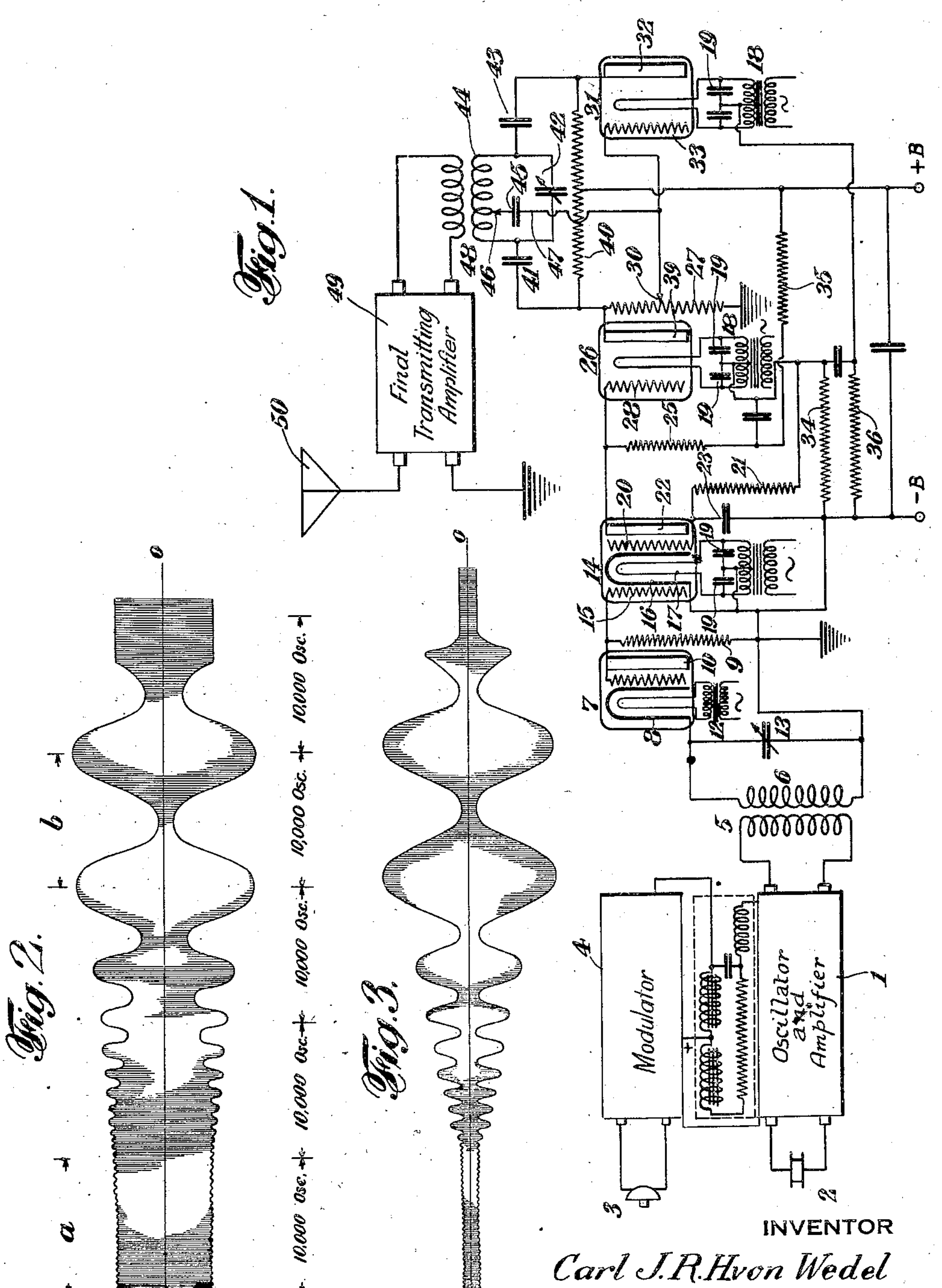
Dec. 8, 1936. C. J. R. H. VON WEDEL 2,063,278

