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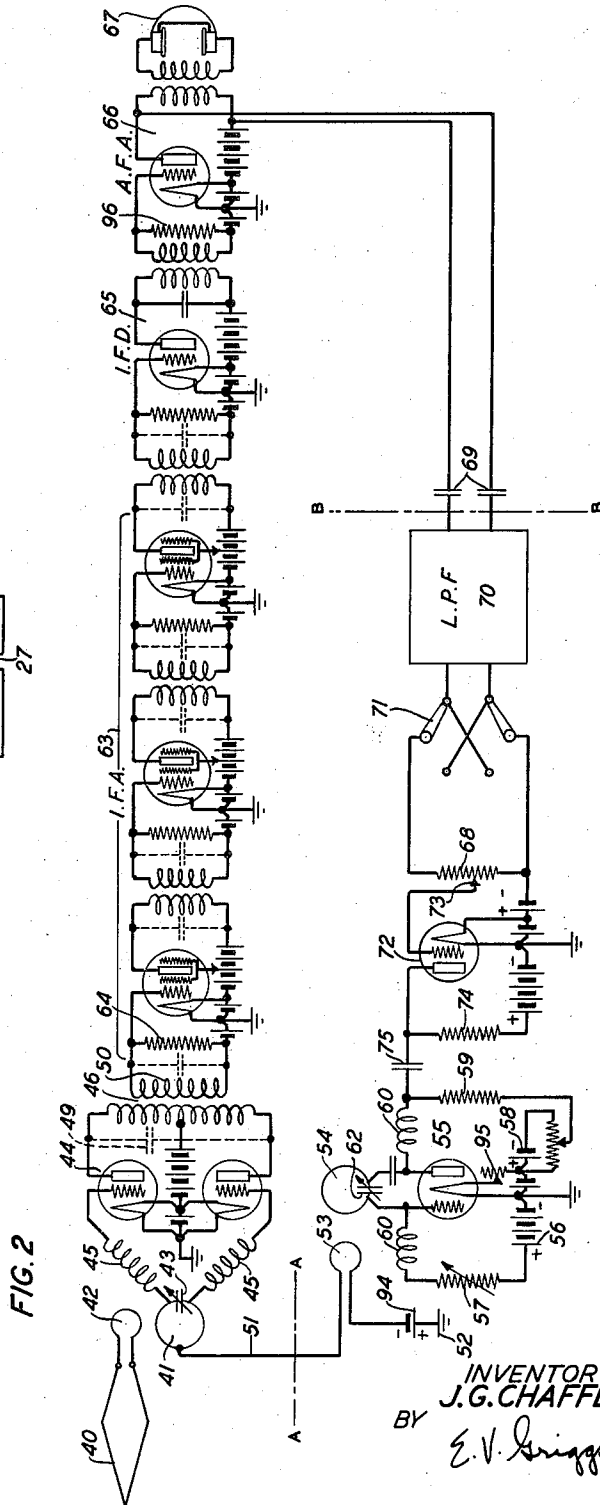
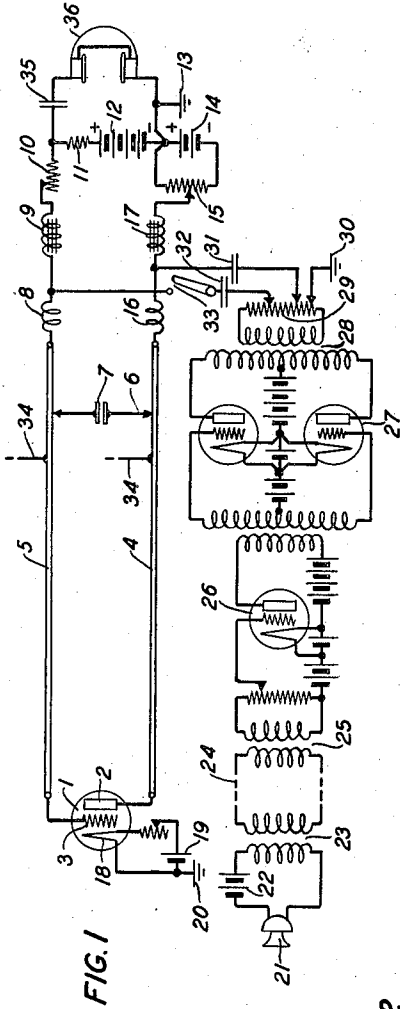
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2,141,376

