Aug. 16, 1932. H. A. BROWN 1,872,398

SUPPRESSED WAVE RADIO CARRIER SYSTEM

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Fig. 1.

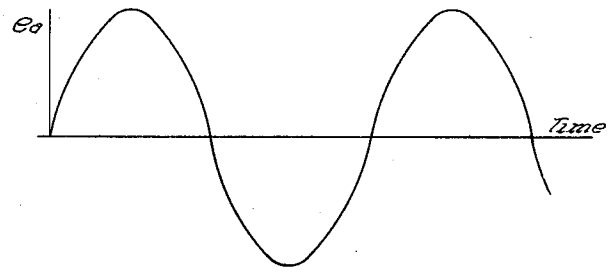


Fig. 2.

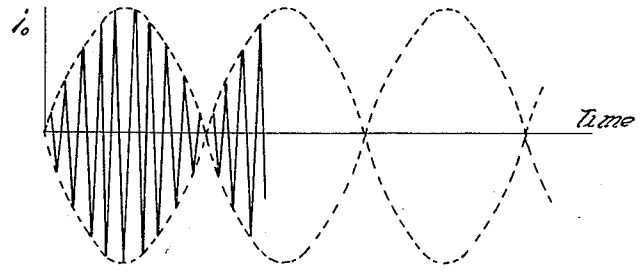
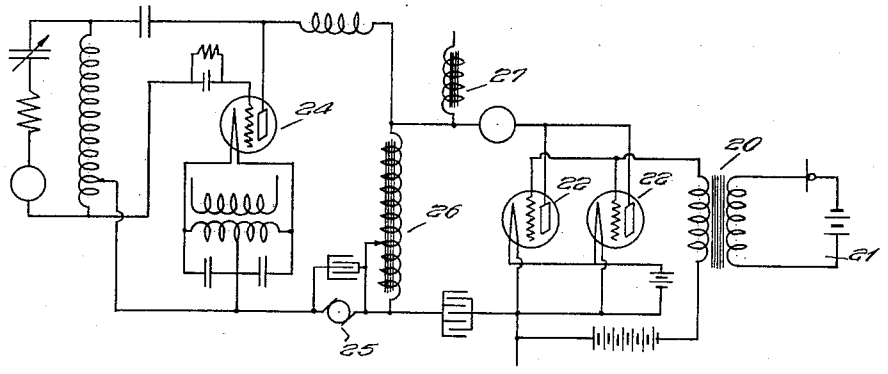


Fig. 3.



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SUPPRESSED WAVE RADIO CARRIER SYSTEM

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Fig. 4.

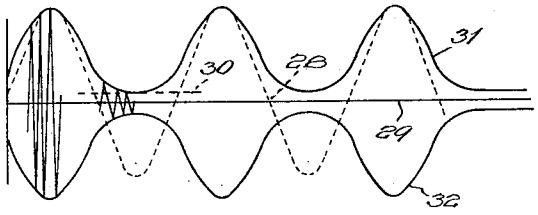


Fig. 5.

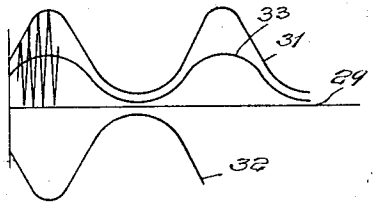


Fig. 6.

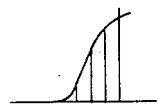
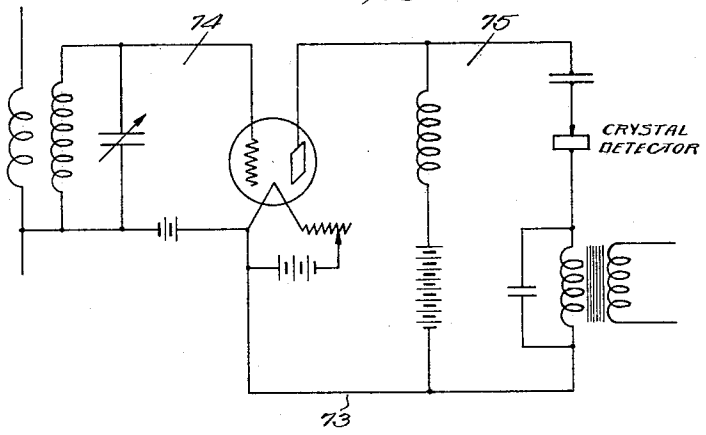


Fig. 10.



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SUPPRESSED WAVE RADIO CARRIER SYSTEM

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Fig. 7.

