

March 17, 1931.

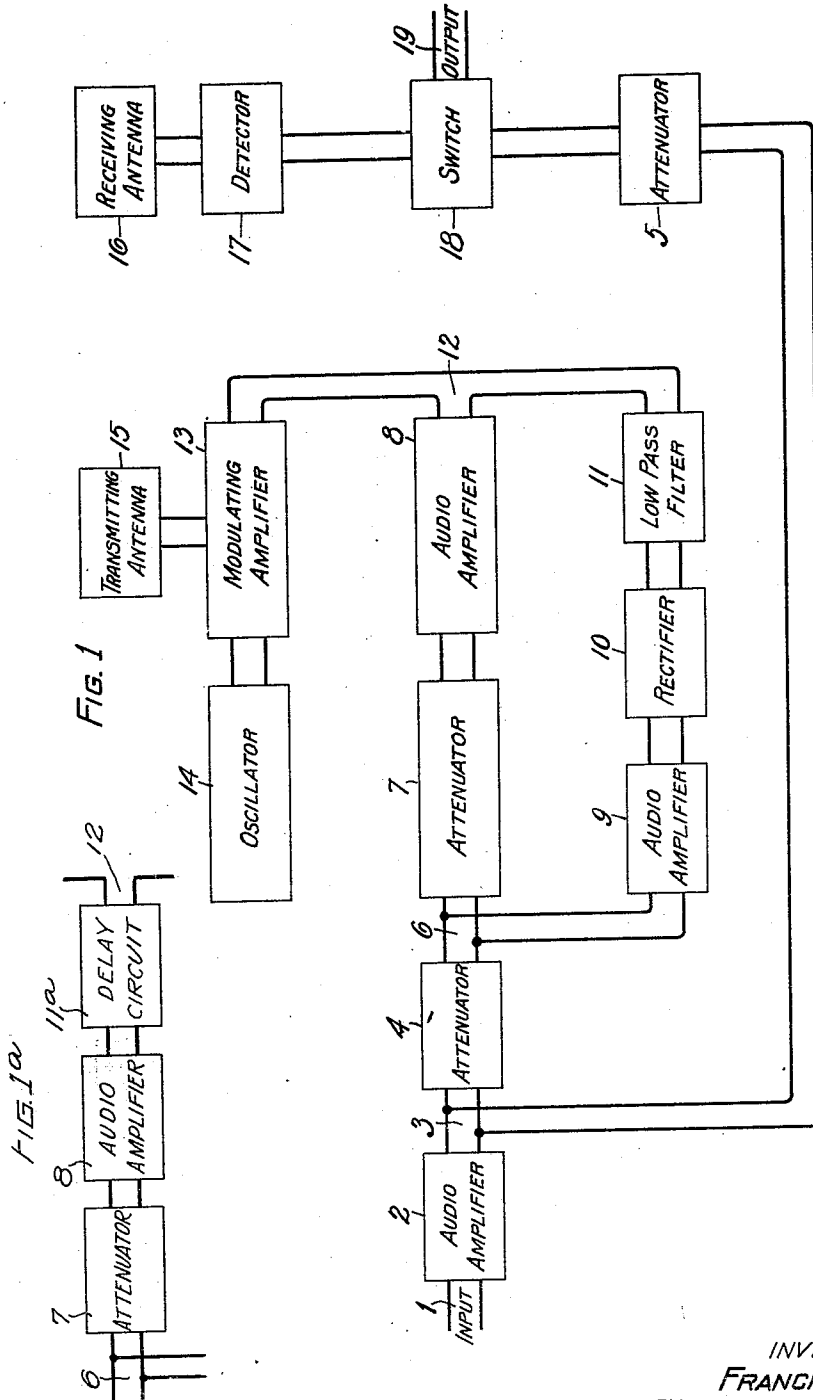
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1,796,965