FREQUENCY REGULATION OF OSCILLATORS IN ULTRA SHORT WAVE RECEIVERS

Filed Oct. 10, 1935

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FIG. 3

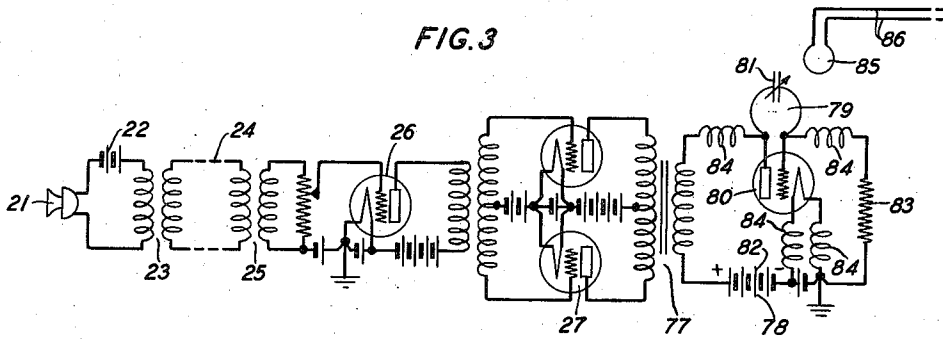
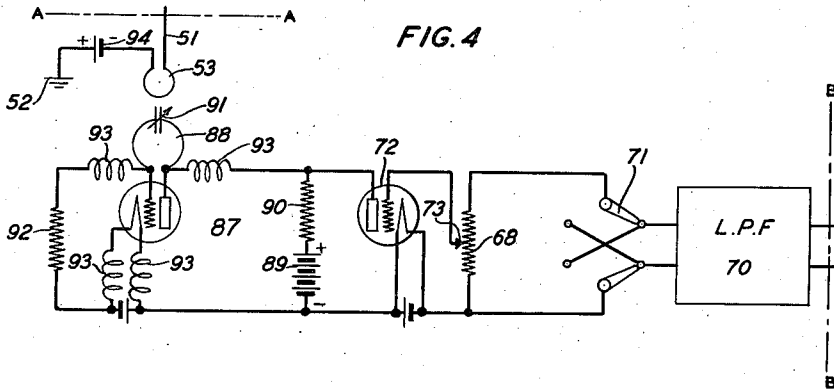


FIG. 4



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FREQUENCY REGULATION OF OSCILLATORS
IN ULTRA SHORT WAVE RECEIVERSJoseph G. Chaffee, Hackensack, N. J., assignor to
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Application October 10, 1935, Serial No. 44,322

10 Claims. (Cl. 250-6)

This invention relates to transmission of signals by ultra-short waves and more particularly to frequency regulation of oscillators in ultra-short wave receivers.

5 An object of the invention is to enable the frequency of the oscillator of an ultra-short wave receiving system to be regulated so as to bear a definite relation to the frequency of incoming ultra-short carrier waves.

10 Transmission of signals and control currents at ultra-short wave frequencies may be effected by amplitude modulation of an ultra-short carrier wave in accordance with signals or control currents or both. The reception of such amplitude modulated ultra-short waves may be accomplished by the superheterodyne method in which the incoming carrier frequency is stepped down to a so-called intermediate frequency which may be effectively amplified by amplifiers of well-known type.

Intermediate frequency amplifiers may readily be given a relatively flat transmission characteristic for waves within a limited frequency range. If, however, the range of frequencies which they must transmit becomes very large, it is difficult to design them so as to have a sufficiently uniform transmission throughout their range and they are likely to introduce undesired distortions in the incoming waves. Even if it be possible to secure a relatively uniform transmission, the cost is excessive, since the amplification obtainable per stage will be low, and, moreover, the over-all selectivity of the system is decreased since that depends primarily upon the band width of the intermediate frequency amplifier. At ultra-short carrier wave frequencies, Barkhausen oscillators are frequently used for carrier wave production. As is well known, amplitude modulation employing Barkhausen oscillators generally is attended with an undesired carrier frequency shift or carrier wave modulation. It is possible to reduce this by devices such as that described in my application, Serial No. 702,443, filed December 15, 1933, Patent No. 2,038,992, dated April 28, 1936, but even under optimum conditions there is likely to be a residual undesired carrier frequency shift. This same problem is encountered also in cases where the more conventional feed-back oscillators are used at very high frequencies since these, too, are susceptible of carrier frequency variation under the influence of the varying potentials imposed by the modulating signals. As a result, amplitude modulation of these devices when operated at wave-lengths less than a few