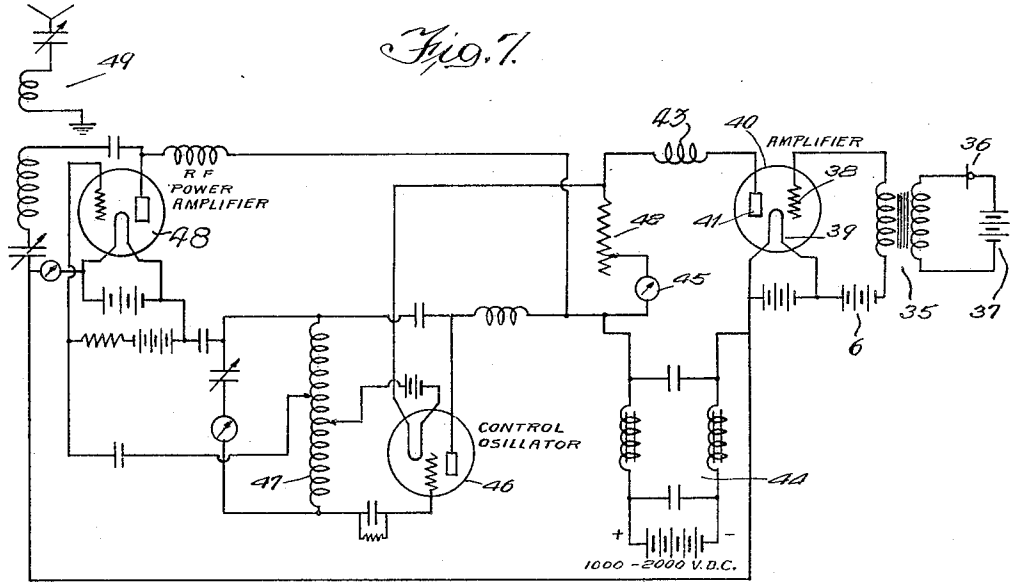
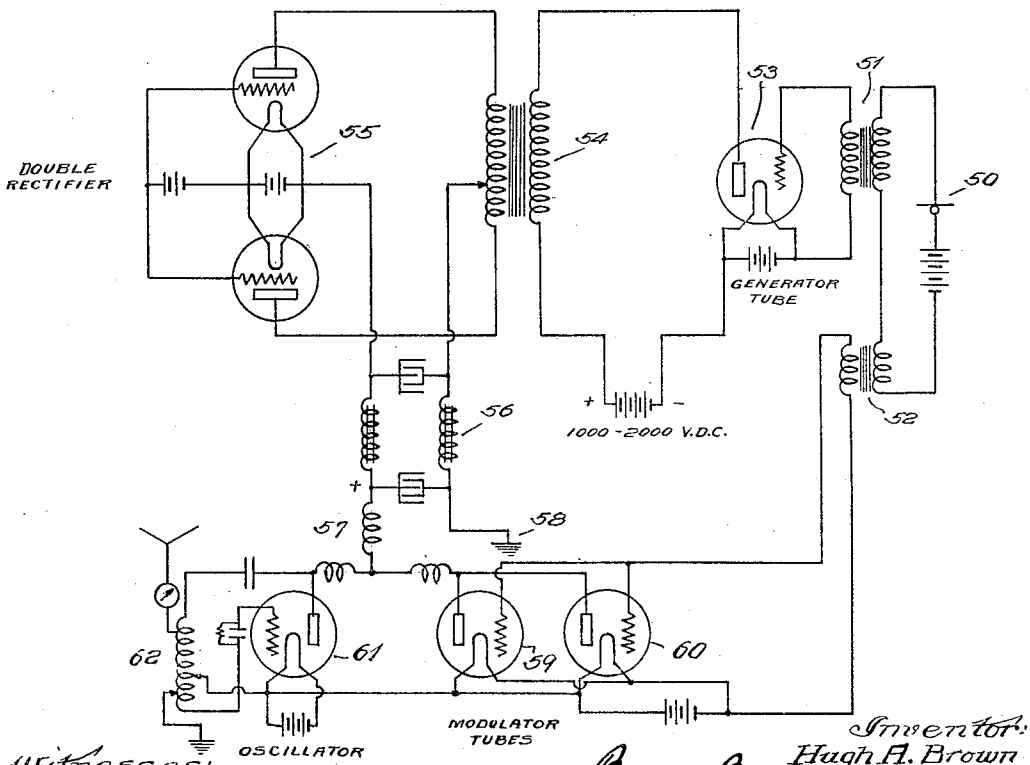


Fig. 8.