TRANSMITTING SYSTEM

Original Filed Jan. 13, 1931 2 Sheets-Sheet 1



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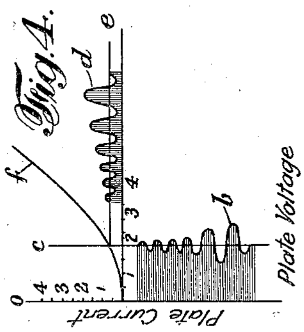

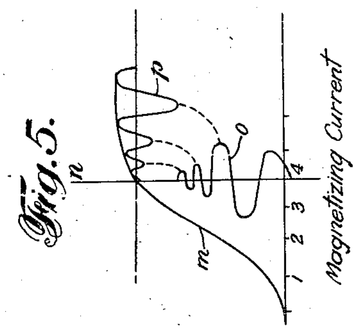

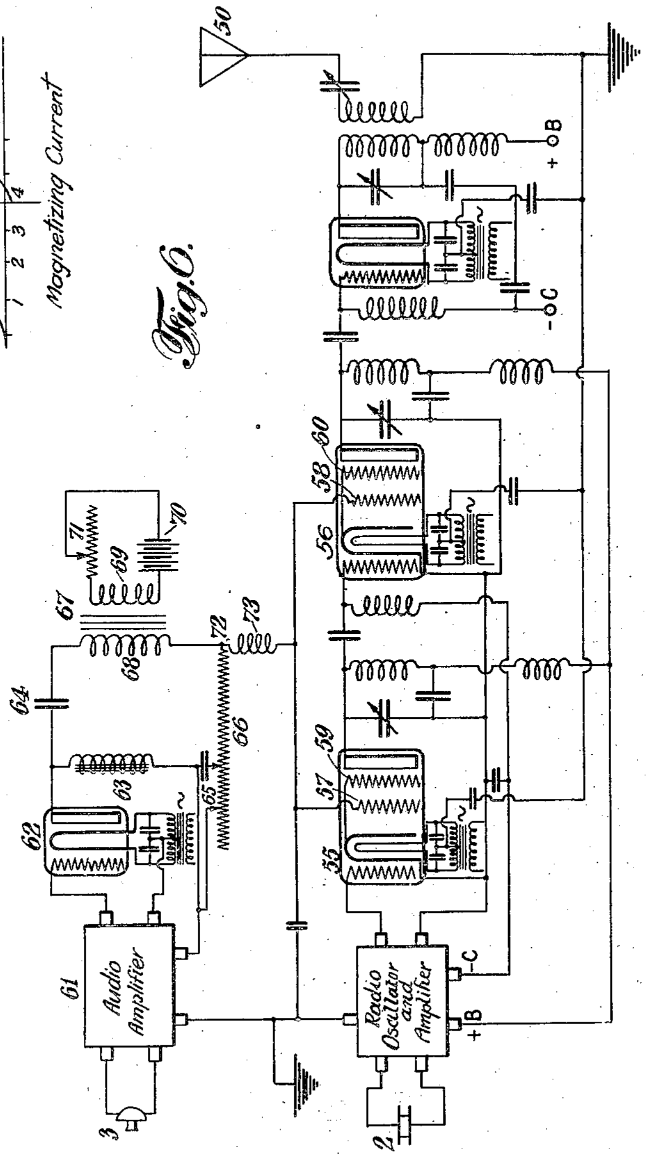

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Patented Dec. 8, 1936 2,063,278

UNITED STATES PATENT OFFICE

2,063,278

TRANSMITTING SYSTEM

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Application January 13, 1931, Serial No. 508,437
Renewed August 12, 1935

6 Claims. (Cl. 250—17)

This invention relates to transmitting systems in which high frequency carrier waves are modulated in accordance with signals to be transmitted.

The objects of the invention are to modulate carrier waves in a more suitable and efficient manner; to reduce disturbances and eliminate heterodyning between transmitters of similar wave lengths; to reduce the noise level of the transmitting station with reference to the audio signal; and to enable the transmitted waves to be more easily and faithfully reproduced by the receiving sets.

