

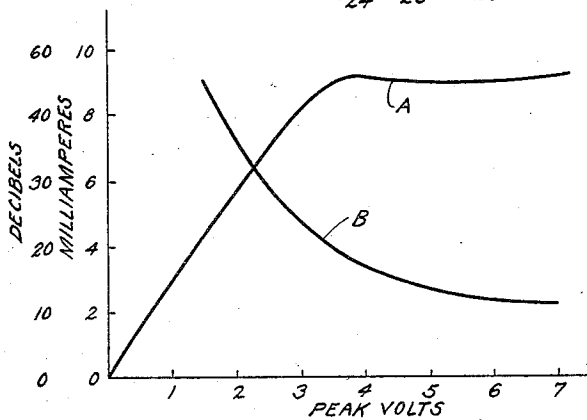
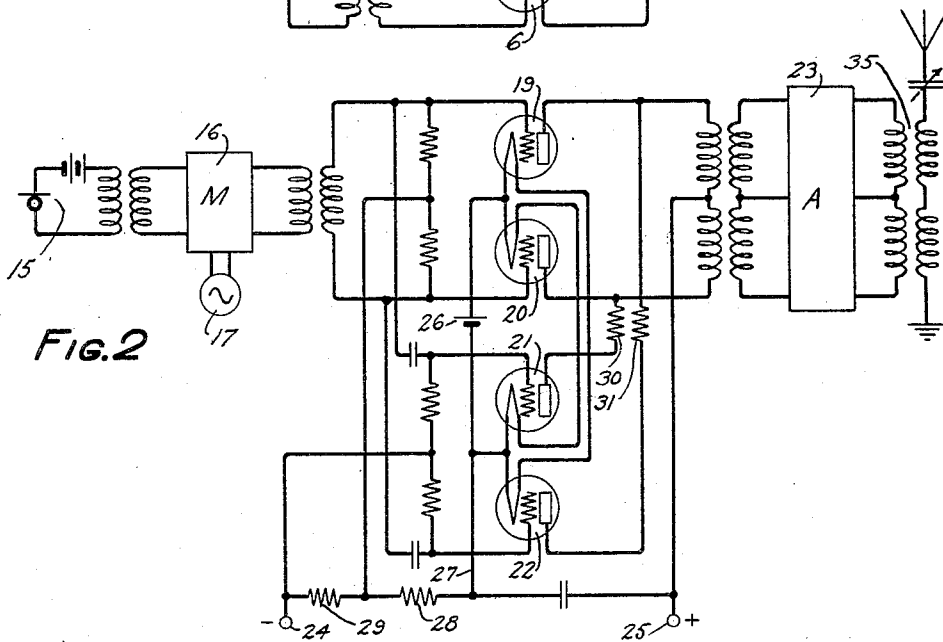
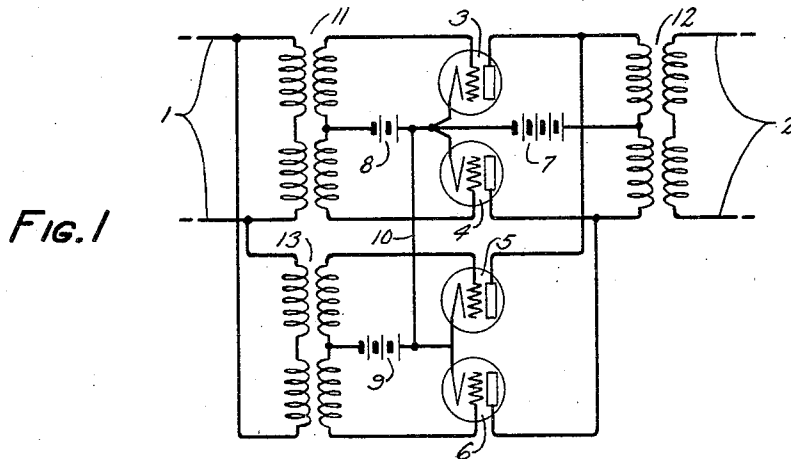
March 21, 1933.

