circuit of amplifier 17 is coupled by means of a transformer 18 to the input circuit of detector 19, while the output circuit of this detector includes the primary winding 20 of an audio-frequency transformer 58, and also includes the primary winding of a transformer 21, which serves to introduce the first harmonic of the fundamental radio frequency into the input circuit of amplifier 22. This amplifier may include one or more amplifying stages, each having one or more vacuum tubes and the customary associated circuits. The output circuit of amplifier 22 is coupled by means of transformer 23 to the input circuit of a second detector 24, and the output circuit of this last-mentioned detector includes the second primary winding 25 of audio-frequency transformer 58, and also includes the primary winding of a transformer 26 which serves to couple the output circuit of the second detector to the input circuit of a third radio-frequency amplifier 27. Amplifier 27 may include one or more tuned or untuned stages of amplification each having

one or more vacuum tubes. Transformer 26 introduces the first harmonic of the frequency rectified by detector 24 into the input circuit of amplifier 27, while the output circuit of this last amplifier is coupled by means of a transformer 28 to the input circuit of a third detector 29, the output circuit of which includes a third primary winding 30 of the mentioned audio-frequency transformer 58. The windings 20, 25 and 30 in the output circuits of detectors 19, 24 and 29, respectively, couple these circuits through transformer 58 to the input circuit of an audio-frequency amplifier 31. This amplifier may consist of one or more vacuum tubes arranged in circuits now well known, and includes an output circuit for controlling a telephone, or loud speaker, T.

It will be seen that in this last-considered arrangement, the received signal is amplified and then rectified, after which the first harmonic frequency appearing in the output circuit of the first detector is amplified and rectified; thereafter the first harmonic frequency appearing in the output circuit of the second detector is amplified and rectified, whereupon the three rectified audio-frequency components are combined in a transformer, then amplified and caused to actuate a telephone, or other indicating device.

At this point it should be noted that each radio-frequency amplifier, regardless of the number of stages therein, may be considered, together with the rectifier or detector next following, as a unit or group, which is preferably operated on a single frequency. For instance, in Fig. 1, components 5, 6, 7 and 8 operate on the fundamental; 9, 11 and 12 operate on the first harmonic; and 13, 14, 16 and 15 operate on the first harmonic of the first harmonic, or double the frequency of the first harmonic of the fundamental. Likewise, referring to Fig. 2, components 56, 17, 18 and 19 operate on the fundamental; 21, 22, 23 and 24 operate on the first harmonic; and 26, 27, 28 and 29 operate on double the frequency of the first harmonic of the fundamental. The components, or apparatus, of Figs. 3 and 4 may be similarly grouped.

Fig. 3 shows a slightly modified arrangement of that shown in Fig. 2, and indicates an antenna 32, which is coupled by means of radio-frequency transformer 33 to the input circuit of an amplifier 34. This amplifier may be of the type previously mentioned, consisting of several stages of tuned or untuned radio-frequency amplification, each of which includes a vacuum tube. The output circuit of this amplifier is coupled by means of a transformer 35 to the input circuit of a detector 36, the output circuit of which includes primary windings of the transformers 37, 39 and 42. Transformer 37 introduces the first harmonic of the fundamental radio

frequency into amplifier 38, which may consist of one or more stages arranged for vacuum tube amplification. The output circuit of this amplifier is connected by means of transformer 40 to a second detector 41 having an output circuit including a primary winding 61 of audio-frequency transformer 39. Transformer 42 introduces the second harmonic of the fundamental radio frequency into amplifier 43, which may be of the character of amplifier 38, and amplifier 43 is in turn coupled to a third detector 44 by means of transformer 45. The output circuit of this detector includes the primary winding 46 of audio-frequency transformer 39, which introduces the combined frequencies developed in the output circuits of the three detectors, 36, 41 and 44, into the input circuit of audio amplifier 47, which may be of the multistage vacuum tube type and whose output circuit includes a telephone, or other indicating device, 48.

The arrangement shown in Fig. 3, it will be observed, differs from that of Fig. 2 in that the second harmonic of the fundamental frequency is utilized as well as the first harmonic. This is made possible because of the fact that the primaries of transformers 37 and 42 are connected in series with the output circuit of the first detector, in which circuit both the first and second harmonics of the fundamental frequency are present. Of course the third and higher harmonics are present as well, but in this example only the first and second have been utilized. The first harmonic is amplified by amplifier 38, and the second harmonic by amplifier 43. The fundamental and the first and second harmonics are rectified by detectors 36, 41 and 44, respectively, after which the audio-frequency signals are combined in transformer 39, amplified at 47, and indicated at 48.