The strong carrier wave of the present transmitters becomes more or less deflected in accordance with the frequency and amplitude of the audio signal to be transmitted, but maintains its total transmitting energy constant without regard to the energy or amplitude of the audio signal. The result is that a high frequency audio signal of low amplitude is carried on a powerful carrier, while a low frequency audio signal of large amplitude is carried by a relatively weaker carrier.

In the present invention, however, I use a carrier of low amplitude and accordingly with low transmitted energy if no signal is applied, or when the carrier is not modulated, and vary its energy directly with the variation in amplitude of the audio signal, so that a low frequency audio signal which has a high amplitude will cause the transmitter to send out its full energy, whereas the carrier energy will be relatively low when a high frequency audio signal of low amplitude is transmitted, that is, the amplitude or energy of the carrier will increase with an increase in the amplitude or energy of the audio signal determining the envelop of the carrier. The amplitude of the carrier wave is always directly proportional to the amplitude of the audio signal so that a very high precentage of modulation of the carrier wave is maintained at all audio frequencies of both high and low intensities, and the radiated energy is therefore directly proportional to the amplitude of the audio signal to be transmitted.

Fig. 1 shows a transmitting circuit embodying the invention,

Figs. 2, 3 and 4 show various forms of the modulated carrier wave in different portions of the circuit of Fig. 1,

Fig. 5 shows a form of the audio signal in the circuit of Fig. 6, and

Fig. 6 shows a transmitting circuit embodying a modification of the invention.

Referring to Fig. 1, there is shown a crystal controlled oscillator and amplifier 1 for generating a radio frequency carrier wave, and having a quartz crystal 2 for maintaining the carrier frequency constant. The carrier is modulated in accordance with sound waves impressed upon a microphone 3 of the modulator 4, the output of the modulator being preferably coupled to the plate of the output tube of the amplifier in accordance with the well known Heising method, as shown by the coupling arrangement within the dotted lines. Any other suitable modulator and amplifier apparatus than that shown may be employed, however, and may be coupled together in any desired manner.

The radio frequency oscillator and amplifier 1 is coupled to a cascade amplifier by means of a transformer 5, the secondary winding 6 of which is connected at one end to the cathode 8 of a thermionic valve 7, and at the other end through coupling resistance 9 to the plate 10 of the valve. A three element tube in which the grid and plate are connected together is used for the valve, and is preferably of the indirect heated type as shown. The indirectly heated cathode 8 is supplied with heating current from transformer 12 connected to an alternating current source of supply. A tuning condenser 13 is connected across the transformer winding 6 to make the amplifier more selective.

The valve 7 is coupled by resistance 9 to the control grid 15 of the first cascade amplifier tube 14. This amplifier tube is preferably of the indirect heated type whose cathode 16 is heated by a filament 17 energized by alternating current supplied from transformer 18. The mid-point of the secondary winding of the supply transformer is connected to ground to minimize hum, and filter condensers 19 also function to minimize disturbances in the power supply. A screen grid 20 is maintained positive with respect to the control grid 15, and less positive than the plate 22, by means of resistance 21 and direct current supply B, and shields the control grid against disturbances from the plate circuit. A condenser 23 connected between the screen grid and ground serves to neutralize the capacity effect between the grid and plate.

Tube 14 is coupled by resistance 25 to amplifier tube 26, the output of the latter tube being coupled through resistance 40 and the tuned circuit 42—44 and grid condenser 45 to amplifier tube 31 to obtain a push-pull effect, and also to neutralize to some extent introduced harmonics, particularly those of the second degree. A variable tap 30 on the leak resistance 27 permits the proper value of grid potential to be impressed upon grid **33** so that the desired character of amplification will be obtained in tube **31**.