METHOD OF AND MEANS FOR SIGNALING

Filed Oct. 19, 1928

3 Sheets-Sheet 1



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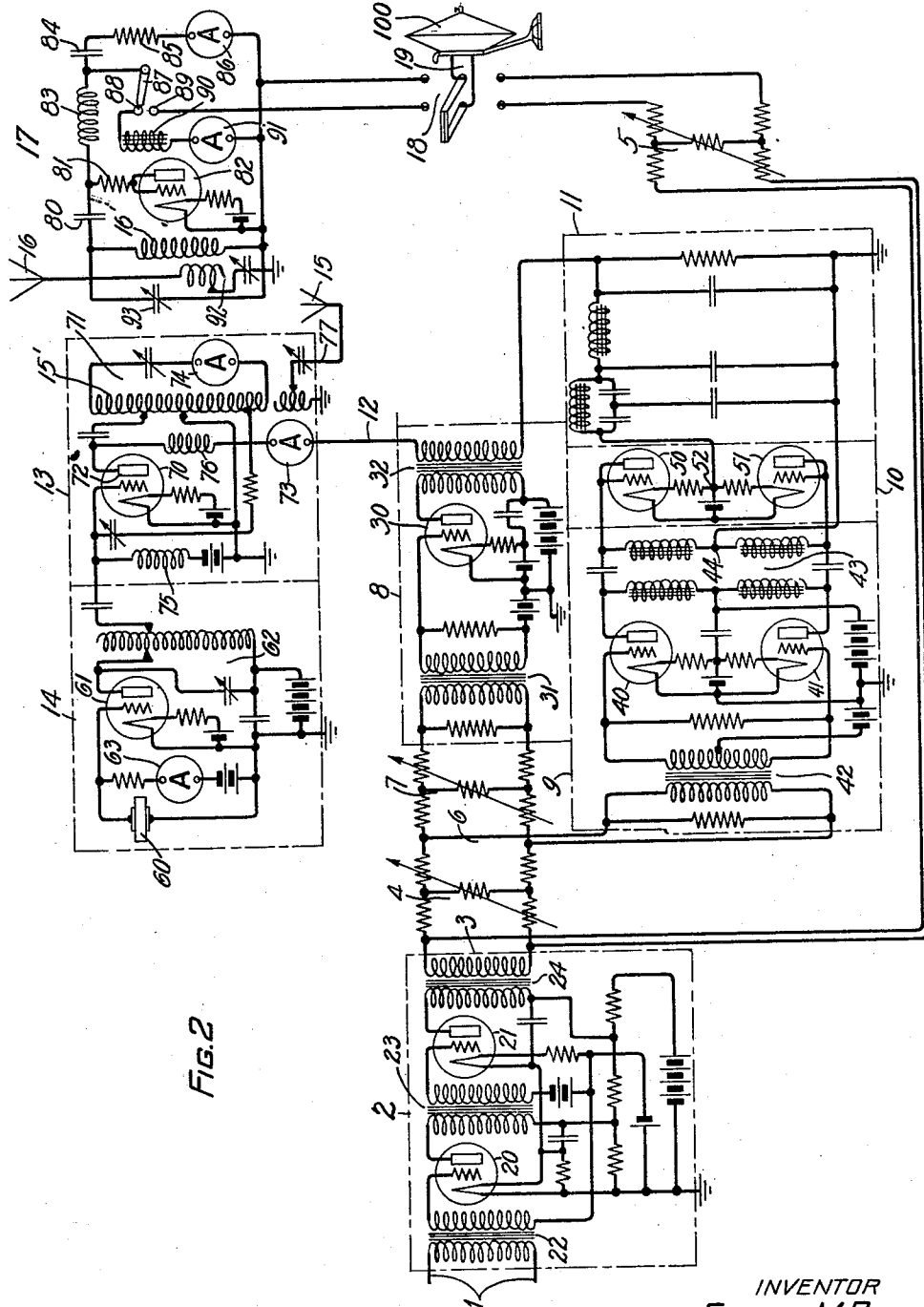
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METHOD OF AND MEANS FOR SIGNALING