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Aug. 16, 1932. H. A. BROWN 1,872,398

SUPPRESSED WAVE RADIO CARRIER SYSTEM

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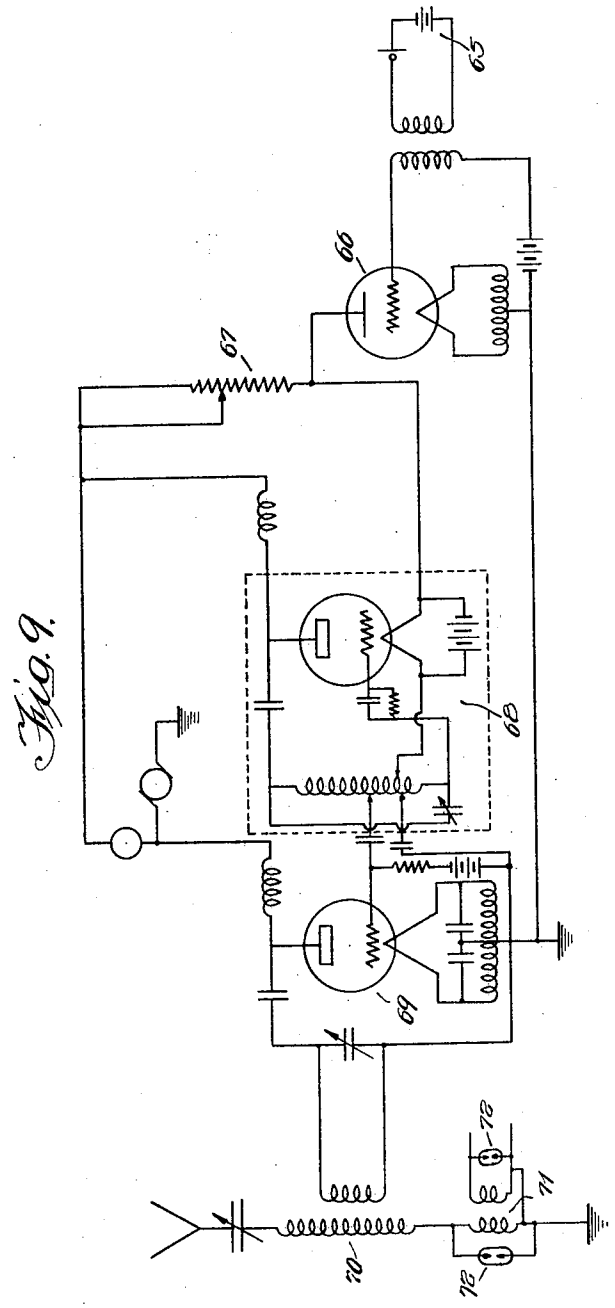


Fig. 9.

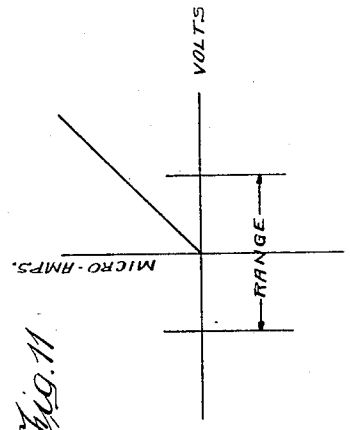


Fig. 11

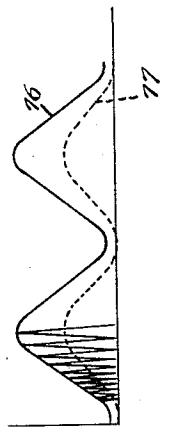


Fig. 12

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SUPPRESSED WAVE RADIO CARRIER SYSTEM