The flow of plate current of tube **26** through resistance **34** imparts to the right-shown end thereof (and hence to the filament of tube **26**) a potential positive with respect to ground. A less positive potential is applied to the grid **28** of tube **26** and to the plate **22** of tube **14** through resistances **25** and **35**. A positive potential also less than that of the filament of tube **26**, and as hereinabove mentioned even less than that of plate **22**, is maintained on screen grid **20** of tube **14** by virtue of screen grid current flow through resistance **21**. By virtue of plate current flow from tube **31** through resistance **36**, the filament of this tube is maintained at an intermediate potential positive with respect to ground, so that a relatively more negative potential is readily imparted from tap **30** onto the grid **33** of tube **31**, the positive potential on plate **32** being supplied through resistance **40** from D. C. supply B.

A resistance **40** in the plate circuit of tubes **26** and **31** gives a difference of potential across its ends which will vary as the plate current, and an oscillating circuit comprising condensers **41**, **42** and **43** and transformer winding **44** is connected across the resistance to transfer the radio frequency oscillations to the final transmitting amplifier **49**. A connection **46** taken from transformer winding **44** provides a path for the high frequency oscillations through condenser **45** back to the grid **33** of tube **31** for regeneration and high frequency control purposes. The output of the cascade amplifier is radiated from aerial **50**, after it has been transferred by transformer **48** to the final amplifier.

The operation of the circuit is as follows. The modulated, radio frequency carrier from aplifier **1**, having a form such as shown in Fig. 2, passes through the valve **7** which rectifies the greater part of the carrier above the line *o* of Fig. 2, and in so doing creates a difference of potential across resistance **9**. This also establishes a negative bias on the grid **15** of the first amplifier tube **14**, so that this biasing potential automatically varies in accordance with the strength or amplitude of the carrier wave, the bias becoming more negative as the carrier becomes stronger. It is true that the tube **7** eliminates the lower part of the rectified carrier above the line *o* in Fig. 2, but the modulation at the top of the carrier, in case the modulating audio frequency signal is of low amplitude (e. g., high frequency), as shown at *a* in Fig. 2, comes through with substantially the same wave formation as it had, and the modulated part will therefore pass to the grid of tube **14** with no material change. In the case, however, where the carrier is modulated by audio signals having a large amplitude (e. g., of low frequency) as indicated at *b* in Fig. 2, one half of the modulating signal causes a greater increase in the plate current of tube **7** than the corresponding opposite half on the rectified carrier which reaches into the bend of the characteristic curve of the rectifier, and this causes a much greater increase in the carrier frequency oscillation amplitude on tube **14** than is caused when the amplitude of the modulating audio signal is low.

This is shown graphically by Fig. 4, in which the variation in the plate current of tube **7** caused by a variation in the voltage impressed upon the plate is shown. The wave form *b* represents the variations in plate voltage due to the envelop of the modulated carrier and is symmetrical about the line *c* along the ordinate of the characteristic curve *f* of the rectifier. That half of wave *b* which is to the left of line *c* will cause only a small variation (shown by the portion of wave *d* below the line *e*) in the plate current because it is working in the bend of the curve *f*, but the positive half of wave *b* to the right of line *c* works on the straight line portion of curve *f* and causes a much greater increase in the plate current as shown by that portion of wave *d* above the line *e*, and thereby causes a much greater increase in the carrier frequency oscillation amplitude on the grid of tube **14** for the stronger audio signals. It may more properly be said that the wave *d* is bent out of proportion at one side with a rising amplitude of the carrier wave, because it is not a suppression of the peak of one half of the wave since this would introduce undesirable harmonics.

It is obvious in the curve *d*, which of course represents not only plate current of tube **7** but also grid potential on tube **14**, that the mean amplitude of the modulated carrier frequency oscillations impressed on tube **14** increases with the amplitude of the audio modulating wave; by the passage of these modulated carrier frequency oscillations through the succeeding amplifier this increase may be heightened, so that in the output the mean carrier frequency oscillation amplitude is substantially proportional to the amplitude of the audio modulating wave. This is explained as follows:

The mean negative potential on the grid of tube **14** of course rises with increasing modulating wave amplitudes. Accordingly the potential of its plate **22** and of the grid **28** of tube **26** is rendered increasingly positive. This increases the amplification in and plate current of tube **26**; and, in the by-passed system **34**—**21**, there are increased the drop across **34** and the positive potential of screen grid **20**, the latter action beneficially influencing the amplification in tube **14**. Thus in the amplifying system **14**—**26** the amplification is automatically controlled by the modulated carrier, and with proper apportionment of parameters there may be produced an output wave in which the mean carrier energy is substantially directly proportional to the modulating wave amplitude.