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1,901,929

VOLTAGE LIMITING SYSTEM

Filed March 6, 1930



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VOLTAGE LIMITING SYSTEM

Application filed March 6, 1930. Serial No. 433,567.

This invention relates to signaling systems and more particularly to a method and means for limiting the voltage applied to a specific part of a transmission system.

5 In order to attain high efficiency in a transmission system it is necessary to operate certain elements, such as vacuum tubes, at nearly the maximum safe load. In order to do this and to prevent damage
10 to the tubes or other elements of the circuit, it is desirable to employ some means which will prevent high voltage peaks from reaching the high power tube stages or other apparatus to be protected.

15 Voltage limiters have been proposed in the past for protecting vacuum tube amplifiers from excessive voltages which might damage the apparatus. In the case of a radio telephone transmitting system, or other
20 signaling system, the requirements extend further than merely protecting the apparatus against excessive voltages. It has been found in practice that voltage limiting circuits which act very effectively from the
25 standpoint of protection may result in distorting the transmitted signal waves to an undesired extent. It is desirable that the voltage limiter should act not only to protect the circuit, but further, that it should
30 not interfere with the attainment of high quality of transmission of the speech or other signals.

It is an object of the present invention to prevent the application to a power amplifier, or the like, of voltage peaks in excess
35 of a predetermined limit while at the same time preserving a high degree of quality in the transmitted waves.

40 Further objects and features of the invention will be understood from the following detailed description in connection with the accompanying drawing in which Fig. 1 discloses basically in diagrammatic form an amplifying and voltage limiting circuit in
45 accordance with the invention, Fig. 2 shows schematically a radio telephone transmitting circuit in accordance with the invention, and Fig. 3 gives graphs showing certain relations characteristic of the invention
50 as will be described.

In the present invention two transmission paths are provided between an incoming circuit and an outgoing circuit, these paths co-operating to permit transfer from the incoming to the outgoing circuit of waves of
55 less than a predetermined voltage while sharply discriminating against and suppressing waves of higher voltage than the predetermined maximum. A system of this general character is disclosed in the U. S. patent to Oswald, 1,705,993 of March 19,
60 1929. The present invention, however, presents marked advantages over the system disclosed in the Oswald patent. In the Oswald patent, both of the two transmitting
65 paths provided between the incoming and the outgoing circuits are operative to transmit the signal waves in varying amounts for all values of applied voltage both lower and higher than the normal peak value.

70 The present invention differs mainly from the Oswald system in confining transmission between the incoming and outgoing circuits to but one of the two transmission paths for all values of input voltage lower
75 than the normal peak and causing both transmission paths to transmit waves only after the normal peak has been exceeded. The waves transmitted through both paths simultaneously are opposed in their effect
80 on the output circuit in the same general manner as in the Oswald patent. However, by not allowing both paths to transmit at any point in the voltage range below the
85 normal peak value it has been found that the quality of the system for radio telephone purposes is very materially raised without sacrifice of protection against the excessive applied voltages.

The invention also differs in specific ways
90 from the system of the Oswald patent as will be seen from the detailed description to follow.

Referring to Fig. 1, the incoming circuit 1 is shown at the left and the outgoing
95 circuit 2 at the right. Interconnecting these circuits is the normal transmission path comprising vacuum tubes 3 and 4 connected in balanced or push-pull relation. A second or auxiliary path is also connected be-
100

tween circuits 1 and 2, this path comprising vacuum tubes 5 and 6 also connected in balanced or push-pull relation.

The tubes 3 and 4 are provided with a plate or anode source 7 and a grid bias source 8, shown in the form of batteries, although any suitable source of supply may be used at both 7 and 8. The tubes 5 and 6 are provided with a grid bias source 9. A lead 10 interconnects the cathodes of all of the tubes, and the anode voltage for the tubes 5 and 6 is obtained from the source 7.