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3 Sheets-Sheet 2



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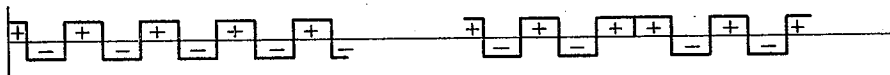
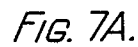
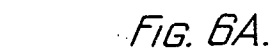
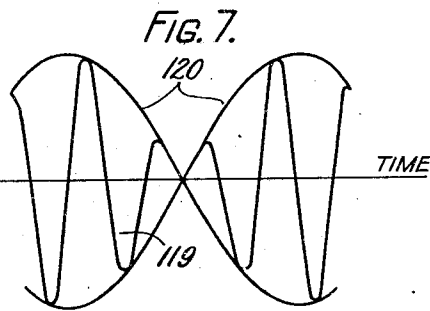
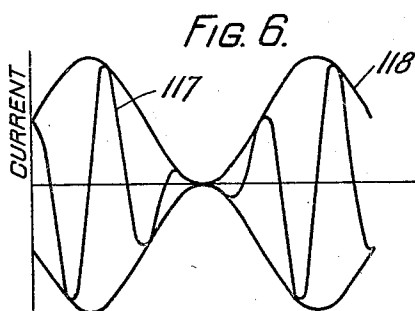
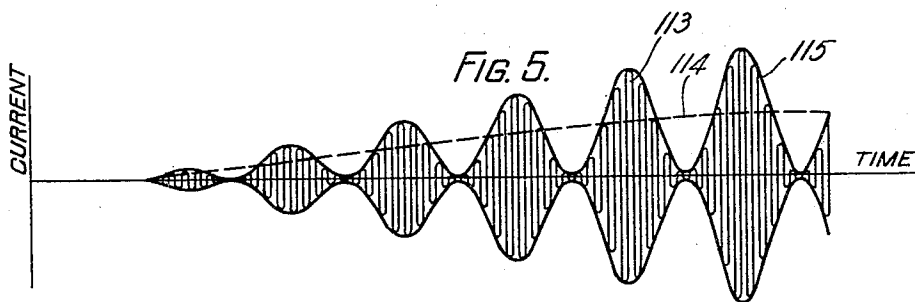
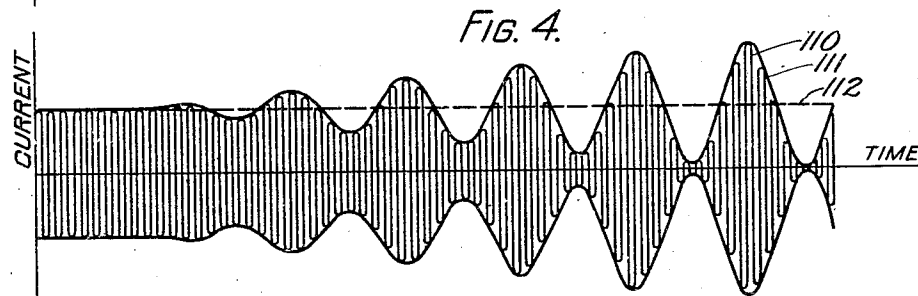
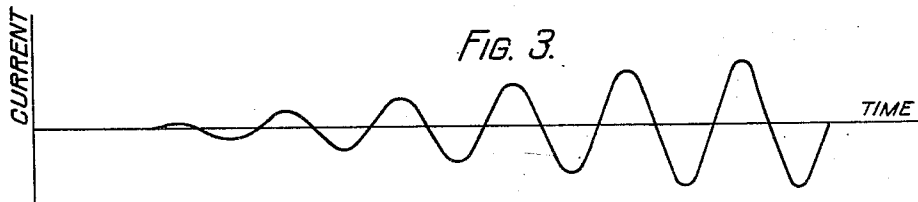
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METHOD OF AND MEANS FOR SIGNALING

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3 Sheets-Sheet 3



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METHOD OF AND MEANS FOR SIGNALING

Application filed October 19, 1923. Serial No. 313,394.

The invention relates to a method of and means for signaling, wherein there is employed a modulated carrier wave having side bands for transmitting signals and having a carrier frequency component the amplitude of which varies as a function of the signal or modulating wave. The signals may comprise speech, music, or other subject matter.

Heretofore, in general, the amplitude of the carrier frequency component of a modulated wave has been independent of the modulating wave. In some cases, it has been proposed to produce a modulated wave having a carrier component which varies as a function of the modulating wave, but the method of producing the wave has resulted in its being seriously distorted.

In one system which has been proposed, a carrier wave is applied to the input circuit of a three-electrode space discharge device, the control electrode or grid of which is supplied with a negative biasing potential of such value as to reduce the anode current substantially to zero. If then, a signal wave is impressed upon the input circuit of the device, the positive loops of the wave partially offset the negative biasing potential and permit pulses of anode current to flow, thereby generating a modulated wave in the output circuit.

In this and similar systems the signal wave is effectively subjected to rectification and the rectified wave, instead of the true signal wave, is used to modulate the carrier wave, with resultant serious distortion of the received signals.

In another system which has been proposed, an auxiliary wave having the shape of the envelope of the signal wave is derived from the signal wave by rectification and filtering. The auxiliary wave, which is non-alternating and fluctuating in value, is substituted for a constant plate current supply in a modulator of the type disclosed in U. S. Patent No. 1,442,147, January 16, 1923, to R. A. Heising and commonly known as a Heising constant current modulator. The signal wave is in effect, modulated by the envelope wave and the resultant wave is used to modulate the carrier wave, thereby distorting the mod-

ulated wave and making serious distortion of the received signal unavoidable.

In accordance with the present invention, however, a portion, only, of the signal wave is rectified and passed through a filter which eliminates ripples, to thereby produce an auxiliary wave, having the shape of the envelope of the signal. An unmodified portion of the signal wave is combined, additively and without intermodulation, with the auxiliary wave, to produce a fluctuating, non-alternating combined wave having zero value during intervals between signal pulses and also at negative peaks of each cycle of the signal wave. The combined wave is used to control the amplitude of a carrier wave, thereby producing a modulated wave which may be detected without material distortion and which has a carrier component that varies as a function of the modulating wave.