Amplifier tubes **14** and **26** are arranged to form a direct-coupled cascade amplifier. It is a peculiarity of such a circuit that the tube **26** may be worked with signals which are apparently above its normal capacity for undistorted amplification. The reason for this is that its bias is not constant, but is varying with the signal strength since it is dependent upon the plate current of tube **14**. Even though a high signal from tube **14** may tend to draw current from the grid of tube **26**, this produces only a minor disturbance, not only because of the bias re-adjustment just mentioned, but also because of the limitation of grid current by the high resistance through which potential is applied to the grid **28**.

Instead of impressing the audio signal on a strong carrier, the system described causes an increase in the energy of a relatively weak carrier wave in direct proportion to the audio signal so as to obtain a highly modulated carrier wave at all audio frequencies and intensities, and at any instant the average energy of the carrier is varying directly as the amplitude of the modulating audio signal. This is particularly advantageous because the high amplitude or low frequency audio signals require higher carrier amplitudes for transmission, and therefore a more powerful transmitting wave, than the low amplitude or high frequency audio signals to give the impression of the same loudness when received. Since a high percentage of modulation of the carrier is maintained, regardless of the frequency or amplitude of the modulating audio signal, this reduces the noise level of the transmitter.

Also, since the high amplitude and low frequency audio signals are comparatively rare and are employed but a small fraction of the total transmitting time, the transmitter is not radiating energy which is any stronger than necessary, and this tends to reduce disturbances and heterodyning between nearby transmitting stations, or between stations having similar wave lengths.

I believe the present method of transmitting radio energy is largely responsible for the inefficient reproduction of the receiver. The high frequency tuner of the receiver has to handle the heavy carrier wave when proportionately weak audio signals of high frequency are impressed on it, and if the amplification is high and the damping of the tuning circuit low, these feeble audio signals are partially lost. The circuits are set in heavy oscillation by the strong carrier, their damping being low, there is apparently nothing to damp their acquired oscillating energy and the small variation of the carrier strength is not able to suppress the oscillating energy of the circuit at higher audio frequencies. It is a fact that in operating a receiver with sufficient feedback to bring in a distant station, the receiver will suddenly start to oscillate if a heavy static disturbance occurs. What happens is that the feedback in the tube was suddenly increased on account of that sudden strong signal and that it continued oscillating after the input voltage had risen to a sufficiently high level so that the reaction of the output circuit could maintain the high amplitude oscillations. Therefore a highly excited high frequency system passing a strong carrier wave will change its damping effect to such an extent that it apparently suppresses the feeble signals of the high audio frequencies. Furthermore, it happens that the tubes in the third or fourth stage of the amplifier are often overloaded by the amplified strong carrier, and, therefore, the amplification of the slight modulation occurs outside the small straight line section of their characteristic curves, and will be less due to distortion. If the same receiver, however, obtained a weak carrier wave with approximately 100% modulation by the high frequency audio signal it would amplify it with less apparent sideband cutting, because the tubes would amplify the modulated part of the carrier more efficiently, that is, on the straight line part of their characteristics.

The above effect is particularly exaggerated in the detector portion of the circuit. It is well known that the sensitivity of a detector is highly dependent on its bias with regard to signal strength, and in most cases its bias should increase with increasing signal strength. In the method now in use, however, it has to detect a very weak audio signal on a very strong carrier wave and this it cannot perform. Its bias becomes very negative to handle the strong carrier and this makes it insensitive to the impressed audio signal, or if a high amplitude low frequency wave is impressed on the carrier the detector bias will not be enough, so that it will distort the lower audio frequencies, and/or suppress the high audio frequencies.