meters is usually accompanied by a certain amount of frequency modulation. If this reaches the point where the intermediate frequency signal in the receiver is caused to vary to such an extent that it may at times fall outside of the transmission band of the intermediate frequency amplifier, severe distortion of the detected signal currents will result. Thus, the degree of amplitude modulation which can be imposed upon the transmitter may be very definitely limited by the width of the band of uniform transmission of the intermediate frequency amplifier.

In accordance with the invention, the shift in carrier frequency which transpires at the transmitting station as a function of the applied modulating signal electromotive forces is compensated for at the receiving station by subjecting the receiving station oscillator to signal frequency electromotive forces derived from the demodulated incoming waves in such manner that the frequency of the receiving station oscillator tends to rise or fall with that of the incoming waves and thus to maintain a fixed relation between the two frequencies.

In the drawings,

Fig. 1 discloses a transmitter for producing ultra-short waves which are amplitude modulated in accordance with signals;

Fig. 2 discloses a superheterodyne receiving system for receiving signals from the remote transmitting system of Fig. 1;

Fig. 3 discloses a modified transmitting system employing an oscillator of the feed-back type; and

Fig. 4 discloses a modification of the receiving system of Fig. 2.

The transmitter of Fig. 1, as illustrated, corresponds to one modification of the transmitter of application Serial No. 702,443, filed December 15, 1933, Patent No. 2,038,992, dated April 28, 1936. It involves a Barkhausen or retarded field type oscillator including an electron discharge device 1, the anode 2 and grid 3 of which are respectively connected to the two Lecher conductors 4 and 5 with which a sliding tuner 6 including a very large capacity short-circuiting element 7 is associated to tune the Lecher circuit. High positive polarizing potential is applied to the grid 3 over conductor 5, high frequency choke coil 8, speech frequency choke 9, variable resistance 10 and fixed resistance 11 from source 12, the negative terminal of which is connected to ground at 13. Anode 2 is polarized at a potential in the proximity of the cathode and in this instance slightly negatively with respect

thereto by source 14 and its associated potentiometer 15 over a path comprising conductor 4, high frequency choke coil 16, speech frequency choke coil 17 and the potentiometer 15 and source 14 to ground 13. Cathode 18 is heated by a source 19 in a circuit connected to ground at 20. Speech sounds or other signals impressed on the microphone 21 produce corresponding electric signal currents in the circuit of its local source 22. The energy of these currents is transferred by the transformer 23, line 24 and transformer 25 to the input circuit of speech frequency amplifier 26. These currents are further amplified by a balanced or push-pull amplifier 27 and impressed by transformer 28 upon potentiometer element 29 which is connected by a variable tap to ground at 30. An additional variable tap provides a path by way of large capacity blocking condenser 31 to a point in the anode circuit between choke coils 16 and 17. Accordingly, speech current electromotive forces are superimposed upon the anode 2 over the path extending from ground 30, potentiometer 29, capacity element 31, high frequency choke 16 and conductor 4. Inasmuch as the amplitude of the oscillations of a Barkhausen or retarded field type oscillator is dependent upon the anode potential the ultra-short wave oscillations produced by the oscillator will be modulated in amplitude in accordance with speech. In order to prevent undesired variation in the frequency of the oscillations produced by the Barkhausen oscillator when speech frequency electromotive forces are impressed upon its anode, means are provided for simultaneously impressing electromotive forces from the same source of speech current upon the grid 3 of the Barkhausen oscillator. As is explained in detail in application Serial No. 702,443, filed December 15, 1933, Patent No. 2,038,992, dated April 23, 1936, the effects of superimposed potentials on the grid and anode of a Barkhausen oscillator are opposite with respect to the change which they produce in the frequency of the oscillations. It is accordingly possible to so adjust the potentiometer taps over which the speech frequency electromotive forces are applied to the anode and grid to cause the resulting frequency variations to be substantially annulled. Accordingly, the modulating system illustrated in Fig. 1 serves to produce signal modulated oscillations and to impress them upon transmitting antennas or the high frequency line connected to the conductors 34 leading from the Lecher circuit.

