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R. A. HEISING

TRANSMISSION SYSTEM

Filed April 18, 1924

Fig. 1

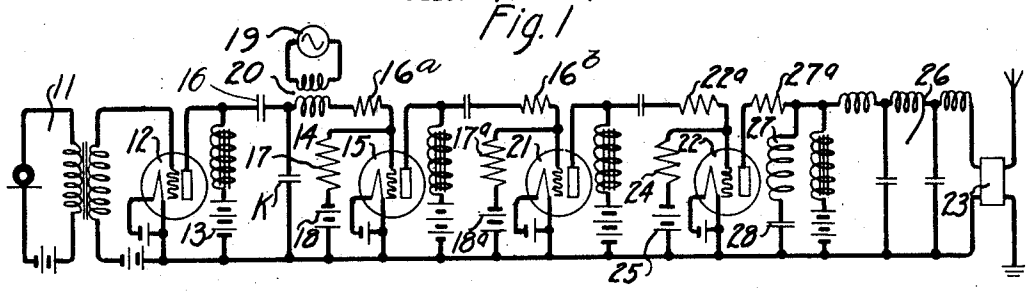


Fig. 2

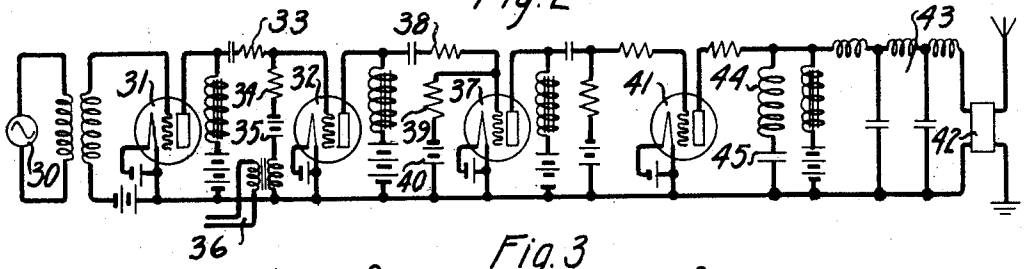


Fig. 3

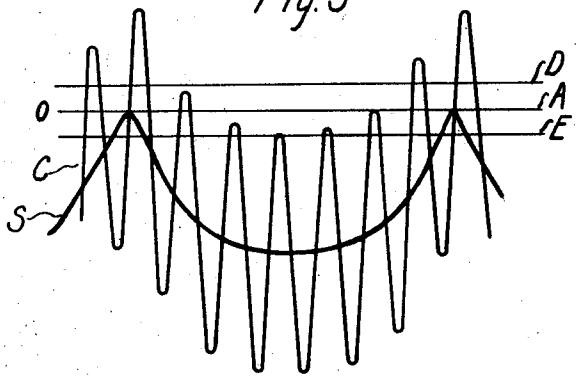


Fig. 4

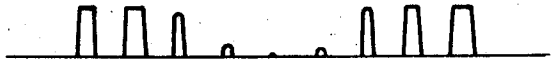


Fig. 5



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UNITED STATES PATENT OFFICE.

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TRANSMISSION SYSTEM.

Application filed April 18, 1924. Serial No. 707,327.

This invention relates to the transmission of signals by electrical waves and has for an object a system for producing high frequency waves and modifying them in accordance with signals or other effects to be transmitted which is economical in power consumption and highly effective in the modulation of the high frequency waves.

An object of the invention is to provide for the distortion of speech or other signal waves in such a manner that the production of uniform amplitude flat topped impulses of higher frequency than signal waves and modulated in length will have their total energy over a speech cycle proportional to the energy of the corresponding cycle of signal waves.

A further object is to increase the efficiency of operation of the variable impedance element of a constant current or equivalent modulation system by decreasing the energy loss therein.

In a typical system the objects of the invention are attained by producing a series of electrical impulses varying in length in accordance with the amplitude of signaling waves and impressing these impulses upon the grid-filament circuit of the modulator tube of a constant current system for producing modulated high frequency waves. To obtain these impulses signaling waves are superposed upon the carrier frequency waves and the resultant waves are impressed upon the input circuit of a vacuum tube amplifier, the normal grid potential of which is so negative with respect to the cathode that substantially no space current flows when no waves are impressed upon the input circuit; when upon the normal grid potential there is superimposed a positive potential of considerably less than the peak value of the carrier frequency waves the grid becomes positive to such an extent as to limit the space current. The application of a positive half wave of the intermediate carrier frequency will carry the potential of the grid from such a negative value that no space current flows to beyond such a positive value that increase of space current ceases. The signaling wave may be impressed directly upon the carrier frequency wave or instead of the signaling wave, we may employ a wave, the amplitude of which is proportional to the square of one-plus-the-sine of the signaling wave. In the former case, the length of the impulses is directly proportional to the amplitude of the signaling wave whereas in the latter case the lengths of the impulses are substantially proportional to the square of the amplitude of the signaling wave. The modulator and oscillator are connected through a filter, the transmission band of which is approximately such as to pass freely waves of all frequencies below the mean of the intermediate carrier frequency and the highest speech frequency. Across the output circuit of the modulator is provided a shunt path for waves of carrier frequency. Thus, there is transferred to and impressed upon the high frequency oscillator, a modulating current of large energy which has been produced from a relatively feeble voice current in a manner involving efficient energy utilization.