Finally, the amplified strong carrier wave is difficult to dispose of and by the ordinary means of efficiently by-passing will cause further leakage of the higher audio frequencies. If the strong carrier enters the audio amplification system, still more undesirable features occur.

The foregoing points out generally why the so-called, but wrongly explained, sideband cutting occurs in our selective receivers and this may be effectively counteracted by employing the principle of modulating carrier waves according to my invention.

Fig. 6 discloses a modification of the invention in which the voltage amplification of a crystal controlled radio oscillator and amplifier is caused to vary as the frequency and amplitude of the audio signal to be transmitted. In the system shown pentodes or five element tubes **55** and **56** are used in the amplifying steps of the high frequency transmitter. A characteristic of these tubes is that their amplification factor is increased with an increase of positive potential on their screen grids **57** and **58**, respectively. Therefore, their amplificator factor may be made to vary in accordance with the amplitude of the signal in the output circuit of the audio amplifier **61**.

In such a system the audio signal wave should be impressed upon the screen grids in such manner that with increasing audio amplitudes the positive potential of the screen grids should be built generally ascending in proportion with the increasing signal amplitude. In case the positive screen grids are operated at a potential higher than that which will give the highest amplification factor of the tube, the positive potential of the screen grids should, in a similar manner, be decreased with increasing audio amplitudes. Apparently the negative half of the audio wave should be less effective on the screen grid so that its effect on the screen grid potential is substantially less, and this is accomplished in the following manner. The output of the last amplifier tube **62** of an audio amplifier **61** is varied by a microphone **3** and impresses a varying difference of potential in accordance with the audio signal across impedance **63**. The impedance is coupled by means of condenser **64** and variable contact **65** on resistance **66** to the winding **68** of an iron core transformer **67**. The variable contact provides a means for maintaining a given potential on the screen grids **57** and **58**. The other winding **69** of the transformer is connected to a source of magnetizing current comprising a battery **70** so that the transformer core may be kept at or near the upper bend of its magnetic saturation curve, and this is the point at which the transformer works, its operating point being controlled by the variable resistance **71**.

The action of the transformer on the signal is shown graphically by Fig. 5 in which the magnetization curve m of the transformer core is plotted and in which flux density is plotted against the magnetizing current. At all points on the curve m to the right of the vertical line n it will be seen that a further increase in magnetizing current causes only a very slight increase in magnetization, that is, the core is saturated and the flux density through the core remains substantially constant after this point regardless of the increase in value of the magnetizing current. To the left of line n, however, the transformer works on the straight line portion of the curve m, and a small change in the magnetizing current causes a relatively large change in the magnetization, or in the flux density in the transformer core. With this performance the impedance of the transformer or its choke action to the audio signal is varied automatically.

The curve o represents the wave form of the audio signal across the impedance **63** and which is impressed upon the transformer winding **68**. That portion of the curve to the left of line n represents the negative half of the audio signal which changes the values of the magnetizing current to the left of line n, or below the saturation point of the core, and the flux flow through the core will vary, so that the inductive effect of winding **68** will choke back the signal and substantially prevent its passing.

The positive half of the signal curve o, however, which is to the right of vertical line n, has little effect upon the magnetization of the core, as shown by the portion of curve p which is above the horizontal line q, and therefore its inductive effect is relatively small, so that the signal will pass rather freely through the winding **68** to drop across the right-shown portion of resistance **66**. The result is that the positive half of the signal causes an appreciable variation in the potential at point **72**, and this potential passes through radio frequency choke **73** to the screen grids **57** and **58** of the pentode amplifiers to impress a more positive potential thereon which varies as the audio signal amplitude increases.

Plate screens **59** and **60**, having the same potential as the cathodes, are placed between the plates and screen grids to prevent interference or reaction of the plate circuit upon the screen grids. The operation of the remainder of the circuit will be apparent to those skilled in the art and need not be explained here.

It may be found that the variation in the amplification factors of the pentode tubes is not directly proportional to the signal wave amplitude, but follows more nearly a square law variation, and in this case the audio signal amplifier circuit may be arranged, by methods known to the art, so as to amplify more or less with increasing signal amplitudes, so that the total transmitted high frequency energy will be proportional to the sound waves influencing the audio amplifier.