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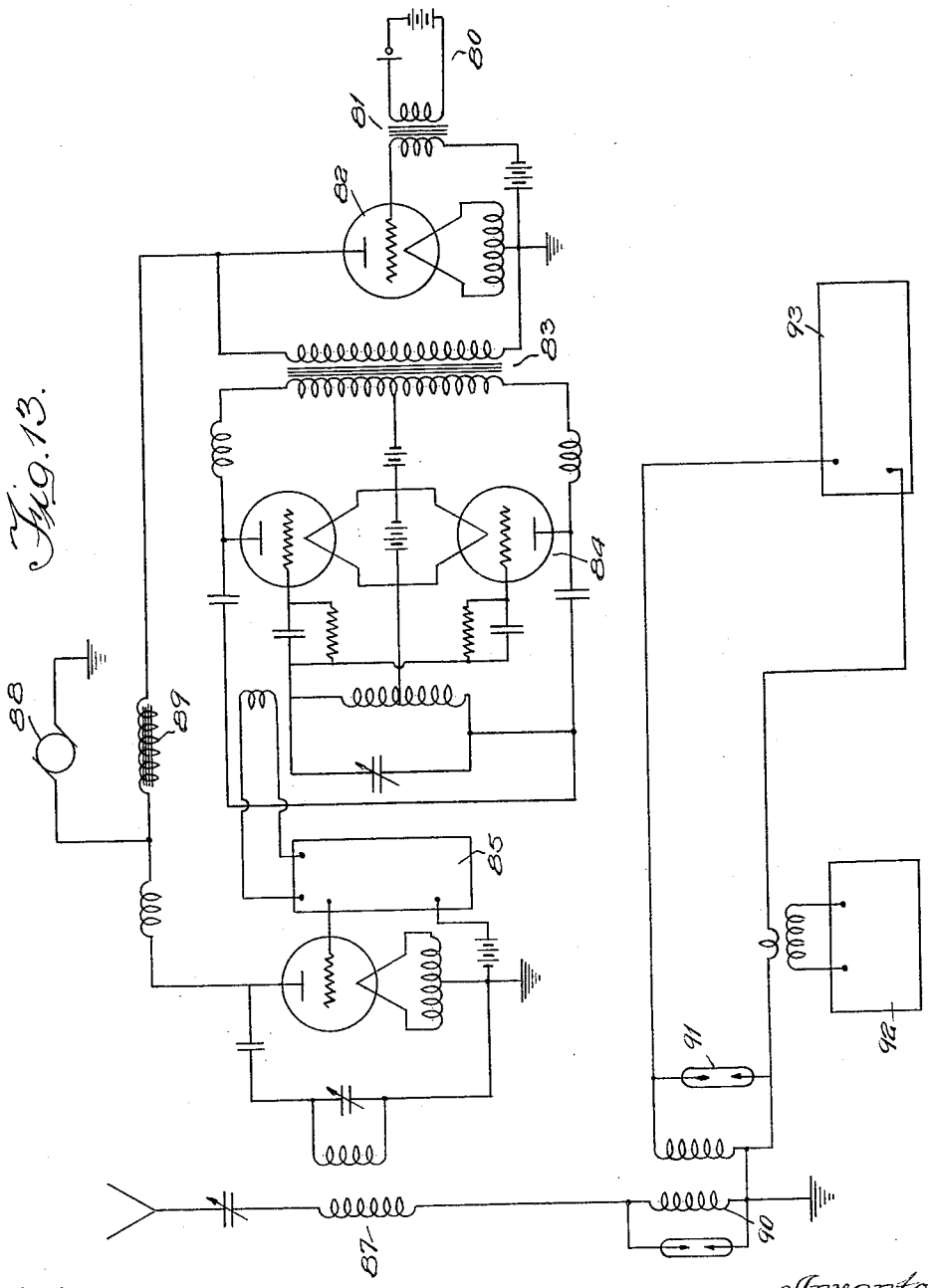


Fig. 13.

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1,872,398

UNITED STATES PATENT OFFICE

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SUPPRESSED WAVE RADIO CARRIER SYSTEM

Application filed July 1, 1925. Serial No. 40,725.

This invention relates to an improvement in radio telephone transmitting systems which has for its object the production of radio frequency waves only during periods of modulation.

At the present time, all of the standard transmitting systems make use of what is known as a "carrier wave" which is a wave of high radio frequency which is modulated in intensity in accordance with audio-frequency variations. The result is that energy is being used up in the continuously radiated carrier wave. If it could be eliminated, much greater efficiency of transmission would result. Not only this, but also the heterodyne between unmodulated carrier waves, would be eliminated. Tests have also shown that a considerable portion of static seems to be inherent in the carrier wave. This is because the static which is tuned in with the carrier wave is merely an audio-frequency modulation of the carrier wave caused by natural electrical phenomena or by radiation from power transmission lines, etc. Elimination of the carrier wave would be of great benefit to reception in that it would greatly reduce the volume of static.

Another feature of my invention is that it makes simultaneous communication possible. Heretofore, it has been impossible, without the use of complicated balanced circuits using two antennæ, to carry on simultaneous communication. In systems employing a continuous carrier wave, it is impossible to carry on intercommunication or simultaneous communication because the carrier wave of the local station paralyzes its own detector.