Referring now to the drawings,

Fig. 1 discloses one system embodying the invention;

Fig. 2 discloses a second system embodying the invention; and

Figs. 3, 4 and 5 are diagrams for explaining the operation of the system.

In the system disclosed in Fig. 1, the microphone circuit 11 indicates any source of speech or signaling waves, such, for example, as a telephone line. This circuit is inductively connected to the grid-filament circuit of a vacuum tube 12, the output circuit 13 of which feeds into the input circuit 14 of a vacuum tube 15 through a stopping condenser 16 and resistance 16^a. Shunted across the input circuit 14, between the resistance 16^a and the grid of the tube 15, are a resistance 17 and a polarizing battery 18. The resistance 16^a is of such value that the impedance of the output circuit 13 to audio-frequency waves is considerably lower than the internal impedance of the tube. Therefore, the current in the output circuit 13 varies substantially according to the square of one plus the sine of the potential impressed upon the grid of the tube 12. Thus, a speech or other signaling sine wave impressed upon the input circuit of the tube 12 produces in the output circuit 13, a wave having its amplitude proportional to a function of the impressed grid potential.

A source 19 of carrier frequency waves preferably of about 20,000 cycles is induc-

tively connected at 20 to the circuit 14. There is provided a by-pass condenser K of relatively low impedance to the carrier frequency and of relatively high impedance to the signaling frequency. The battery 18 is of such electromotive force as to produce a normal condition of zero or very small space current from the plate to the cathode of the tube 15. The resistances 16^a and 17 and the battery 18 are so proportional relative to each other and with respect to the amplitude of the waves produced by the device 19 that when no signaling waves are being impressed, positive half cycles of the carrier frequency wave impressed upon the input circuit of the tube 15 render the grid so positive that the space current in the output circuit reaches its maximum value at considerably less than the peak value of the carrier frequency wave. The output circuit of the tube 15 feeds into the input circuit of an amplifier 21. The resistances 16^b and 17^a and battery 18^a bear the same relationship to each other as resistances 16^a and 17 and battery 18 so that the space current in the output circuit of amplifier 21 reaches its maximum value at less than the peak of the input voltage. Thus, when no speech is being impressed upon the circuit, the current in the output circuit of the tube 15 comprises a series of flat topped positive impulses of equal length and amplitude. However, when speech is impressed upon the system, the intermediate frequency is superposed on the speech wave and the resultant wave impressed upon the grid of the tube 15 is of such form that the current in the output circuit of the tube 15 consists of a series of impulses of different length and of approximately the same amplitude, these impulses recurring in regular sequence and at regular intervals and corresponding in length to a function of the instantaneous amplitudes of the impressed speech waves.

The operation of the system up to this point when signaling waves are being produced in the microphone circuit 11, is apparent by reference to Figs. 3 and 4. In Fig. 3, O represents the zero axis, the curve S represents the distorted signaling voltage produced by the tube 12 from the undistorted voltage produced in the microphone circuit. The curve C represents the voltage of the carrier frequency waves. As shown in Fig. 3, the voltage of the carrier frequency is superposed upon the signaling wave S so that the curve C of Fig. 3 may be taken to represent the voltage impressed upon the input circuit of the vacuum tube 15. The curve D represents the maximum current flow in the output circuit of tube 15 and the curve E represents the normal grid potential of the tube 15. Hence, as shown in Fig. 4, there will be produced in the plate circuit of tube 15 a series of impulses of variable length and amplitude resulting from the peaks of the impulses of higher amplitude being flattened or cut off. Because of the distortion of the signaling wave by the tube 12, the instantaneous amplitude of the curve C is substantially proportional to the square of the potential impressed upon the grid of the tube 12. Consequently, the length of each impulse in the output circuit of the tube 15 is also substantially proportional to the square of the voltage impressed upon the grid of tube 12. By repeating the wave forming process as often as is necessary through the medium of one or more additional amplifiers, such as amplifiers 21, the series of impulses disclosed in Fig. 4 will assume the form shown in Fig. 5 wherein all of the impulses are of substantially uniform amplitude but vary in length proportionally to the maximum amplitude of that particular portion of the curve C from which they were derived. The net result is to form a series of impulses modulated in length rather than amplitude; the length being substantially proportional to the square of the voltage impressed upon the grid of tube 12.