A blocking condenser 32 and a switch 33 are provided in the path between the potentiometer 29 and the grid 3. The blocking condenser 32, like condenser 31, serves to isolate the uni-directional polarizing paths and the grid and anode from ground. The switch 33 permits the grid modulating circuit to be disconnected when not required.

Condenser 35 and monitoring receiver 36 connected in a path in parallel to resistance 11 and source 12 serve for monitoring purposes. Although the choke coils 9 and 17 are, of course, not of infinite impedance for audio frequency currents, they do prevent the production of sounds in the receiver 36 by the electromotive forces produced from the potentiometer 29 in the absence of production of ultra-short wave oscillations. In other words, speech frequency electromotive forces applied from the potentiometer 29 undergo sufficient attenuation by the audio frequency choke coils 9 and 17 to prevent appreciable audio frequency electromotive forces

from being impressed upon receiver 36. When ultra-short wave oscillations are produced and modulated, the audio frequency variations in the grid current which result from modulation are very much higher than any speech frequency currents coming directly from the potentiometer 29. During the modulation, the total audio frequency energy is sufficiently high so that even though an extremely small portion of it is diverted to the receiver 36, it is sufficient to actuate the receiver and to give the necessary indication of the quality and the quantity of the modulation.

Although the circuit of Fig. 1 has been described as operating in response to speech currents, it will readily be appreciated that transmitter 21 and source 22 may be replaced by any other source of electric signaling currents.

In Fig. 2, a receiving antenna 40 of rhombic or any other well-known form may be employed. In the case of a conductive circuit between the transmitting and receiving stations, the antenna 40 would be replaced by the incoming portion of the transmitting conductor. Antenna 40 is coupled to tuned input circuit 41 by a coupling coil 42. The input circuit includes a variable tuning condenser 43 to the terminals of which are connected the input terminals of balanced or push-pull radio frequency detector 44 by paths including ultra-short wave reactors 45 which serve as impedance transformers to effectively increase the input impedance of the radio frequency detector as viewed from the terminals of the capacity element 43. The function of the impedance transformers in bringing the radio frequency detector input impedance up to a magnitude suitable to connect to the tuned circuit is more fully disclosed and is claimed in my pending application Serial No. 44,321, filed October 10, 1935, Patent No. 2,097,514, dated November 2, 1937.

The output circuit of the radio frequency detector 44 comprises the input winding of intermediate frequency transformer 46. The primary winding of transformer 46 is self-tuned as indicated by the capacity shown in dotted lines at 49 so that in conjunction with the similarly tuned input circuit including loosely coupled secondary winding 50 and terminating resistance 64, it forms a broad band pass intermediate frequency filter which offers substantially uniform attenuation to currents of all frequencies within its pass band. A path 51 connected to a central point on the tuning inductance of input circuit 41 extends to ground at 52 by way of a source 94 for negatively polarizing the grids of the tubes of detector 44 and the secondary winding 53 of a coupling transformer, the primary winding of which forms a portion of the tuned circuit 54 of a local oscillator 55, also of the Barkhausen type. Oscillator 55 comprises an electron discharge device having a grid positively polarized by source 56 over a path including variable resistance 57. The anode of oscillator 55 is negatively polarized by source 58 over a path including resistance 59 and a radio frequency choke coil 60. The tuning of circuit 54 is susceptible of variation by means of variable capacity 62 and by proper choice of sources 56 and 58 and adjustment of resistances 57 and 95, the latter of which serves to adjust the cathode heating current to the proper value. It is so adjusted that the oscillations produced by the local oscillator 55 will differ from the frequency of the incoming ultra-short waves by the desired intermediate frequency. For example, in an apparatus in which the frequency of the in-

coming ultra-short waves is approximately 500 megacycles, the local oscillator may be tuned to approximately 495 megacycles or 505 megacycles to produce an intermediate frequency of approximately 5000 kilocycles. An intermediate frequency amplifier 63, as shown, consists of three stages of screened grid amplifying devices having input and output circuits tuned as described in connection with the windings of transformer 46. In each instance the secondary winding of the coupling transformer is shunted by a resistance element 64 to assist in well-known manner in obtaining the desired broad band pass characteristic. The final stage of the intermediate frequency amplifier is coupled to the similarly tuned input circuit of intermediate frequency detector 65 to the output circuit of which is coupled an audio frequency amplifier 66. A terminating resistance 96 is connected across the input terminals of audio frequency amplifier 66 to prevent possible phase shift which might otherwise occur through the amplifier input transformer. Telephone receiver 67 which may be a loud-speaker or any other signal indicating device is coupled to the output circuit of the audio frequency amplifier.