It may be desirable in some cases to employ pentode tubes for the radio frequency amplifier with the plate screens **59** and **60** between the screen grid and plate disconnected from the cathode, so that their negative potential can be influenced simultaneously with the positive screen grid potential to arrive at the same effect, i. e., that the total voltage amplification of the radio frequency amplifier is directly proportional to the sound wave amplitude. In some cases to bridge apparent lack of efficiency of our receivers generally employed today, it may be even favorable to emphasize the low frequency audio signals.

It may also be desirable to use a type of amplifier tube operating with two emitting cathodes, in which one cathode operates with secondary emission, and whereby the amplification of the tube is controlled by the amount of emission from this second bombarded cathode, which bombardment from the first cathode is controlled by means of a second grid control.

I claim:—

1. The method of transmitting a high frequency carrier wave modulated with a complex audio signal composed of various frequencies at varying amplitudes which comprises creating a modulated high frequency wave the average energy of which over a period of several audio cycles remains substantially constant with or without modulation, rectifying this modulated high frequency wave and using trains of high frequency impulses to bias at audio frequencies the control grid of an amplifying tube through which the high frequency wave is passed, thereby suppressing the average amplitude of the unmodulated carrier and building up its average energy continuously and only once for each audio cycle of the modulating wave in direct proportion to its amplitude and creating a carrier the average transmitted energy of which during each cycle of the modulating audio wave remains substantially directly proportional to the instantaneous maximum amplitude of the modulating wave.

2. A transmitting system having means for generating a high frequency carrier wave, means for amplifying said wave, means for modulating said carrier wave with a complex audio signal of varying amplitude and frequency comprising additional amplifying means for said modulated carrier, and means for controlling the amplification thereof by said modulated carrier for increasing the mean value of energy of the carrier wave only once during each audio cycle of said signal continuously and substantially in direct proportion to the amplitude thereof.

3. A transmitting system comprising means for generating a carrier wave, a multiple grid amplifier tube one grid of which is used for amplifying said carrier at radio frequencies, a modulator for complex audio signals to be transmitted and means for impressing potentials corresponding to half-cycles of said signals on another one of said grids which is capable of changing the amplification factor of said tube thereby causing the carrier wave to increase its average energy only once during each audio cycle according to the amplitude of the audio signals, said means causing substantial suppression of the carrier when unmodulated.

4. The method of transmitting a highly modulated carrier wave which remains highly modulated with varying amplitudes and frequencies of the modulating audio signal at any instant during the transmitting period, which comprises the steps of generating a high frequency carrier wave of constant amplitude and frequency, modulating this carrier wave by a complex audio frequency wave thereby obtaining a modulated carrier wave of substantially constant average energy, selectively amplifying said modulated carrier wave so that the unmodulated portion thereof is suppressed and maintained at substantially constant amplitude while the modulated portion thereof is amplified only once and continuously during each audio cycle, and selecting the resulting highly modulated wave for transmission into space.

5. A transmitting system having means for generating a high frequency carrier wave, means for modulating said carrier wave with a complex audio signal of varying amplitude and frequency, amplifying means for said modulated carrier, and means responsive to said modulated carrier for controlling the amplification of said amplifying means for increasing the mean value of energy of the carrier wave only once during each audio cycle of said signal and without discontinuities, to render the output mean carrier energy sub-

stantially directly proportional to the amplitude of said audio signal.

6. The method of generating for transmission a highly modulated carrier wave which remains highly modulated with varying amplitudes and frequencies of the modulating audio signal at any instant during the transmitting period, which comprises the steps of generating a high frequency carrier wave of constant amplitude and frequency, modulating this carrier wave by a complex audio frequency wave thereby obtaining a modulated carrier wave of substantially constant average energy, and selectively amplifying said modulated carrier so that the unmodulated portion thereof is suppressed and maintained at substantially constant amplitude while the modulated portion thereof is amplified only once during each audio cycle and without discontinuities.

CARL J. R. H. VON WEDEL.