The output circuit of the amplifier 21 is connected through a resistance 22^a to the input circuit of a modulator comprising a vacuum tube 22. Shunted across the input circuit of the tube 22 is a resistance 24 and a polarizing battery 25. The resistances 22^a and 24 and the battery 25 bear the same general relationship to each other as the corresponding resistances and battery of the amplifiers 15 and 21 so that the space current in the output circuit of tube 22 reaches its maximum value at less than the peak of the input voltage. The output circuit of tube 22 is connected to the oscillator 23 to form a constant current modulating system of the type disclosed on page 334 of the Proceedings of the Institute of Radio Engineers for August, 1921. The modulator tube 22 is connected to the oscillator by a filter 26, the transmission band of which is such as to pass audio-frequency waves and exclude waves of carrier frequency produced by the source 19. Shunted across the output circuit of the modulator is a by-pass path for frequencies higher than speech comprising the inductance 27 and capacity 28, the path preferably being tuned to the carrier frequency supplied by the source 19. Any carrier frequency appearing in the modulator circuit is shunted out through this path. A resistance 27^a in the output circuit of the tube 22 serves to absorb energy which otherwise would be dissipated in the tube.

The impulses disclosed in Fig. 5 are impressed upon the input circuit of the modulator tube 22 thereby causing the modulation of the high frequency waves produced by the oscillator 23 in accordance with the

speech wave represented by these impulses. The energy transferred to the oscillator is substantially proportional to the square of the amplitude of the signal wave, since the impulses impressed upon the grid of the tube 21 vary in length according to a function of the square of the amplitude of the signaling wave.

The system disclosed in Fig. 2 differs from that disclosed in Fig. 1 in that an undistorted signaling wave rather than a distorted wave is impressed upon the carrier frequency wave. A source 30 of carrier frequency waves is inductively connected to the input circuit of a distortionless amplifier 31. The output circuit of the amplifier 31 is connected to the input circuit of a vacuum tube 32 comprising the first tube in a wave flattener circuit of the type described in connection with Fig. 1, the input circuit of tube 32 including a resistance 33. Shunted across the input circuit of tube 32 between the grid and the resistance 33 is a resistance 34 in series with a polarizing battery 35. A telephone line 36 or other source of signaling waves is inductively connected with this shunt circuit. The battery 35 is of such electromotive force as to produce a normal condition of zero or very small space current from the plate to the anode of the tube 32. Furthermore, the resistances 33 and 34 and the battery 35 are so proportioned relative to each other and to the amplitude of the carrier frequency waves that impressed potentials of considerably less than the peak value of the impressed carrier waves cause the grid to become positive to such an extent as to limit the space current between the anode and cathode. The result is that there is produced in the output circuit a series of positive impulses of the same duration and amplitude. However, when speech waves are impressed upon the circuit, the carrier frequency waves are superposed thereon in a manner similar to that described in connection with Figs. 1, 3 and 4, the difference being that the duration of the impulses varies according to the amplitude of the speech wave rather than in accordance with the square thereof. The output circuit of the vacuum tube 32 is connected to the input circuit of the vacuum tube 37 through a resistance 38. A resistance 39 and a polarizing battery 40 in series are shunted across the input circuit of the vacuum tube 37 between the resistance 38 and the grid of the tube. These resistances and battery are so proportioned relative to each other that tube 37 likewise operates to produce flat topped impulses. By means of this tube, the impulses produced in the vacuum tube 32 are amplified and brought to uniform amplitude. The output circuit of vacuum tube 37 is connected to the input circuit of the modulator tube 41 which is connected to the oscillator 42 to form a constant current system for producing modulated high frequency waves. The flat topped impulses are impressed upon the grid of the modulator tube and cause the high frequency waves generated by the oscillator to be modulated in accordance with the speech frequency component of the impulses. The modulator tube is connected to the oscillator through a filter 43, the transmission band of which is such that audio frequencies are transmitted freely but carrier waves of frequency produced by the source 30 are attenuated. Shunted across the output circuit of the modulator tube is an inductance 44 and capacity 45 of proper design to provide a low impedance path for waves of the carrier frequency. By means of this arrangement, the high frequency carrier waves produced by the oscillator 42 are modulated in accordance with the signaling wave.