In operation, waves below a predetermined maximum peak voltage in circuit 1 are transmitted through input transformer 11 to the tubes 3 and 4 which may act as an amplifier to amplify the waves and impress them upon outgoing circuit 2 through output transformer 12. The circuit 2 leads to the power amplifier or other apparatus to be protected. The source 8 is adjusted in relation to the source 7 and the other constants of the circuit to cause the tubes 3 and 4 to operate at the desired point on the dynamic characteristic.

The waves in circuit 1 are also applied in part through input transformer 13 to the grid circuits of the tubes 5 and 6. However, the source 9 applies such a large negative biasing voltage to the grids of the tubes 5 and 6 that these tubes transmit no space current in response to any voltages present in circuit 1 below the value at which limiting is to take place.

Excessive voltage peaks, or voltages present in circuit 1 due to any cause, which exceed the normal limit swing the grid voltages of tubes 5 and 6 alternately so far positive on successive half waves as to permit the tubes 5 and 6 to transmit current.

The two input transformers 11 and 13 are so poled as to make the voltage phase of the grid of tube 3 opposite to that of the grid of tube 5 at any instant. Similarly the voltage is opposite on the grids of tubes 4 and 6 at any instant. It will be seen, therefore, that an excessive voltage in circuit 1 which tends to produce excessive current flow through the tube 3 also causes current to flow through tube 6. The space current which flows through the tube 3 flows (considering positive current) in a direction from the positive pole of source 7 upward through the upper half of the primary winding of output transformer 12, anode of tube 3, cathode of tube 3 and back to the negative pole of source 7. The space current through tube 6, however, flows from the positive pole of source 7 downward through the lower half of the primary winding of output transformer 12 and through tube 6 and connection 10 back to the negative pole of source 7. These currents in the primary of transformer 12 are mutually opposed to each other and this opposition results in

preventing production of excessive voltage peaks in circuit 2. Also by suitable design of coil 12, the anode voltages on the tubes 3, 4, 5 and 6 are prevented from rising to excessive values.

It will be understood that the voltage of source 9 is adjusted to the point such that tubes 5 and 6 begin to transmit current as soon as the voltage in circuit 1 exceeds, by any amount, the predetermined maximum limit. In effect therefore, tubes 5 and 6 may be considered as shunting off from the output of tubes 3 and 4 all current in excess of that corresponding to the maximum safe operating limits of the system.

The employment of push-pull circuits in the normal amplifier and auxiliary paths results in limiting both halves of the waves in symmetrical manner.

In the circuit of Fig. 1 the phase between the normal and auxiliary transmitting paths was reversed on the input side of the paths.

Fig. 2 illustrates a system in which the phase is reversed on the output side of the paths and in which the circuit details also differ somewhat from those of Fig. 1.

In Fig. 2 speech waves originating in the telephone circuit 15 are impressed on the modulator 16 which is supplied with radio or carrier waves from source 17, such as a vacuum tube oscillator or any other suitable source. The modulator 16 may be of any desired type and may be considered to include not only a modulator per se, but whatever preliminary amplifiers may be necessary, and if desired, a band filter for suppressing all output components except a single side band.

The speech side band produced in modulator 16 is applied to the input side of the power amplifier comprising vacuum tubes 19 and 20.

A portion of the input side band voltage waves is also applied to the input circuit of the auxiliary path comprising tubes 21 and 22.

The amplified side band waves are then transmitted on to the power amplifying and radio transmitting circuit. The power amplifier is not shown in detail but is diagrammatically indicated at 23. It may comprise any suitable type of amplifier circuit such as a push-pull vacuum tube amplifier the output of which is coupled as indicated to the transmitting antenna 35 which may be tuned to the signals being transmitted.

All of the space discharge devices 19 to 22 inclusive are supplied with anode voltage from a source whose terminals are indicated at 24 and 25. The filaments are supplied with filament heating current from source 26 and are connected to the plate source by lead 27. Resistance 28 in series with the space current circuit applies a negative grid bias to tubes 19 and 20 while this same resistance

and resistance 29 in series therewith apply a larger negative grid bias to the tubes 21 and 22.