An object of the invention is to produce a modulated wave including a carrier frequency component which varies in amplitude as a function of the modulating wave and which is eliminated during all intervals between pulses in the modulating wave.

Another object is to produce in a modulated wave, a fluctuating carrier frequency component which may be used to effect detection of the wave at the receiving station.

Still another object of the invention is to generate a modulated wave the degree of modulation of which is at all times complete, regardless of the amplitude of the modulating wave, without introducing into the modulated wave any material distortion, particularly any distortion which is not readily removed by well known methods.

A feature of the invention is a reduction of noise and interference associated with the reproduced signal, especially during periods of silence or of comparatively faint signals.

The expression "amplitude of the carrier frequency component of a modulated wave" is used herein to mean the average amplitude of the modulated wave taken over a period of time considerably greater than the periodic time of the audio frequency or signal variations by means of which the wave was modulated. The amplitude of the carrier fre-

quency component of a modulated wave may be measured by the current which the modulated wave will produce when applied to a sharply resonant system tuned to the carrier frequency.

The term "modulation" in its broadest sense may include any variation whatever in the amplitude of the carrier wave. Ordinarily, however, the term is restricted to mean variations in the amplitude of the carrier wave in accordance with the essential characteristics of the signal wave, and this common meaning will be implied herein.

The expression "variable amplitude of carrier frequency component" will be used to designate such variations in the amplitude of the carrier frequency component as occur more slowly than the slowest essential variations in the signal wave.

The invention is hereinafter more fully described with reference to the accompanying drawings in which,

Fig. 1 discloses in a schematic manner an arrangement of elements which may be used in practicing the invention,

Fig. 1A is a modification of a portion of Fig. 1,

Fig. 2 discloses in detail a specific embodiment of a system such as is shown schematically in Fig. 1,

Fig. 3 is a graphical representation of a signal wave of a form adapted to illustrate the essential features of the invention.

Figs. 4 and 5 represent carrier waves of constant and variable amplitude, respectively, each modulated by the signal wave of Fig. 3,

Fig. 6 discloses in detail a portion of a modulated wave similar to the one illustrated in Fig. 5,

Fig. 7 is a detailed representation of a portion of a modulated wave in which the carrier component has been suppressed, and

Figs. 6A and 7A are graphical devices for illustrating an essential difference between the waves illustrated in Figs. 6 and 7 respectively.

Referring to Fig. 1, a signal wave representing speech, music or other subject matter, may be applied to the input circuit 1 of an audio-frequency amplifier 2 and amplified therein. The energy of the amplified wave may be divided into two portions at a branch point 3. One portion is applied to an attenuator 4 for amplitude adjustment in connection with the transmission of signals, and the other portion is applied to another attenuator 5 for amplitude adjustment if it is desired to test the faithfulness of reproduction provided by the system or otherwise monitor upon or observe the operation of the system in a manner to be described hereinafter.

The energy output from attenuator 4 is divided into two parts at a second branch point 6. One part is applied to an attenuator

7 and to an audio-frequency amplifier 8 connected in tandem thereto for further adjustment of the amplitude of the signal wave. The other part is applied to an audio-frequency amplifier 9 which is connected in tandem with a rectifier 10 and a low pass filter 11 for providing an auxiliary wave having the shape of the envelope of the signal wave.

The auxiliary wave from filter 11 and the signal wave from amplifier 8 are additively combined, without material intermodulation, in circuit 12, in order to provide a wave of fluctuating potential for controlling a modulator or modulating amplifier 13, the function of which is to control, in turn, the radiation from a transmitting antenna 15 of carrier waves supplied by an oscillator 14.

A receiving antenna 16 and a detecting circuit 17 may be employed at a second station for receiving and detecting waves radiated from the transmitting antenna 15.

A similar detector, with a receiving antenna of reduced sensitivity, may be employed at the transmitting station for monitoring or observing the operation of the system. For the latter purposes, the detector 17 may be connected by means of a switch 18 to an output circuit 19 which may be connected to a loud speaking telephone receiver or other reproducing means. The switch 18 may be operated at other times to connect the energy output from the attenuator 5 to the output circuit 19 for purposes of comparing the waves produced by detector 17 with the waves transmitted by attenuator 5.

