July 3, 1928. 1,675,323

E. H. ARMSTRONG

WAVE SIGNALING SYSTEM

Filed May 10, 1923 2 Sheets-Sheet 1

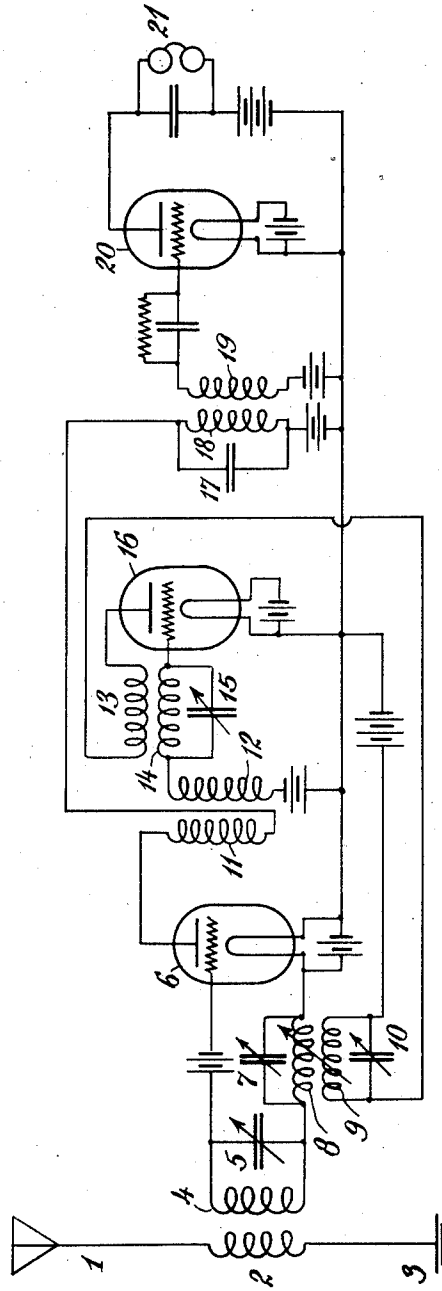

Fig. 1.

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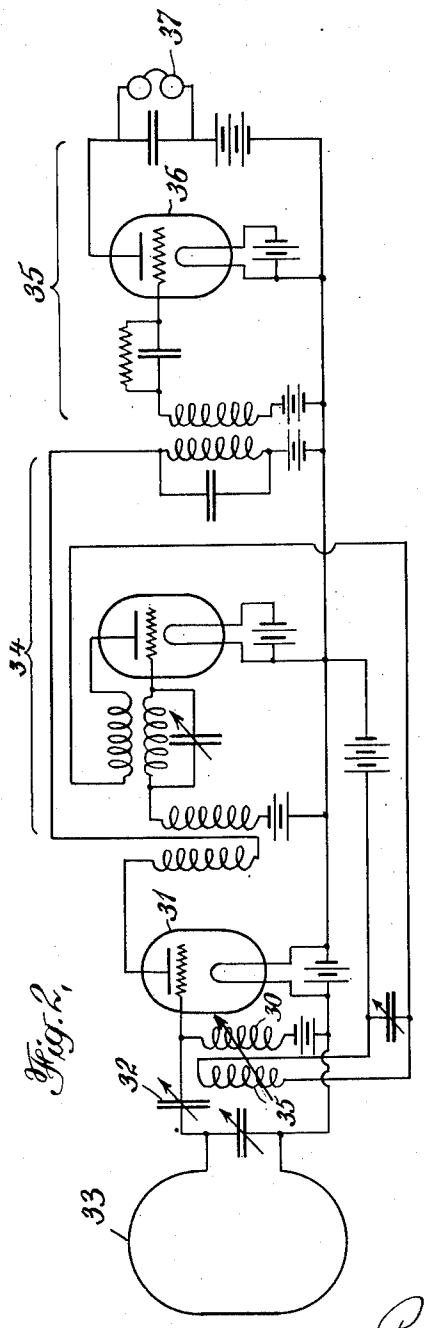

Fig. 2.