The figures herewith illustrate the coupling means between the amplifiers and detectors as being of the electromagnetic type. This showing of coupling transformers, such as 7, 16, 57, 23, 26, T_2 and T_3 , is for convenience only, since other coupling means, as, for instance, capacitive, or resistive, might be used with equal success.

Referring to Fig. 4, there is indicated an antenna directly connected to the input circuit of vacuum tube V_1 , which is tuned by inductance T_1 and variable condenser C_1 . The plate circuit of vacuum tube V_1 is connected by means of radio-frequency transformer T_2 to the input circuit of vacuum tube V_2 . This last-mentioned input circuit is tuned by means of variable condenser C_2 connected across the secondary of transformer T_2 . In accordance with well-known practice, a neutralizing condenser C_{n1} , connected to the grid of vacuum tube V_1 and to an appropriate point on the secondary wind-

ing of transformer T_2 , functions to neutralize undesirable capacitive coupling between the input circuit and the output circuit of vacuum tube V_1 . The output circuit of vacuum tube V_2 is coupled by means of radio-frequency transformer T_3 to the input circuit of detector V_3 , which includes variable condenser C_3 functioning in the customary manner to tune the input circuit. As in the case of vacuum tube V_1 , the condenser C_{n2} , connected between the grid of vacuum tube V_2 and an intermediate point on the secondary winding of transformer T_3 , neutralizes the undesirable capacitive coupling between the input circuit and the output circuit of vacuum tube V_2 . Vacuum tubes V_1 and V_2 , together with associated input and output circuits as described, constitute a tuned radio-frequency amplifier, which is suitable for use in the previously described arrangements. Any number of similar stages may be employed within practicable limits.

The output circuit of detector V_3 includes primary winding 50 of the audio-frequency transformer 51, and also the primary winding 52 of transformer T_4 . A by-pass condenser 53 is connected across the primary winding 50, and a variable tuning condenser C_4 is connected across the primary 52 of transformer T_4 . The secondary winding of transformer T_4 is shunted by variable condenser C_5 to tune the input circuit of the second detector V_4 , the output circuit of which includes a second primary winding 54 of audio-frequency transformer 51. This last-mentioned winding is shunted by a by-pass condenser 55. Primary windings 50 and 54, included in the output circuits of the respective detectors V_3 and V_4 , serve to couple those detectors to the audio-frequency amplifier, the vacuum tube of which is designated V_5 . The rectified signals appearing in the output circuits of the detectors are amplified by the audio-frequency amplifier, which in turn actuates a telephone, or loud speaker, LS.

In operating the receiver illustrated in Fig. 4, the input circuits of vacuum tubes V_1 , V_2 and V_3 would normally be tuned to the incoming, or fundamental, radio frequency. Accordingly, transformer T_1 would be tuned to the first harmonic of the fundamental frequency. The detector V_4 would then rectify this first harmonic frequency, and combine, in audio-frequency transformer 51, the audio component thereof with the audio component of the fundamental frequency derived from detector V_3 . The audio-frequency currents from the two detectors would then be amplified by audio-amplifying tube V_5 , and actuate loud speaker LS.

Radio-frequency amplifiers of types other than that described in connection with Fig.

4 might be employed in accordance with this invention with more or less satisfactory results, depending upon the circumstances. For instance, in the place of any of the radio-frequency amplifiers, such as 6 or 14 of Fig. 1, or 38 or 43 of Fig. 3, a radio-frequency amplifier of the super-heterodyne type might well be used. Again, increased amplification might be obtained if one or more of the amplifiers were of the well-known resistance coupled type, followed by a detector tuned to the second harmonic of the current which is being amplified, rather than to the same frequency as suggested in the other examples herein. If such a system were used in the circuit of Fig. 1, amplifier 6 might be tuned to the fundamental, detector 8 to the second harmonic thereof, amplifier 9 to the first harmonic of the frequency of the current in detector 8, which would be six times the frequency of the fundamental, and so on.