According to my invention, the radio frequency wave is impressed upon the antenna and hence upon the ether only during the period that the microphone is active. The result is that there is practically no power radiated from the antenna during the intervals that the microphone is inactive. Present results show that there is a saving of antenna power in my system of from one-half to two-thirds of that required for the carrier wave transmission systems.

Furthermore, it is impossible to tune the created non-carrier wave bands to a greater degree of sharpness than the modulated carrier wave without a band filter. Since the frequency bands are theoretically the same for both kinds of waves, the increased selectivity in the case of a non-carrier wave is undoubtedly due to the absence of unmodulated current. The action of the detector is likewise more efficient, since there is not the usual initial decrease in plate current which is caused by the carrier wave.

The present invention will be more readily understood by reference to the following detailed description when taken in connection with the accompanying drawings.

In the drawings:—

Fig. 1 represents a sine wave of sound;

Fig. 2 represents an audio frequency controlled wave of high frequency;

Fig. 3 is a diagram of connection of what I call the "exciting half-wave system";

Fig. 4 represents the high frequency output current of the oscillator in the system shown in Fig. 3;

Fig. 5 represents the detector plate voltage and current waves using the system of Fig. 3;

Fig. 6 is the characteristic curve of the tube used to the detector curve shown in Fig. 5;

Fig. 7 is a diagram of a non-continuous radiator system of my invention;

Fig. 8 is another type of a non-continuous radiator system;

Fig. 9 is a diagram of a non-continuous radiator system of two-way telephony;

Fig. 10 is the receiving system used in connection with the system shown in Fig. 9;

Fig. 11 represents the ideal linear characteristic for a crystal rectifier;

Fig. 12 illustrates sinusoidal curve of a high frequency current through a crystal rectifier by the solid line, and the average current in the windings of an amplifying transformer by the dotted line; and

Fig. 13 is a diagram of a non-carrier non-continuous radiator system of two-way telephony.

When a sine wave of sound, as shown in Fig. 1 originates in front of the transmitting microphone, the E. M. F. generated in the

secondary of a speech transformer, the primary of which is in the microphone circuit, will have the same wave shape. If this wave is amplified until it provides a source of power to excite an oscillation generator with an audio-frequency supply E. M. F., and the oscillator is one which has a linear relation between supply voltage and output current, and is capable of functioning on either the positive or negative portions of the supply E. M. F. wave, the high frequency output current will be as shown in Fig. 2. From this it is evident that the maximum value of radio frequency current I_o, occurs at the instant of maximum audio-frequency E. M. F. Now, if the currents in a receiving antenna are rectified, the result will be a double frequency average telephone current having a wave shape approximating the envelope of the upper half of Fig. 2, depending more or less upon the characteristics of the detector.

However, in actual tests, with a large number of standard transmitting systems now in use, it was found that because of the double frequency, that the received signals were very much distorted. For this reason the transmitter was modified so that the oscillator functioned only on one-half the speech frequency supply voltage. This system, I call the "exciting half-wave system" and the diagram of connections is shown in Fig. 3. In this diagram the numeral 20 designates a transformer, the primary side of which is connected to the microphone circuit 21 and the secondary to the grid circuit of the exciter tubes 22. A speech amplifier is inserted in the microphone circuit 21 when high power tubes 22 are used. An oscillator tube 24 is kept weakly excited by means of a dynamotor 25 when the audio supply voltage on its plate is zero. A high inductance choke 26 is placed in the plate circuit of the exciter tubes and pulsating fluctuations of voltage across it, are impressed on the oscillator 24. A constant current choke 27 serves to deflect power from the exciter tubes 22 to the oscillator 24.

Now when a sine wave of sound is produced in front of the microphone in the circuit 21, a sinusoidal E. M. F. will be impressed upon the grids of the exciter tubes 22. This results in an E. M. F. of the same form being impressed on the oscillator 24 so as to produce a high frequency output current as shown in Fig. 4. In this figure the dotted curve 28 represents the wave of E. M. F. impressed on the oscillator tube and is not quite symmetrical above and below the horizontal axis 29 because of the direct-current potential of the dynamotor 25, represented by the horizontal dotted line 30. However, because of the "smoothing out" action which takes place in the different circuits, the envelope of high frequency currents will take the form shown by the curves 31 and 32 which are respectively above and below the axis 29.