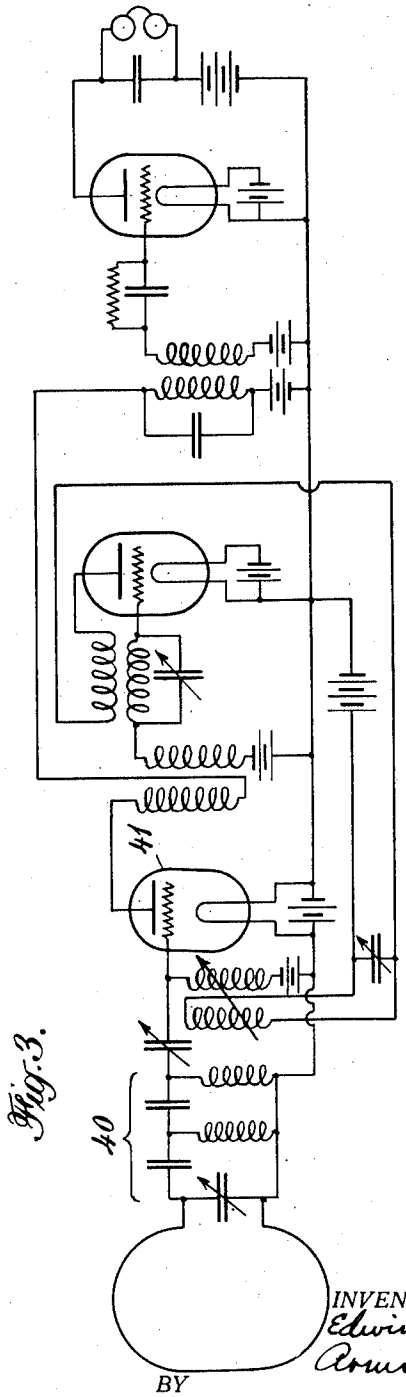

Fig. 3.

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UNITED STATES PATENT OFFICE.

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WAVE SIGNALING SYSTEM.

Application filed May 10, 1923. Serial No. 638,144.

This invention relates to improvements in the superheterodyne system of indirectly amplifying and receiving radio frequency electrical oscillatory energy, as described in my United States Letters Patent No. 1,342,885, and to improvements in the arrangement described in a co-pending application of Harry W. Houck, filed March 3, 1923, Serial No. 622,521. The invention has for its object the provision of a method and apparatus whereby the intermediate frequency produced, for example, by the Houck arrangement, is caused to react on the frequency converting or transforming system to increase the efficiency with which the frequency conversion takes place.

As is well known, a superheterodyne arrangement enables the indirect amplification and reception of signal wave frequencies which can not be conveniently and effectively amplified and received in a direct manner, by transforming or converting the incoming signal frequency which is too high to conveniently or efficiently amplify directly, down to some intermediate or lower frequency which may be readily amplified and subsequently detected.

The superheterodyne system is generally recognized as being ideal and would be more widely used in modern wave signaling receiving apparatus were it not for the fact that a very large number of tubes are required for its operation, it being necessary heretofore to employ a vacuum tube for carrying out each separate function necessary to the operation of the system as a whole. The use of a large number of vacuum tubes results in heavy consumption of filament current even tho so-called "low filament current" tubes are employed and moreover when a large number of tubes are employed tube replacement costs are correspondingly high.

The need for a large number of tubes in a superheterodyne system arises in two ways: first, two tubes are required to change the high or radio frequency of the incoming signal energy down to the intermediate frequency value which is two tubes more than would ordinarily be required if the amplification of the incoming signal energy could be carried out directly; second, the conversion or transformation in the frequency is accompanied by a considerable loss so that the amplitude of the new intermediate frequency is below the amplitude of the initial incoming signal frequency. It is, therefore, necessary to employ additional tubes for amplifying the intermediate frequency in order that its amplitude may be brought up to at least the equal of the amplitude of the original high frequency current before any advantage is gained by employing additional intermediate frequency amplifying tubes.