In accordance with the well-known superheterodyne method of operation, source 55 will supply locally produced oscillations to the path 51. The incoming ultra-short wave oscillations received by antenna 40 and impressed on input circuit 41 will be combined with the local oscillations from source 55 in radio frequency detector 44 to produce intermediate frequency currents which, after amplification by intermediate frequency amplifier 63, are demodulated by intermediate frequency demodulator 65 and produce audio frequency signal currents which are amplified by amplifier 66 and indicated by device 67.

As was explained in connection with the operation of Fig. 1, the frequency of the transmitted carrier wave is subject to undesirable variations as a result of the modulating action. Even with the compensating apparatus of Fig. 1, it is, in general, not practicable to entirely eliminate the undesired frequency shift. Accordingly, the amount of amplitude modulation which can be utilized may be limited by the concomitant carrier frequency shift if it reaches such a point that the excursions in carrier frequency carry the received signal outside of the transmission band of the receiver. It has been found that there is a close proportionality between frequency and amplitude modulation at the transmitting station. Accordingly, since the frequency modulation at the transmitter is occasioned by the modulating signal, it is possible to impress a portion of the demodulated signal at the receiving station on the anode circuit of the local Barkhausen oscillator to cause variations in the frequency of the locally produced oscillations of a magnitude approximating that produced in the ultra-short carrier wave at the transmitting station. In order to accomplish this result a potentiometer resistance 68 is connected through a path including very large capacity blocking condensers 69, a low pass filter 70 and a reversing switch 71 across the output terminals of audio frequency amplifier 66. Speech current amplifier 72 has its input circuit connected by a variable tap 73 to potentiometer resistance 68. The output circuit of amplifier 72 includes a resistance 74 which serves with series capacity element 75 to couple the output of amplifier 72 to the resist-

ance 59 in the space current path of oscillator 55. It follows that speech current variations are superposed on the anode circuit of local oscillator 55. Accordingly, as the speech modulation currents at the transmitter cause the incoming ultra-short carrier wave to vary in frequency, the corresponding demodulated speech currents at the receiver cause the frequency of the local oscillator to vary in a similar manner and to a like extent. The intermediate frequency oscillations produced by the radio frequency detector 44 and corresponding to the difference between the frequencies of the incoming oscillations and the local oscillations will therefore remain at an approximately constant intermediate frequency.

The reversing switch 71 is provided to enable the demodulated speech current electromotive forces to be impressed upon the anode of the local oscillator 55 in such phase as to insure that the variations in frequency of the local oscillator 55 take place in the same direction as the variations of the incoming carrier frequency. Should the tuning of the local oscillator be changed to reverse the order of the incoming and local oscillation frequencies, it will be necessary to operate reversing switch 71 to reverse the phase of the audio frequency electromotive force applied to the anode of source 55. The resistance coupling serves to prevent the possibility of phase shifts between the receiver output and the point at which modulating voltages are applied to the local oscillator 55. The purpose of the low pass filter 70 is to prevent possible intermediate frequency feedback to the oscillator 55 and consequent singing. Filter 70 should, therefore, have an upper cut-off frequency somewhat higher than the highest modulating frequencies.

On account of the difference in the frequencies of the incoming carrier wave and the local oscillations, it may not be possible to obtain perfect compensation for a given amount of feed-back except at one modulating amplitude. There will, accordingly, be a residual frequency shift for other amplitudes. However, due to the fact that the intermediate frequency amplifier has a relatively wide transmission band width, it is merely necessary to reduce the apparent frequency modulation of the intermediate frequency oscillations to a point where the band width of the intermediate frequency amplifier is not exceeded by the residual frequency excursion of the intermediate frequency oscillations.