By referring to Fig. 4, it will be observed that the upper envelope is not sinusoidal in form, and if the current in the telephone receiver is to be sinusoidal it must be due to the saturation performance characteristics of the system. Fig. 5 shows a portion of this envelope redrawn, accompanied by a characteristic curve 33 of a typical detector tube. The tube characteristic is shown in Figure 6. Now if the grid bias potential is adjusted for a low plate current, 31 will represent the envelope of the high frequency plate currents and the curve 33 the average telephone current, which is nearly sinusoidal. If a grid condenser and leak are used, the results are problematical, but in actual tests, using both, reception was found to be perfect with this type of transmission. Investigation shows that clearness of articulation in speech or quality of sound in music depends mostly on the reproduction of the higher harmonic frequencies. Hence speech and music should be faithfully reproduced even though the negative loops of the sound waves are cut off in the receiver.

However, because of the fact that most of the energy in a voice wave is in the lower harmonic frequencies, it was found that the power output of the oscillator tube was comparatively low. It was also found necessary to make the D. C. voltage of the dynamotor 25 from 35 to 45 per cent of the positive amplitude to overcome the effect of a negative charging potential on the oscillator tube and to keep it excited.

To get around the above difficulties, I found that it would be possible to utilize the variable I. R. drop across a resistance in the plate circuit of a speech amplifier tube to excite an oscillator. This drop is very low during intervals of silence and rises to a high value when sound is produced at the microphone, due to the resulting rise of current in the amplifier tube plate circuit.

A diagram of connections embodying the above idea is shown in Fig. 7 in which the numeral 35 designates a transformer to the primary side of which is connected a microphone 36 in series with the battery 37. The secondary side of the transformer 35 is, in turn, connected to the grid 38 and the filament 39 of the speech amplifier 40 through the battery 6. The plate 41 is connected to the resistance 42 through the radio frequency choke 43. The resistance 42 is variable and has its variable connection connected to the filter 44 through the ammeter 45, the opposite side of the filter 44 being connected to the filament 39. When the system is in operation, a direct current voltage of between 1,000 to 2,000 volts is placed across the opposite terminals of the filter 44. Hence, when the speech amplifier 40 is not excited,

there is always a current flowing in the plate circuit. This causes an I. R. drop across the resistance 42 which is impressed on the control oscillator 46, causing it to oscillate weakly. When the microphone 36 is spoken into, it will cause the plate current of the speech amplifier to vary between high and low values. This variation in current of the plate circuit of the speech amplifier, will in turn cause a corresponding varying I. R. drop across the resistance 42. These fluctuations across the resistance will in turn be impressed upon the control oscillator 46, causing it to oscillate with frequencies which vary in direct proportion to the audio-frequencies, which, in turn, vary in direct proportion to the audio-frequencies impressed upon the microphone 36. The radio frequency output of the control oscillator 46 is tuned by means of the variable inductance 47, and is then fed into the power amplifier 48 which serves to amplify it. By means of a suitable transformer or coupling the output of the power amplifier is fed into the antenna circuit 49. By means of the connections shown, the same plate voltage supply is used for the amplifier 48 as is used for the plate voltage of the speech amplifier 40. Although there is radio-frequency power being sent out from the antenna during the periods that the microphone is silent, this power is practically negligible. For a sustained "ah" sound at the microphone, the antenna power in a given case will be 200 watts. The antenna power when the microphone is silent under the same conditions will only be about 20 watts.

The above method has a distinct advantage over the exciting half-wave system in that the energy in one-half of a wave containing an even harmonic would not be taken out. It will also be noted that the use of the exciting resistance 42 results in a unidirectional pulsating power supply to the oscillator 46; hence, the name "unidirectional system" was given to this circuit.

In the embodiment shown in Fig. 8, a D. C. power supply is generated which is used to excite a constant current modulated transmitter. In this case, the microphone 50 is connected in series with the primaries of transformers 51 and 52. When sound occurs at the microphone 50, the current from the secondary side of the transformer 51 will be impressed upon the speech frequency generator or exciter 53, the plate side of which is connected to one of the primary supply terminals of the transformer 54. The opposite primary terminal of the transformer 54 is in turn connected to the positive side of the direct current line. The negative side of this same line is connected to the filament of the generator 53. When the microphone 50 is spoken into, the generator tube 53 will produce a speech frequency voltage at the primary of the transformer 54. This voltage is induced into the secondary side of the transformer 54 and is rectified and smoothed out by means of the vacuum tube double wave rectifier 55 which is connected across the secondary terminals of the transformer 54. A filter 56, of special design, is also provided to aid in rectifying and smoothing out the current which is also connected into the secondary circuit of the transformer 54. The constant current from the filter 56 is fed into the constant current oscillator system, which is connected across the secondary terminals of the transformer 52, through the choke 57 and the ground connection 58. In this constant current oscillator system, are a pair of modulator tubes 59 and 60 which are excited by the microphone 50. These modulator tubes serve to vary the direct current power supply of the filter 56 into the oscillator system when the microphone 50 is spoken into. They also serve to control the radio-frequency power of the oscillator 61 during the period that the microphone is excited. The result is that both direct current and radio-frequency power are generated and modulated only when audio-frequency waves are directed at the microphone 50. While the oscillator 61 functions only when it is modulated by means of the modulator tubes 59 and 60, it will work more efficiently if a low D. C. potential is provided in the plate circuit so as to keep it weakly excited. Fig. 8 shows the output of the oscillator 61 being fed into the antenna through a tuned inductance 62. However, if greater power is desired in the antenna, the output from the oscillator may be first fed into a power amplifier before it is sent into it.