5 Plate voltage for the tubes 21 and 22 is obtained from the sources 24—25, the connections to the respective anodes of tubes 21 and 22 including resistances 30 and 31 respectively.

10 So long as the impressed side band voltages are below the normal peak limits the tubes 21 and 22 transmit no space current. Tubes 19 and 20 then act to transmit the applied waves through to the power amplifier circuit, with amplification if desired.

15 Voltages in the output of the modulator in excess of the normal peak value cause space current to flow in opposite half cycles in the tubes 21 and 22 alternately. Due to the manner of connection of the input and output circuits, the tubes 19 and 20 are prevented from carrying excessive currents by the coming into play of the tubes 21 and 22 which draw current at the proper instants of time and in the proper amount to prevent transmission through to the power amplifier circuit of any voltages in excess of the permissible limit.

20 The resistances 30 and 31 are for the purpose of regulating the action of the tubes 21 and 22. If the resistances 30 and 31 are too small or are absent, the plate voltage fluctuations on tubes 21 and 22 are so great as to make the input-output voltage curve for the limiter as a whole droop for higher and higher excess voltage inputs. If the resistances 30 and 31 are too large, on the other hand, the characteristic for the system as a whole rises with increasing excessive voltages. With the proper value of resistances 30 and 31 together with the proper amount of grid bias for the auxiliary tubes 21 and 22 a substantially flat maximum output is obtained for inputs in excess of the predetermined limit.

25 Fig. 3 indicates observed characteristics of a power amplifying system in accordance with the invention. Curve A shows the relation between input and output voltages throughout a range of seven volts input where the normal maximum is $3\frac{1}{2}$ volts. The output voltage is seen to rise substantially linearly to the peak value of $3\frac{1}{2}$ and from there on to be substantially flat up to peak voltages twice as great as the normal maximum. Applicant has obtained experimental results indicating that it is possible to build a circuit of the type disclosed such that the output would be constant to within plus or minus $\frac{1}{2}$ db. over a range of inputs from that at which limitation begins up to at least 20 times that input.

30 Curve B shows the amount of third order modulation occurring in the output for various voltages. Curve B was obtained by impressing two voltages of equal amplitude

but slightly different frequency on the input circuit and measuring the amount of third order modulation appearing in the output when the amplitudes were simultaneously varied in the same direction. The third order distortion is seen to the more than 20 db. lower than the fundamentals for all inputs less than the normal peak input, to increase slowly for greater values of input and to reach about 12 db. at twice the normal input. In practice the higher distortion which occurs for larger inputs than normal is not serious because the signal will reach these high values only during a small portion of the time.

35 A characteristic of the circuit of the invention not shown by the curves of Fig. 3 is the stability as regards changes in filament or plate voltages. It has been found in practice that variations in filament voltage of plus or minus 20% will not appreciably affect either the gain or limiting action of the system. A variation in plate voltage between 113 and 135 volts produced negligible effect on the limiting action and changed the gain by only plus or minus 1 db.

What is claimed is:

1. The method of limiting the voltage impressed on an outgoing circuit from an incoming circuit comprising impressing voltages between said two circuits through a normal transmission path including a space discharge device, impressing on the output circuit of said device opposing voltages only at such instants of time as the voltages in the incoming circuit exceed the normal maximum, and controlling the magnitude of the opposing voltage to limit the voltages impressed on the outgoing circuit to substantially constant maximum value.

2. The combination with an incoming circuit and outgoing circuit of a transmission path for transmitting waves from the incoming circuit to the outgoing circuit, said path including a space discharge device, an auxiliary path connecting the incoming circuit to the output side of said discharge device and including another space discharge device, means for preventing said second mentioned discharge device from transmitting current in response to voltages in the incoming circuit less than a predetermined value, and means causing said second mentioned device to oppose production in the outgoing circuit by said first mentioned discharge device of voltages in excess of a predetermined maximum.