In the application of H. W. Houck above referred to, a method and apparatus are described whereby the transformation or conversion of frequency which heretofore required the use of two vacuum tubes can now be effected by a single vacuum tube in a self heterodyne arrangement, operating with an efficiency equal to or better than a two tube separate heterodyne arrangement.

In accordance with the present invention, the arrangement described in the above mentioned Houck application is employed, and in addition provision is made for causing the intermediate frequency oscillations which result from the combination and conversion of the incoming energy and the locally generated oscillations, to react on the frequency transforming or converting vacuum tube and system to greatly increase the efficiency of conversion so that the change in frequency is accomplished not only without loss but with an actual gain in signal strength, whereby fewer intermediate frequency amplifying vacuum tubes are required to produce the desired degree of amplification of the intermediate frequency oscillations. It is important that the polarity of the intermediate frequency transformer thru which the intermediate frequency oscillations are passed, be correct and this polarity should be such that the reaction is in the opposite sense to that which produces the ordinary form of regeneration.

Referring now to the drawings and to the following description from which a more complete understanding of the invention may be had:

Figure 1 illustrates a simple form of the invention; Figure 2 illustrates a more effective embodiment of the general arrangement shown in Figure 1; and Figure 3

illustrates a superheterodyne system embodying the invention which includes a high pass filter for eliminating certain difficulties which may be encountered in the course of the operation of a system such as shown in Figure 1.

Referring now to Figure 1, an energy collecting circuit or tuned antenna 1, 2, 3, is coupled to the secondary system 4, 5, which is tuned to the frequency of the incoming signaling energy. The secondary circuit 4, 5 is connected in the control electrode-cathode circuit or input of a high frequency vacuum tube repeater or amplifier system including an electron discharge device or vacuum tube 6. The output circuit of the high frequency amplifier system contains a primary 11 of a radio frequency transformer. In this way the incoming signaling energy is repeated and amplified and subsequently impressed on the self heterodyne frequency converter or transformer including the tube 16 having a cathode or filament, a control electrode or grid, and an anode or plate, and circuits associated therewith so that the arrangement functions in the manner described in the above entitled Houck application. To that end the circuit 14, 15 is preferably tuned to a fundamental frequency equal to one half the frequency of the incoming energy, plus or minus, one half of the desired intermediate or third readily amplifiable frequency. In this way the second harmonic (which is twice the frequency of the fundamental) differs in frequency from the incoming energy by the desired intermediate frequency. It is to be understood, however, that other multiple values of the fundamental frequency or other sufficiently strong harmonics may be employed, provided they differ in frequency from the incoming signaling energy by a readily amplifiable intermediate frequency which it is desired to produce.

For the purposes of illustration the feed-back circuit arrangement including the coil 13 associated with the tuned circuit 14, 15 is shown on the high potential side of the grid-filament circuit, but in practice it has been found that better results are obtained if the tuned circuit 14, 15 is inserted on the lower potential side or filament side of the input circuit. The feed-back coil 13 is then associated with the circuit so as to produce the desired fundamental frequency.

The output or plate circuit of the tube 16 of the self heterodyne system is associated with the input or grid circuit of the high frequency repeater-amplifier tube 6 by means of a transformer coupling arrangement 8, 9 which may be tuned by condensers 7, 10 respectively, as described hereinafter. The output circuit of the tube 6 is then connected by means of an intermediate frequency transformer 18, 19 to a detector tube 20 wherein the intermediate frequency oscillations are detected and subsequently indicated in the telephone receivers 21 or other indicating device. Of course, it will be understood that additional steps of intermediate frequency amplification may be obtained by inserting a properly designed amplifier between the self-heterodyne system and the detecting and indicating device.