In Fig. 9 is shown a diagram of connections for a system of two-way radio telephony. The transmission part of this system is the same in principle as that shown and described in connection with Fig. 7. It essentially consists of the microphone circuit 65 which is inductively coupled to the grid circuit of the exciter tube, the plate circuit of which contains a variable resistance 67. The I. R. drop across the resistance is impressed on the oscillator circuit 68, which is enclosed in dotted lines, and from there passes to the power amplifier 69 and thence to the antenna circuit 70.

The receiving set is inductively coupled to the antenna circuit 70 by means of an inductive coupling 71. Across the coupling coils of the coupling 71 are bridged a pair of neon tube gaps 72. These neon tube gaps are made by sealing two wire electrodes into a small glass tube and extending the electrodes into the tube until they make a gap of about one-sixteenth of an inch. A correctly adjusted partial vacuum should be provided in the tubes, the residual gas being either nitrogen, neon, hydrogen, or any gas which shows low resistance at a critical pressure. These neon

gaps are needed because when the operator speaks into his microphone, the enormous voltage drop across the receiver coupling coils will produce extremely loud signals in his head set or loud speaker which would confuse him while he is talking. There would also be danger of damaging the detector or amplifier tubes.

The receiving set which is to be used in connection with the transmission system is shown in Fig. 10 and is preferably of the type designated generally by the numeral 73. It consists essentially of the tuned radio frequency circuit 74 and the detector circuit 75.

In the constant current transmission system the distortion ratio, that is, the ratio of true signal to the distorted signal is 8—1, while its value for the system shown in Fig. 9 is only 4—1 when the conventional type of vacuum tube detector, or what is known as the "square law" detector, is used. Further analysis, however, has shown that by using crystals which have a characteristic curve such as that shown in Fig. 11, that reception will be perfect. What is commonly known as the Lenzite crystal was found to be especially adaptable for reception purposes, particularly if the voltage impressed on the crystal was large enough to go beyond the slight curve near zero. This is accomplished by means of the radio frequency amplifier circuit 74.

In Fig. 12, the curve 76 represents the influence of the pulsating rectified radio frequency voltages effective through the crystal rectifier due to modulation by a simple sine wave. The curve 77 represents the average current through the windings of the amplifying transformer in the circuit, and is sinusoidal just as the assumed modulating sound wave at the microphone shown in Fig. 1. This has been proved by a careful mathematical analysis. Hence it follows that for most satisfactory results as regards the best quality of audible reception, this particular type of receiver should be used with the transmission system shown in Fig. 9.

In Fig. 13 is a diagram of connections of what I call a non-carrier non-continuous radiator system of two way telephony. There is at present a method of transmission which is similar to the one shown in this figure, but which, however, employs what is called a balanced modulator which requires several complicated stages of amplification. In my system the well-known double wave oscillator is used which generates what is known as the double side band component minus the carrier component when sound occurs.

The circuit shown in Fig. 13 comprises the conventional microphone circuit 80 which is inductively coupled through the transformer 81 to the grid circuit of the speech frequency generator 82. The plate voltage to the speech frequency generator 82 is supplied by the generator 88 through the constant current choke 89. The output of the speech frequency generator passes on to the primary side of the transformer 83 and induced therefrom into the secondary which is connected into the plate circuit of the double wave oscillator unit 84. A band filter 85 which is inductively coupled to the double wave oscillator circuit 84 serves to transmit only a single side band instead of the double side band which is generated by the oscillators. From the band filter 85, the current passes on to the power amplifier 86 and thence to the antenna circuit 87. The necessary plate voltage for the power amplifier 86 is supplied by the generator 88.