3. The combination with an incoming circuit and an outgoing circuit of a normal transmission path and an auxiliary transmission path each interconnecting said circuits and each comprising a pair of space discharge tubes connected in push-pull relation, the normal path serving to transmit waves of various amplitudes from the in-

coming to the outgoing circuit, the auxiliary path being inoperative to transmit waves of normal voltage or smaller but being operative to transmit to the outgoing circuit waves corresponding to the voltage peaks of greater amplitude than normal, and means to oppose the waves transmitted through the auxiliary path to those transmitted through the normal path.

4. The combination with an incoming and an outgoing circuit of a normal transmission path and an auxiliary transmission path each including a space discharge tube, each path being coupled to receive voltage waves from the incoming circuit and to impress the transmitted voltage waves on the outgoing circuit, certain of said couplings being reversed so that the output waves from the auxiliary path oppose those from the normal path, and a negative grid bias applied to the space discharge tube of the auxiliary path sufficient in magnitude to prevent transmission through the auxiliary path of waves except at the instants when abnormally high voltages are present in the incoming circuit.

5. In combination, a pair of space discharge tubes connected in balanced or push-pull relation, a second pair of space discharge tubes connected in balanced or push-pull relation, an incoming circuit coupled to impress voltage waves on the grid circuits of both of said pairs of tubes, an outgoing circuit coupled to the output circuits of both pairs of tubes, the second pair of tubes having their grids more negatively biased than those of the first pair of tubes by an amount corresponding to the normal peak voltage of the waves impressed on the grid circuits of both pairs of tubes, the couplings between the two pairs of tubes and the incoming and outgoing circuits being such as to oppose the output of the second pair of tubes to the output of the first pair of tubes as regards the transfer of waves into the outgoing circuit.

6. The combination with an incoming and an outgoing circuit of a normal transmission path for transmitting waves from the incoming to the outgoing circuit, said path comprising a pair of space discharge tubes connected in push-pull relation, an auxiliary transmission path also having its input side connected to the incoming circuit and having its output side associated with said outgoing circuit, said auxiliary path also comprising a pair of space discharge tubes connected in push-pull relation, a common cathode connection for all of said tubes, a common source of space current for all of said tubes, resistances connected in the anode circuits of the tubes in the auxiliary path for lowering the effective anode voltage of the tubes in that path with respect to the anode voltage of the tubes in the normal transmis-

sion path, means for biasing the grids of the tubes in the auxiliary path so far negative as to prevent transmission through the auxiliary path except at the instants when the voltage waves in the incoming circuit exceed a predetermined normal value, and circuit connections for opposing the waves transmitted through the auxiliary path to those transmitted through the normal path.

7. A radio telephone transmitting system comprising a modulating system for producing a speech side band of radio frequencies, a transmitting antenna, a power amplifier feeding into the said antenna, and a voltage limiting circuit for connecting the output of the modulating system to the input of said power amplifier, said voltage limiter having an input-output characteristic which is substantially linear for all input side-band voltages less than a predetermined normal peak value and which is substantially flat for input voltages in excess of said normal peak value.

8. In a transmission system, a voltage limiting circuit comprising two transmission paths having input and output circuits, a transformer common to said output circuits, said transformer having a divided primary winding, and means operative only in response to abnormally large voltage impressed on the input of said circuit to cause opposing currents to flow in the respective portions of said primary winding and prevent the terminal voltage across it from rising to excessive values.

9. A high-quality signal transmitting and voltage limiting circuit comprising a push-pull amplifier having an input and an output circuit, an auxiliary path also connecting said input and output circuits and comprising a pair of tubes in push-pull relation and biased to prevent transmission through them of signals in response to impressed signal voltages within the normal voltage range, whereby the system transmits waves in the normal voltage range as a high-quality push-pull amplifier circuit, said auxiliary path transmitting signal variations in response to impressed signals exceeding the normal voltage range, and means to oppose the signals transmitted through said auxiliary path to those transmitted through said push-pull amplifier such that the output voltage is substantially constant for input voltages in excess of said normal range.

In witness whereof, I hereunto subscribe my name this 5th day of March, 1930.

EUGENE PETERSON.