Referring to Fig. 2, the input circuit 1 is connected to the audio-frequency amplifier 2 which comprises space discharge amplifying devices 20, 21 and coupling transformers 22, 23, 24 together with energy supply sources and auxiliary circuits for the regulation and adjustment of the amplifier, the arrangement of which may be as shown, or in any other suitable form.

As hereinbefore described, the output circuit of amplifier 2 may be divided at the branch point 3 into parallel branches leading to the attenuators 4 and 5 respectively.

Attenuators 4, 5 and 7 may each comprise five adjustable resistance elements arranged to form an H type network as shown, or any suitably adjustable network may be used.

The output circuit of the attenuator 4 is divided, at the point 6, into parallel branches leading, respectively, to the attenuator 7 and to the audio-frequency amplifier 9.

The output terminals of the attenuator 7 are connected to the input terminals of the audio-frequency amplifier 8, which amplifier may comprise a space discharge amplifying device 30 connected between input and output transformers 31 and 32, respectively. Energy supply sources and auxiliary circuits for the regulation and adjustment of the am-

plifier may be arranged in the manner shown, or in any other suitable manner.

The audio-frequency amplifier 9 may comprise space discharge devices 40 and 41 connected in push-pull relation between an input transformer 42 and an impedance coupling device or network 43. Energy supply sources and auxiliary circuits for the regulation and adjustment of the amplifier may be provided as shown, or in any suitable manner.

The rectifier 10 may comprise a pair of two-element or three-element space discharge devices 50, 51 connected for full wave rectification of waves impressed thereon by the coupling device or network 43.

The filter 11 may be a low-pass filter of any suitable type. One terminal of the filter is connected to a terminal 52 which is common to the cathodes of devices 50 and 51. The other terminal of the filter is connected to a terminal 44 which is common to the plates, the grids or other cold electrodes within the devices 50 and 51.

In order that the wave passed by filter 11 may reproduce the envelope of the signal wave as accurately as possible, the filter should be designed to pass as wide a band of frequencies as possible consistently with the requirement that it should not pass any component wave which is of high enough frequency and sufficient intensity to interfere with faithful reproduction or proper interpretation of the signal.

It is well known that a balanced or full-wave rectifier such as rectifier 10 will suppress the fundamental frequency in a wave applied thereto but will generate second and higher harmonics of the fundamental. An unbalanced, or half-wave rectifier, however, reproduces the fundamental frequency of the input wave. The use of a full-wave rectifier in the system of the invention therefore enables the cut-off frequency of filter 11, other things being equal, to be set at twice the value it could have if a half-wave rectifier were used.

It is evident that filter 11 will introduce a slight time delay into the transmission of the rectified current therethrough, thereby tending to throw the rectified wave out of synchronism with the unmodified signal wave from amplifier 8. In the transmission of ordinary speech or music this slight delay has not been found to be appreciable. In any case however, the delay may be compensated, if desired, by inserting another filter or delay circuit 11a in the branch path of the unmodified wave as shown in Fig. 1A, to freely pass said wave but to delay it by an interval of time equal to the delay encountered by the rectified wave.

The oscillator 14 may comprise a piezoelectric resonator 60 maintained in vibration by energy supplied to it by a space discharge

device 61 and may be arranged to produce forced oscillations in a resonant electrical circuit 62. An ammeter 63 is provided for indicating or measuring the conduction current passing through the grid-cathode circuit of space discharge device 61.

The modulator 13 may comprise a space discharge device 70 having an input circuit coupled to the resonant circuit 62 and a resonant output circuit 71, including a coil 15' which may be associated with a transmitting antenna 15 by means of a coupled circuit 77.

An ammeter 73 is provided for indicating the fluctuations of current in circuit 12 and a high frequency ammeter 74 is provided for indicating and measuring the radio frequency current in circuit 71.

A radio frequency choke coil 75 is provided to prevent short circuiting of radio frequency currents through the grid biasing battery associated with device 72. Another radio frequency choke coil 76 is provided to prevent short circuiting of radio frequency currents through circuit 12.

It is the usual practice in the operation of a modulator to supply the plate or anode of the device with energy from a battery or other source of direct current. In accordance with the present invention, however, the anode 72 of device 70 is supplied with energy from the fluctuating source of current comprising the secondary winding of transformer 32 and the output circuit of filter 11 connected in series with the anode 72 by means of circuit 12.

The space discharge device 70 may be provided with sources of filament heating current and grid biasing potential as shown or in any other suitable manner.

By adjusting the amplitude of the carrier wave impressed upon device 70 together with the grid biasing voltage, the device may readily be made to modulate or variably amplify the impressed carrier wave, the degree of amplification being rendered dependent on and proportional to the instantaneous potential applied to anode 72 by circuit 12, as is well known in the art.