The receiving set is inductively coupled at 90 to the same antenna circuit 87. Neon tube gaps 91 are bridged across the coupling coils to prevent any damage being done to the detector and amplifier tubes. An oscillator 92 serves to provide the carrier component necessary to make reception intelligible and is adapted to operate in conjunction with an ordinary vacuum tube receiving set 93.

However, the band filter 85 may be eliminated in which case a double side band will be transmitted instead of a single side band. Experiments show that if both side bands are transmitted that the ideal lineal rectifier, described in connection with Fig. 10, should be used. It was also found that the ordinary "square law" detector is more suitable for single side band reception. The single side band system of transmission, however, has the advantage of being more selective than the double side band system.

I do not wish to be limited to the details shown or described.

I claim:—

1. In combination, a microphone circuit, an oscillator circuit for producing radio-frequency waves, and means for generating a uni-directional pulsating voltage modulated in accordance with the modulation of the microphone circuit and impressing such voltage on the oscillator circuit, oscillation of the oscillator circuit being excited and controlled solely by the uni-directional voltage impressed thereon, and the radio-frequency waves generated in the oscillator circuit being modulated by and in accordance with the modulation of the impressed uni-directional voltage.

2. In combination, an oscillator for producing radio-frequency waves, modulating means for controlling said oscillator, a source of uni-directional current, a resistance connected between said source and said modulating means to conduct current from the source thereto, and means for impressing the voltage drop across said resistance upon said oscillator to cause it to emit radio-frequency oscillations of fixed frequency and amplitude.

3. In combination, an oscillator for pro-

ducing radio-frequency waves, modulating means for controlling said oscillator, a source of uni-directional current, a resistance connected between said source and said modulating means to conduct current from the source thereto, means for impressing the voltage drop across said resistance upon said oscillator to cause it to emit radio-frequency oscillations of fixed frequency and amplitude, and means for controlling said modulator to cause it to draw varying amounts of current from said source to thereby vary the voltage impressed upon said oscillator to control the amplitude of said oscillations.

4. In a transmitting system, the combination of an amplifying tube haing a plurality of elements, a resistor, a source of high voltage direct current, means connecting one end of said source to one of said elements, means connecting the other end of said source to said resistor, means connecting said resistor to a second element of said tube to thereby complete a circuit between said source and tube, an oscillator having an output element and a heater element, a radiating means, circuit connections coupling said output element to said radiating means, a connection between one end of said resistor and said oscillator heater, a connection between the other end of said resistor and said oscillator output element for establishing a potential difference between the heater and output elements of the oscillator equal to the voltage drop across the resistor to thereby cause the oscillator to oscillate feebly, and means for varying the current flow between the two elements of said amplifier to cause an increase in the potential difference between said oscillator elements to thereby increase the amplitude of said oscillations.

5. In combination, a transformer, a microphone and a source of direct current connected in a series circuit which includes the primary winding of said transformer, a multi element speech amplifier, a source of direct current connected between one element of said amplifier and one end of the secondary winding of said transformer, a connection between a second element of said amplifier and the other end of said secondary winding, a resistance, a filter and a source of direct current connected between a third element and said one element of said amplifier, an oscillation circuit, an oscillator in said circuit, a plate and a filament in said oscillator, a connection between the plate of said oscillator and the junction of said resistance and filter, and a connection between the filament of said oscillator and said third element of said speech amplifier.

6. In combination, a microphone circuit adapted for excitation by audio frequency waves, an amplifier, a speech amplifier circuit inductively connected to said microphone circuit, a resistance included in said speech amplifier circuit, an oscillator, a plate and a filament in said oscillator, a connection between the filament of said oscillator and one end of said resistance, a connection between the plate of said oscillator and the other end of said resistance, said oscillator being excited into oscillation only by unidirectional currents derived from the potential differences across said resistance occasioned by current flow in said speech amplifier circuit.

7. In combination, a modulator having a plate, a source of uni-directional current, a resistor connecting said source to said plate, an oscillator having a plate and a filament, connecting means for establishing a potential difference between said plate and filament by the voltage drop across said resistor, and means for varying the current drawn through said resistor by said modulator plate to thereby vary the potential difference between said oscillator plate and filament.

8. In combination, an oscillator for producing radio frequency waves, modulating means including a thermionic tube, a source of uni-directional voltage, a variable resistor connecting said source to the anode of the modulating tube to maintain a potential difference between it and the cathode, and circuit connections between the cathode and anode of the oscillator and said resistor whereby the voltage drop produced in it by current flow to said modulator anode sets up a potential difference in said oscillator.

In witness whereof, I hereunto subscribe my name this 17 day of June, 1925.

HUGH A. BROWN.