The adjustment of the transformers 11, 12 and 8, 9 and of the tuning condensers 7, 10 are of the greatest importance to produce the desired reaction of the intermediate frequency oscillations on the self heterodyne converting system to increase the efficiency with which the conversion takes place. The design of transformer 11, 12 should preferably be such that when the regenerative or feed-back coupling 13, 14 of the tube 16 is loosened so that no oscillations are generated therein the vacuum tube 6 will produce oscillations. When, however, the tube 16 is producing oscillations of the frequency to which the circuit 14, 15 is tuned, then the damping introduced thereby should be sufficient to prevent the high frequency circuits of the tube 6 from oscillating at their natural period. The transformer 8, 9 should have a step-up ratio and a variable coupling so that it is capable of being sharply tuned to the desired intermediate frequency.

The theory of operation of this system is as follows: Incoming high frequency oscillations are repeated and amplified by the tube 6 and impressed thru the transformer 11, 12 on the frequency converting or transforming system including the tube 16 wherein they are combined with the multiple value or suitable harmonic of the fundamental frequency oscillations determined by the circuit 14, 15. The combined energy is then converted by the self heterodyne system to produce the desired intermediate frequency oscillations. The intermediate frequency oscillations are then supplied thru the transformer connection 8, 9 to the input circuit of the tube 6, amplified by this tube and subsequently impressed upon the detecting and indicating system which includes the tube 20. By suitably adjusting the polarity of the transformer 8, 9, by adjustment of condensers 7 and 10 and by adjusting the coupling between the primary and secondary 8, 9, respectively, the intermediate frequency oscillations are caused to react on the oscillating tube 16 to greatly increase the efficiency of conversion and consequently the response in the indicating device or telephones. This adjustment may be made by reversing the secondary 8 and by varying the value of the secondary condenser 7. The proper point of adjustment may be readily determined by gradually increasing the coupling between the primary and sec-

ondary 8, 9, comprising the transformer, until oscillation of the complete system occurs due to a too violent reaction.

The arrangement shown in Figure 2 is substantially the same as that illustrated in Figure 1 except that a difficulty encountered in practice with such arrangement as that shown in Figure 1 is overcome in the following manner: In ordinary practice the most suitable intermediate radio frequency to use for the reception of radio phone broadcast signaling transmitting on a wave length range from 300 to 400 meters, is in the neighborhood of that employed by the high power long wave radio transmitting trans-Atlantic stations. When the desired intermediate frequency is produced by heterodyning the 300 meter wave length energy with the locally generated frequency, a disturbing audible beat note is sometimes produced by the combination of this intermediate frequency oscillation with the wave energy of some nearby high power station, which is picked up by the grid circuit of the tube 6 of Figure 1. The difficulty arises more frequently with single circuit or with loop tuning. In the arrangement of Figure 2 by placing the secondary circuit 30 in parallel with the input circuit of the high frequency repeater amplifier tube 31 instead of in series as shown in Figure 1, and putting the secondary tuning condenser 32 between the grid and one end of the wave energy collector or loop 33 a high pass filter arrangement is produced which overcomes all except the most severe cases of interference. In addition this circuit arrangement has the advantage of removing the loop from the high potential end of the intermediate frequency transformer so that much more stable operation of the system is produced. In all other respects the system of Figure 2 corresponds with that of Figure 1 in that a self heterodyne converting system 34 is provided and the intermediate frequency oscillations produced thereby being caused to react on the self heterodyne system after having been impressed on the high frequency repeater amplifier tube 31 by the coupling coil 35 of the transformer 35, 30; and wherein the resulting amplified intermediate radio frequency oscillations are impressed on the detecting and indicating system 35 including the tube 36 and the telephones 37 or other form of indicating device.

Where extremely bad interference of the character described above is encountered a multi-stage high pass filter 40 as illustrated in Figure 3 may be inserted in the input circuit of the high frequency repeater amplifier tube 41.

It will be understood, of course, that the processes of frequency transformation and amplification can be repeated with the system shown in the drawings as many times as desired, as explained in United States Letters Patent No. 1,342,885.