The detector 17 is preferably designed to produce in its output circuit a wave which is a faithful reproduction of the envelope of a modulated carrier wave applied to its input circuit. For this purpose detector 17 may be designed as described and illustrated herein. Other types of detectors may be employed, but generally with less satisfactory results, due to less faithful reproduction of the envelope of the modulated wave.

The detector 17 may be associated with a receiving antenna 16 having a tuned circuit 92 for coupling the antenna to a tuned input circuit comprising a coil 16' and a variable condenser 93. When detector 17 is to be used in close proximity to the radio transmitter for the purpose of monitoring without dis-

turbing the operation of the transmitter, condenser 93 may also be adjusted to detune the input with respect to the transmitted wave, or the condenser 93 may be left out.

5 The detector circuit may also include a stopping condenser 80, a resistance 81, and a space discharge device or other rectifying means 82 together with circuits for utilizing or measuring the audio-frequency output of the detector.

10 A radio frequency choke coil 83 is provided for preventing the flow of radio frequency currents in the audio-frequency circuits. An audio-frequency circuit comprising a blocking condenser 84, a resistance 85, and an ammeter 86, is provided for measuring the alternating portion of the output current of the detector. A switch, comprising an arm 87 and contacts 88 and 89, is provided for the purpose of converting the circuit from a condition suitable for measuring the output current of the detector to a condition suitable for utilizing said current and vice versa.

15 When switch arm 87 engages contact 88, an audio-frequency circuit is completed through a choke coil 90 and an ammeter 91 for measuring the average value of the output current of the detector.

20 When switch arm 87 is moved to engage contact 89 the output current of the detector, except for a minute portion taken by the shunt path through resistance 85, is connected to the upper terminals of switch 18.

25 When the switch 18 is thrown into contact with its upper terminals the output current is led into the output or load circuit 19 where it may be utilized in any desired manner, for example, to operate a receiver or sound radiator 100. When switch 18 is thrown downward, the load circuit is disconnected from the detector 17 and connected to the output terminals of the attenuator 5.

30 Switch 18 may be of such design that it is capable of rapid operation, thereby facilitating a comparison between direct transmission from attenuator 5 and transmission through the radio system.

35 At a receiving station it will, of course, generally be inconvenient and unnecessary to make this comparison. At such stations switch 18 may be eliminated and the output of detector 17 connected permanently to the load circuit 19.

40 A suitable method of adjusting the audio-frequency circuits at the transmitting station for cooperation with modulator 13 in accordance with the invention will now be described.

45 For the purposes of initial adjustment a modulating wave of about the maximum amplitude, which it is desired to transmit over the system at any time, may be applied to the input circuit 1, and attenuator 7 may be set at a high value of attenuation sufficient to substantially prevent transmission of the modulating wave to circuit 12. The carrier

oscillator 14 should be placed in operation and the amplitude of the carrier wave, together with its frequency, adjusted in the usual manner of supplying a carrier wave to a modulator.

70 Attenuator 4 and amplifier 9 may then be adjusted until the rectified current delivered from filter 11 to circuit 12 is sufficient to produce a suitable output of carrier waves in circuit 71. This output should be the maximum which it is desired to have the system radiate when the amplitude of the modulating wave is the greatest to be employed.

75 Attenuator 7 and amplifier 8 may now be readjusted to increase the amplitude of the modulated wave transmitted to circuit 12 until the carrier wave is completely modulated.

80 With the above mentioned adjustment in effect, the modulating wave may be allowed to vary in any desired manner in accordance with speech, music or the like or other kinds of signals.

85 The amplitude of the carrier wave will be automatically varied by means of the action of the rectifier 10 and the filter 11 in proportion to the amplitude of the signal or modulating wave in such manner as to cause the carrier wave to be at all times substantially completely modulated.

90 In addition, when the amplitude of the signal wave is zero either momentarily or for a considerable period, the voltage applied to anode 72 by circuit 12 will also be zero and during such periods no carrier wave will be radiated, as may readily be observed by a fall to zero in the indication of meter 74.

95 The general form of the modulated wave produced by the system illustrated in Figs. 1 and 2 when adjusted as hereinbefore described will now be more particularly disclosed and compared with wave forms commonly employed, with reference to Figs. 3-7, 6A and 7A.

100 In Figs. 3-7, the abscissæ and ordinates represent intervals of time and values of current, respectively.

105 Fig. 3 is a graphical representation of a signal wave of sinusoidal wave form and of amplitude varying from zero up to the largest value for which the system of Figs. 1 and 2 may have been designed.