Fig. 3 shows an alternative form of transmitting circuit which differs from that of Fig. 1 principally in that an oscillator of the feed-back type is used in lieu of the Barkhausen oscillator of Fig. 1. Similar portions of this circuit are designated by the same reference characters as in Fig. 1. The output circuit of the balanced amplifier 27 is connected by means of an audio frequency transformer 77 with the anode circuit of oscillator 78. As shown, the oscillator comprises a loop circuit 79 connected between the anode and grid of vacuum tube 80 and including a variable tuning condenser 81. The source of plate current 82 is connected between the cathode and anode through the secondary winding of transformer 77. The grid and cathode are connected through a grid leak resistance 83. Radio frequency choke coils 84 are provided in the grid and anode circuit and in each of the leads of the cathode heating circuit. Inductively associated with the loop circuit 79 is a secondary loop or coupler 85 to the terminals of which are connected the conductors 86 of a transmission line 75

which may lead to a remote receiving station or to an antenna. The oscillator 78, accordingly, serves to produce ultra-high frequency oscillations of a frequency determined substantially by the tuning of loop circuit 79. These ultra-high frequency oscillations are modulated in accordance with the modulating electromotive forces impressed on the anode circuit of the oscillator by the secondary winding of transformer 77 and are supplied by the oscillator to the coupler 85 and transmission circuit 86. It should be understood that this transmitter may be used in lieu of that illustrated in Fig. 1 to transmit ultra-short waves modulated in accordance with speech or other signals.

Fig. 4 illustrates a modification of that portion of the circuit of Fig. 2 between the lines A—A and B—B according to which the Barkhausen type oscillator of Fig. 2 is replaced by an oscillator of the feed-back type. Corresponding elements are designated as in Fig. 2, and accordingly, require no further description. A local oscillator 87 comprises a loop circuit 88 coupled to the coupling member 53 of path 51 whereby locally-produced oscillations may be impressed on the radio frequency detector 44 to interact with incoming ultra-short waves. The oscillator 87 is supplied with space current from a source 89 in series with coupling resistance 90 in a path common to the space current circuits of the oscillator and of the modulating signal frequency amplifier 72. Variable capacity element 91 in the tuned circuit enables adjustment of the tuning of the local oscillator to produce the desired intermediate frequency. The grid-cathode circuit of the oscillator is provided with a leak path by way of high resistance 92 and the two leads of the cathode heating circuit which include radio frequency choke coils 93. With this circuit operating at very high frequencies it is possible to produce considerable changes in the frequency of the local oscillator in accordance with the amplitude of the demodulated signal currents. These frequency changes are accompanied by a certain amount of amplitude change but this will produce only a slight regenerative or degenerative effect upon the resulting signal output, depending upon whether the amplitude modulation of the local oscillator 87 is in the same or opposite sense to that produced at the transmitter. The condition which obtains will depend upon whether the local oscillator frequency is greater than or less than that of the incoming signal and also upon the position in which the reversing switch 71 in the feed-back path is placed.

It is to be understood that either the transmitter of Fig. 1 or the transmitter of Fig. 2 may be used in conjunction with either of the receiving circuits of Figs. 3 and 4. With any of the four combinations the receiving circuit will be so adjusted that the frequency of the local oscillator will experience a frequency shift under control of the demodulated signals substantially equal to the frequency shift which occurs at the remote transmitting station in the carrier frequency of the modulated oscillations transmitted therefrom.

What is claimed is:

1. In a superheterodyne receiver for receiving incoming ultra-short carrier waves having amplitude modulations corresponding to signals, a source of interacting oscillations, means for causing said interacting oscillations to undergo a frequency shift similar to that which was ex-

perienced by the incoming carrier waves at the remote transmitter station at which they originated including a demodulator for the modulated incoming carrier waves for deriving a demodulated wave of the amplitude modulation frequency therefrom, and means for applying an electromotive force corresponding in its magnitude to the magnitude of the amplitude modulations of the resulting demodulated wave to the source of interacting oscillations to cause the desired shift in oscillation frequency.

2. A superheterodyne receiver for receiving ultra-short carrier waves having amplitude modulations corresponding to signals comprising a source of interacting oscillations differing in frequency from the ultra-short carrier waves to be received by a predetermined intermediate frequency, and means for causing said interacting oscillations to shift in frequency by the same amount as the incoming carrier oscillations shift when modulated at the remote transmitter including a demodulator for the incoming carrier waves for deriving therefrom output signal waves corresponding in their frequencies to the frequencies of the amplitude modulations of the carrier waves, and means for controlling the frequency of the source of interacting oscillations in accordance with the amplitude modulations of the output waves derived from the demodulator.