I claim:

1. A wave-signaling system comprising an antenna, a heterodyne system, a high frequency amplifier-repeater associated with said heterodyne and interposed between the antenna and the heterodyne, said amplifier-repeater comprising an electron discharge device having a cathode, an anode, and a control electrode and input and output circuits associated therewith, means including said repeater for amplifying the incoming signal wave energy, means including the heterodyne for generating local oscillations, and means for combining the incoming energy with the local oscillations and for converting the combined oscillations to produce oscillations of an intermediate frequency, a circuit connection, associated in parallel relation with the input circuit of said repeater-amplifier for impressing intermediate frequency oscillations on the repeater, means including said repeater for amplifying said intermediate frequency oscillations so impressed, means for causing said amplified intermediate frequency oscillations to react on said heterodyne whereby an increase in the efficiency of conversion is obtained, and means for detecting and indicating said amplified intermediate frequency oscillations.

2. A superheterodyne system for indirectly amplifying and receiving radio frequency electrical oscillatory energy which comprises a self heterodyne arrangement including an electron discharge device for generating a fundamental radio frequency and a second harmonic thereof, said second harmonic differing in frequency from said energy by a readily amplifiable intermediate radio frequency, means for combining said energy with said second harmonic oscillations, means including the self heterodyne arrangement for converting the combined energy by producing the said intermediate radio frequency, a second electron discharge device adapted to amplify the incoming energy, means including the said second device and a circuit associated therewith whereby the intermediate radio frequency oscillations are amplified, and means for causing the resulting amplified intermediate radio frequency oscillations to react on said self heterodyne arrangement to increase the efficiency of conversion; and means for detecting and indicating the resulting amplified intermediate radio oscillations.

3. A self heterodyne system comprising a signal wave energy collector, a self heterodyne arrangement, a high frequency repeater-amplifier associated with the self-heterodyne interposed between the said collector and the self heterodyne, means including said repeater for amplifying the incom-

ing signal wave energy, means including the self heterodyne for generating local oscillations, for combining the incoming energy with the local oscillations, and for converting the combined oscillations to produce oscillations of an intermediate frequency, means including said repeater-amplifier for amplifying said intermediate frequency oscillations and for causing the amplified intermediate frequency oscillations to react on said self heterodyne arrangement, whereby an increase in the efficiency of conversion is obtained; and means for detecting and indicating said amplified intermediate frequency oscillations.

4. The method of receiving signals which consists in amplifying the received signaling energy, mingling with the amplified energy an energy of different frequency, rectifying the mingled energy to produce energy of a beat frequency, mingling the beat-frequency energy with received signaling energy which has not yet been subjected to said first-mentioned mingling, whereby said beat-frequency energy and said received signaling energy are amplified together and apart from said amplification of said energy of different frequency, and separately detecting said beat-frequency energy.

5. In combination, a receiving circuit, a vacuum tube and circuits associated therewith to constitute a self-heterodyne, said associated circuits including a feed-back transformer, an amplifier between said receiving circuit and said self-heterodyne, and a transformer having its primary in circuit with the primary of said feed-back transformer and its secondary in circuit with the input of said amplifier.

6. In combination, an amplifier, a signal-receiving circuit, high-pass means for impressing energy of the signal frequency from said receiving circuit upon the input of said amplifier, means responsive to the energy delivered by said amplifier for producing currents of lower frequency than said delivered energy and reflexing means for impressing energy of said currents of lower frequency on said input, said high-pass means preventing the potential changes caused by said reflexing means from changing the potential of said receiving circuit.

7. In a radio receiving device, means for amplifying the received signal energy, heterodyning means for producing, from the amplified energy, energy of a different frequency and means for impressing the last named energy upon the amplifying means.

8. In a radio receiving device, means for amplifying the received signal energy, heterodyning means for producing, from the amplified energy, energy of a different frequency and means for impressing the last named energy upon the amplifying means, said impressing means being connected to act in a sense opposite to ordinary regeneration.

In testimony whereof I affix my signature.

EDWIN H. ARMSTRONG.