It will be understood that the present disclosure is merely typical of applicant's invention, and that there may be innumerable variations in the types of amplifiers, in the combinations of the detectors and amplifiers, in the harmonic frequencies utilized, and in the methods of combination of the audio-frequency components, all within the scope of the appended claims and without departing from the spirit of this invention.

I claim:

1. In a radio receiving system including a plurality of amplifiers and detectors, means for impressing an incoming signal upon a first amplifier responsive to the frequency of said signal, a first detector linked with said first amplifier and responsive to the frequency of said signal, an output circuit for said detector in which occur a plurality of frequencies which are harmonics of the frequency of said incoming signal, means for separately amplifying and detecting said harmonic frequencies, and means for combining the audio-frequency currents in the output circuits of said detectors whereby an indicating device may be actuated.

2. The method of signal reception which consists in rectifying an incoming signal wave of a fundamental frequency to produce an audio-frequency component and a multiple frequency of said fundamental frequency, rectifying said multiple frequency to produce a second audio-frequency component and additively combining said audio-frequency components to produce an audible signal.

3. The method of signal reception which consists in rectifying an incoming signal wave of a fundamental frequency to produce an audio-frequency component and a multiple frequency of said fundamental frequency, amplifying and rectifying said

multiple frequency to produce a second audio-frequency component, and additively combining said audio-frequency components to produce an audible signal.

4. In a wave signal receiving system, a source of modulated incoming high-frequency waves, a detector operative to rectify said waves and to produce therefrom an audio-frequency current in accordance with the modulation of the waves and, in addition, an harmonic of the incoming wave, a second detector adapted to rectify said harmonic wave and to produce therefrom a second audio-frequency current, signal-indicating means, and means for additively combining said audio-frequency currents and impressing the combined currents upon said signal-indicating means.

5. In a wave signal receiving system a receiving detector, an amplifier for amplifying received waves, a vacuum tube detector for rectifying the amplified received waves, said detector having an output circuit in which are present both the audio-frequency component of the rectified waves and one or more harmonic-frequency components of the received wave, a second vacuum tube detector having an input circuit tuned to the frequency of one of said harmonics and coupled to the output circuit of said first detector, said second detector being operative to rectify waves of the harmonic frequency to which its input circuit is tuned and to produce thereby audio-frequency currents corresponding in form to those produced in the output circuit of said first detector, an audio transformer connected to the output circuits of said first detector and said second detector conjointly, said transformer being operative to additively combine said audio-frequency currents, and signal-indicating means adapted to be operated by said combined audio-frequency currents.

6. In a wave signaling system, a source of incoming high-frequency waves of a fundamental frequency, means operative to rectify said waves and to produce therefrom current of an effective frequency considerably less than that of said fundamental frequency, and also to produce an harmonic of said fundamental frequency, a second

means operative to rectify said harmonic frequency and to produce therefrom current of a frequency considerably less than that of said harmonic frequency, and means for combining said currents, whereby signal-indicating means may be operated by the current resulting from said combined currents.

7. In a wave signal receiving system, a source of modulated incoming radio-frequency waves, a first rectifier having an output circuit and operative to rectify in part said radio-frequency waves to produce therefrom an audio-frequency current in accordance with the modulation of the waves, and also to produce an harmonic of said radio-frequency waves, a second rectifier linked to the output circuit of said first rectifier and operative to rectify a certain radio-frequency current occurring in the output circuit of said first rectifier, and to produce therefrom a second audio-frequency current, a third rectifier linked to the output circuit of said first rectifier and operative to rectify a certain harmonic of the incoming radio-frequency current and to produce therefrom a third audio-frequency current, and means for additively combining said audio-frequency currents, and impressing the resulting current upon a signal-indicating means.

8. In a wave signal receiving system, a source of modulated incoming radio-frequency waves of a fundamental frequency, an amplifier for amplifying the received waves, a detector for rectifying said waves whereby a plurality of harmonics of said fundamental frequency and an audio-frequency component thereof are produced, a second detector linked to said first detector for rectifying one of said harmonics whereby a second audio-frequency component is produced, a third detector linked to said first detector for rectifying another of said harmonics, whereby a third audio-frequency component is produced, and means for additively combining said audio-frequency components and impressing the resulting current upon a signal-indicating means.

In testimony whereof I affix my signature.

WILLIAM A. MACDONALD.