It is, of course, understood that various modifications may be made without in any way departing from the spirit of the invention as set forth in the appended claims.

What is claimed is:

1. The method of modulating which comprises producing a signal wave, converting said wave into a series of uni-directional impulses of duration varying in accordance with said signal wave and impressing said impulses upon radio frequency waves.

2. The method of signaling which comprises producing a signal wave, converting said wave into a series of uni-directional impulses of duration varying in accordance with said signal wave and utilizing said impulses to modulate radio frequency waves.

3. The method of signaling which comprises producing high frequency oscillations, producing a signal wave, converting said wave into a series of uni-directional impulses varying in duration in accordance with said signal wave and impressing said impulses upon said radio frequency oscillations.

4. The method of signaling which comprises producing a signal wave, converting said wave into a series of uni-directional impulses varying in duration substantially according to the square of the amplitude of said signal wave and utilizing said impulses to modulate high frequency oscillations.

5. The method of signaling which comprises producing radio frequency oscillations, producing a signal wave, converting said wave into a series of uni-directional impulses of duration varying substantially in accordance with the square of the amplitude of said signal wave and utilizing said impulses to modulate said high frequency oscillations.

6. The method of producing modulated waves of high power which comprises producing a series of impulses the amplitude

of which varies substantially in accordance with the square of the amplitude of a signaling wave, converting said impulses into impulses of uniform amplitude and varying duration, and utilizing said last named impulses to modulate high frequency oscillations.

7. The method of signaling which comprises producing a series of impulses the amplitude of which varies according to the amplitude of a signal wave, converting said impulses into impulses of uniform amplitude and varying duration, and utilizing said impulses to modulate high frequency oscillations.

8. A system comprising a wave generator, a signaling wave source, means to convert waves from said source into impulses of uniform amplitude and varying duration, and means for impressing said impulses upon said wave generator.

9. A system comprising a signaling wave source, means for producing uni-directional impulses whose time duration is controlled by waves from said source, a wave generator, and means for impressing said impulses upon said wave generator.

10. A system which comprises a source of signaling waves, means for producing a wave the amplitude of which varies substantially in accordance with the square of the amplitude of the signaling waves, means for producing a series of impulses of duration varying in accordance with the amplitude of said last named wave, a wave generator, and means for impressing said impulses upon said wave generator.

11. A system comprising a source of signaling waves, an electron discharge device for producing a wave varying in amplitude substantially in accordance with the square of the amplitude of the signaling waves, means comprising an electron discharge device for producing impulses varying in duration in accordance with the amplitude of said last named waves, a wave generator, and means for impressing said impulses upon said wave generator.

12. A system comprising a source of audio frequency waves, an electron discharge device for producing waves the amplitude of which varies substantially in accordance with the square of the amplitude of the audio frequency waves, means for impressing carrier frequency waves upon said second named waves, means for converting said resultant waves into a series of impulses varying in duration according to the amplitude of said second named waves, a modulating system comprising an oscillator and an electron discharge device connected therewith, means for impressing said impulses upon said last named electron discharge device, a filter connecting said oscillator and electron discharge device the transmission band of which excludes frequencies higher than speech frequencies and a circuit in shunt for passing to the output circuit of said electron discharge device frequencies higher than speech frequencies.

13. A system comprising a source of carrier frequency waves, a source of speech waves, means to impress said carrier waves upon said speech waves, means to convert the resultant waves into a series of impulses of duration varying in accordance with said speech waves, a source of high frequency, an electron discharge device for modulating said high frequency, means for impressing said impulses upon said modulator, a filter connecting said modulator and oscillator, the transmission band of which includes speech frequencies, and a shunt circuit for passing frequencies higher than speech frequencies.

14. The method which comprises deriving from an electromotive force $e=1+K\sin wt$, a current $i=a(1+K\sin wt)^2$ where a and K are constants and w the angular velocity.

15. The method of converting a speech wave which comprises producing a wave of amplitude equal to the square of a constant-plus-the-amplitude of the speech wave.

16. The method which comprises distorting a sinusoidal wave to produce a second wave varying in accordance with the square law, and producing a series of flat topped impulses of a higher frequency of recurrence than the frequency of the sinusoidal wave and varying said impulses in length according to the second wave.

17. A constant current modulating system comprising a device for producing modulated high frequency waves, a variable impedance device, a source of current for said devices, means tending to maintain constant the sum of the currents supplied thereto by said source, and means for varying the impedance of said variable impedance device in accordance with a series of flat topped impulses modulated in length as a function of a signal wave, such as a sound wave.

In witness whereof, I hereunto subscribe my name this 11 day of April, A. D. 1924.

RAYMOND A. HEISING.