110 As a matter of convenience and in the interests of clarity of explanation, the signal wave is represented as varying in amplitude from zero to the maximum value at a uniform time rate. Such a signal wave might be supplied to the system of Figs. 1 and 2 to test the performance of the system over the whole range of signal intensities. The system is operative, of course, for any signal wave within the limits of amplitude and frequency for which the system may be designed and is in no way restricted to a signal wave of the form illustrated in Fig. 3.

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In Fig. 4 the rapidly alternating curve 110 is a graphical representation of a modulated wave of a type very extensively used. The instantaneous value of the amplitude of curve 110 is indicated by the envelope 111. In this modulated wave the amplitude of the carrier wave has been varied above and below its normal value, indicated by horizontal line 112, in accordance with the instantaneous values of the signal current of Fig. 3. In other words, the envelope 111 is a faithful copy of the signal current or wave represented in Fig. 3.

It may be noted that even when the amplitude of the signal wave is zero, a carrier wave of considerable amplitude, as represented by line 112 is generated. It may also be noted that the wave 110 is completely modulated only when the signal wave is of maximum amplitude. Therefore, when incomplete modulation occurs during modulating periods, the production and radiation of the unmodulated carrier component constitutes a waste of power. Also, the carrier wave or unmodulated component, which is not used for the actual transmission of the signals and is radiated may be combined at a receiving station with other similar carrier waves, modulated or unmodulated, or with waves caused by "static" or atmospheric disturbances, to produce beat notes, or other disturbing sounds, noises, or effects in the receiving device. These effects are, in the nature of the case, present at the time when the disturbance therefrom is most noticeable, for when the signal wave is of zero amplitude signaling is suspended, and the signal cannot in any way over-ride, mask, or drown out the disturbing effects.

In Fig. 5, the rapidly alternating curve 113 represents a wave, modulated in accordance with the present invention, having sidebands and having a variable amplitude of carrier frequency component. The broken line 114 represents the envelope of the signal wave of Fig. 3. The slowly fluctuating curve 115 represents the sum of the signal wave of Fig. 3 and its envelope 114.

In accordance with the invention, the curve 115 is the envelope of the modulated wave 113 and the line 114 represents the average amplitude of the carrier component of wave 113. It is evident that the average carrier amplitude is proportional to the envelope of the signal wave. It will also be noted that the carrier amplitude is zero whenever the signal amplitude is zero and that the wave 113 is at all times completely modulated. The latter condition is evidenced by the fact that the envelope 115 makes contact with the time axis once during every cycle of the signal wave. As noted hereinbefore, in describing the method of adjusting the system of Figs. 1 and 2, a wave similar to wave 113 may be generated by first adjusting the am-

plitudes of the carrier wave from oscillator 14 and of the signal wave from amplifier 8 to produce a completely modulated wave in antenna 15 when the signal wave at input 1 has the maximum amplitude for which the system is designed and then adjusting the amplitude of the envelope wave from filter 11 to substantial equality with the amplitude of the signal wave from amplifier 8.

It will be evident that the wave 113 is not only more economical of power, but that it is also adapted to prevent disturbing effects due to beat notes produced by interference between wave 113 and other waves which may be present in the detector. During silent intervals the wave 113 is of zero amplitude, or in other words, is absent and ineffective to produce beat tones.

The modulated wave 113 does, however, contain a carrier component which is available for detection of the signal at the receiving station when the signal amplitude is not zero and in that respect the wave 113 differs materially from a "suppressed carrier wave", as will be evident from a comparison between Figs. 6, 6A and 7, 7A.

Referring to Fig. 6, the wave 117 is similar to a portion of wave 113 and envelope 118 is similar to a portion of envelope 115 in Fig. 5.

Fig. 6A indicates graphically the succession of positive and negative loops in the wave 117 of Fig. 6, directly above Fig. 6A. The loops form a perfectly regularly alternating series irrespective of the point of contact between envelope 118 and the time axis. By virtue of this property of uninterrupted alternation, the electric counterpart of wave 117 is capable of inducing sustained currents, through suitable coupling devices, in a circuit sharply tuned to the carrier frequency. In other words, the modulated wave 117 contains a carrier frequency component. This carrier component enables the modulated wave to be suitably detected at a receiving station without the necessity for supplying a carrier component from a local source.

In Fig. 7 is illustrated a portion of a modulated wave 119 in which the carrier component has been suppressed. The wave 119 is characterized by an envelope 120 which is not a smooth curve but which has a cusp making contact with the time axis.

Fig. 7A indicates graphically the succession of positive and negative loops in the wave 119. It will be noted that the regularly alternating series of loops is interrupted at the point at which the envelope 120 makes contact with the time axis. When an electric wave of this nature is applied to a resonant circuit sharply tuned to the carrier frequency, a few alternating loops in regular succession tend to start the circuit oscillating, but the following series of loops in reversed phase relation tend to offset the effect of the first series and destroy the incipient oscillations.