3. A superheterodyne system for receiving and demodulating amplitude modulated ultra-short carrier waves comprising a local source of interacting oscillations differing in frequency from the desired received frequencies by a predetermined intermediate frequency, means for causing the received waves and local oscillations to interact to produce intermediate frequency waves, an intermediate frequency selecting device which transmits with substantially equal attenuation waves of all frequencies in a range including the intermediate frequency and the extent of which is relatively small in comparison with the received wave frequency and means for automatically controlling the frequency of the locally generated waves so as to hold constant the difference frequency between that of the incoming waves and interacting oscillations comprising means for demodulating the intermediate frequency waves to reproduce the modulation wave and means for applying to the local source an electromotive force corresponding in intensity to the reproduced amplitude modulations of the incoming wave to cause the frequency of the local source to vary in accordance with the intensity of the amplitude modulations.

4. The method of communication which comprises modulating the amplitude of an ultra-short carrier wave and transmitting the resulting modulating wave to a distant point, receiving the transmitted wave by causing it to interact with locally produced oscillations to produce intermediate frequency waves and controlling the frequency of the locally produced oscillations in accordance with the amplitude modulations of the transmitted ultra-short wave to cause the frequency of the intermediate frequency waves to remain substantially constant.

5. An ultra-short wave receiving system comprising a local oscillator, means for causing oscillations therefrom to interact with received oscillations, means for demodulating the resultant difference frequency oscillations to produce signal currents corresponding to the amplitude modulations of the incoming waves, and means for

controlling the frequency of the local oscillator in accordance with the variations of amplitude of the signal currents resulting from the demodulation.

5 6. A superheterodyne receiving system for amplitude modulated ultra-short waves comprising a local source of oscillations of the retarded field type, a radio frequency demodulator, an intermediate frequency amplifier and an intermediate frequency demodulator for deriving from intermediate frequency waves audio frequency electromotive forces corresponding at all times in their frequencies to the amplitude modulation frequencies of the received amplitude modulated
10 ultra-short waves connected in sequence in the order named, the local source having a cathode, a grid polarized highly positively with respect thereto and an anode polarized slightly negatively thereto, and means for impressing audio frequency electromotive forces derived from the output circuit of the intermediate frequency demodulator upon the anode of the local source.

7. A receiving system for amplitude modulated high frequency waves comprising a circuit upon which received modulated high frequency waves
25 may be impressed, a local oscillator connected to the circuit, means for causing the received high frequency waves and oscillations produced by the local oscillator to interact, means for deriving from the resultant interaction a controlling wave having the same frequencies as the waves by which the received high frequency waves are modulated and amplitude variations corresponding to the amplitude modulations of the received
30 high frequency waves, and means for controlling the frequency of the oscillations produced by the local oscillator in accordance with the instantaneous amplitude of the derived controlling wave.

8. The method of receiving amplitude modulated high frequency waves which comprises combining therewith locally generated oscillations, deriving from the resultant controlling waves having the same frequencies as the amplitude modulations of the received high frequency waves and amplitude variations corre-
40
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sponding to the amplitude modulations of the received high frequency waves, and controlling the frequency of the locally generated oscillations in accordance with the instantaneous amplitude of the derived controlling wave.

9. A receiving station for receiving amplitude modulated oscillations transmitted from a remote transmitting station, said receiving station including a beating oscillator, means for causing the received amplitude modulated oscillations and oscillations from the beating oscillator to interact, means for demodulating the resulting oscillations to reproduce the amplitude modulations corresponding to the transmitted signals, and means responsive to and controlled by the amplitude modulations of the demodulated signals for causing the beating oscillator to undergo frequency variations substantially equal to the variations in frequency of the transmitted oscillations.

10. In combination, a transmitting station comprising a retarded field type oscillator, means for modulating the amplitude of the oscillations produced thereby and means for counteracting the tendency of the modulating operation to produce frequency modulation of the oscillations, a receiving station, means for transmitting the modulated energy from the transmitting station to the receiving station, said receiving station comprising a beating oscillator also of the retarded field type, a combining device, means for impressing incoming amplitude modulated oscillations together with oscillations from the local beating oscillator upon the combining device, means for demodulating the resulting oscillations derived from the combining device, and means under the control of the demodulated waves for regulating the frequency of the beating oscillator to cause it to vary in consonance with the frequency variations which the transmitting oscillator undergoes during modulation in such manner as to maintain the frequency difference of the two oscillators substantially constant.

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