The result is that no material or sustained amplitude of carrier current can be induced by a wave of the character of wave 119. Thus the wave 119 cannot be suitably detected at a receiving station unless a carrier current is provided from a local source.

What is claimed is:

1. A modulating system comprising a source of carrier waves, a source of modulating current, means for supplying said current to a circuit having two branches, rectifying means in one branch for producing a rectified current from a portion of said modulating current, a network in said branch for substantially damping out the fluctuations of undesired frequency in said rectified current, means jointly controlled by said modulating and rectified currents for producing an electromotive force varying substantially proportionally to the sum of said currents, a space discharge tube having a cathode, an anode and a control electrode, input and output circuits connecting said cathode with said control electrode and anode, respectively, means for applying to said input circuit carrier waves from said carrier source, and means for impressing said electromotive force upon said anode whereby carrier currents are set up in said output circuit and are controlled in accordance with the variations in said electromotive force.
2. A modulating system comprising a source of carrier waves, a source of modulating current, means for supplying said current to a circuit having two branches, current regulating means in each of said branches for adjusting the amplitudes of the currents therein, rectifying means in one branch for producing a rectified current from a portion of said modulating current, a network in said branch for substantially damping out the fluctuations of undesired frequency in said rectified current, means jointly controlled by said modulating and rectified currents for producing an electromotive force varying substantially proportionally to the sum of said currents, a space discharge tube having a cathode, an anode and a control electrode, input and output circuits connecting said cathode with said control electrode and anode, respectively, means for applying to said input circuit carrier waves from said carrier source, and means for impressing said electromotive force upon said anode whereby carrier currents are set up in said output circuit and are controlled in accordance with variations in said electromotive force.
3. A signal transmission system comprising a source of carrier waves, a source of signal current, means for supplying said current to a circuit having two branches, current regulating means in each of said branches for adjusting the amplitudes of the currents therein, rectifying means in one

branch for producing a rectified current from a portion of said signal current, a network in said branch for substantially damping out fluctuations of undesired frequency in said rectified current, means jointly controlled by said signal and rectified currents for producing an electromotive force varying substantially proportionally to the sum of said currents, a space discharge tube having a cathode, an anode and a control electrode, input and output circuits connecting said cathode with said control electrode and anode, respectively, means for applying to said input circuit carrier waves from said carrier source, means for impressing said electromotive force upon said anode whereby carrier currents are set up in said output circuit and are controlled in accordance with the variations in the said electromotive force, and means associated with said output circuit for transmitting said modulated wave.

4. A signaling system comprising a source of carrier waves, a source of signal current, means for supplying said signal current to a circuit having two branches, current regulating means in each of said branches for adjusting the amplitudes of the currents therein, rectifying means in one branch for producing a rectified current from a portion of said modulating current, a network in said branch for substantially damping out fluctuations of undesired frequency in said rectified current, means jointly controlled by said signal and rectified currents for producing an electromotive force varying substantially proportionally to the sum of said currents, a space discharge tube having a cathode, an anode and a control electrode, input and output circuits connecting said cathode with said control electrode and anode, respectively, means for applying to said input circuit carrier waves from said carrier source, means for impressing said electromotive force upon said anode whereby carrier currents are set up in said output circuit and are controlled in accordance with the variations in the said electromotive force, means in said output circuit for transmitting said modulated wave, and means for detecting said transmitted wave.

5. A signaling system comprising a source of carrier waves, a source of signal current, means for supplying said signal current to a circuit having two branches, current regulating means in each of said branches for adjusting the amplitude of the currents therein, rectifying means in one branch for producing a rectified current from a portion of said modulating current, a network in said branch for substantially damping out fluctuations of undesired frequency in said rectified current, means jointly controlled by said signal and rectified currents for producing an electromotive force varying substantially proportionally to the sum of said currents, a

space discharge tube having a cathode, an anode and a control electrode, input and output circuits connecting said cathode with said control electrode and anode, respectively, means for applying to said input circuit carrier waves from said carrier source, means for impressing said electromotive force upon said anode whereby carrier currents are set up in said output circuit and are controlled in accordance with the variations in the said electromotive force, means in said output circuit for supplying said modulated wave to a transmission circuit, wave responsive means for producing an effect substantially proportional to the modulated amplitude of said transmitted wave, and means for utilizing said effect to reproduce the signal.

In witness whereof, I hereunto subscribe my name this 17th day of October, 1928.

FRANCIS M. RYAN.