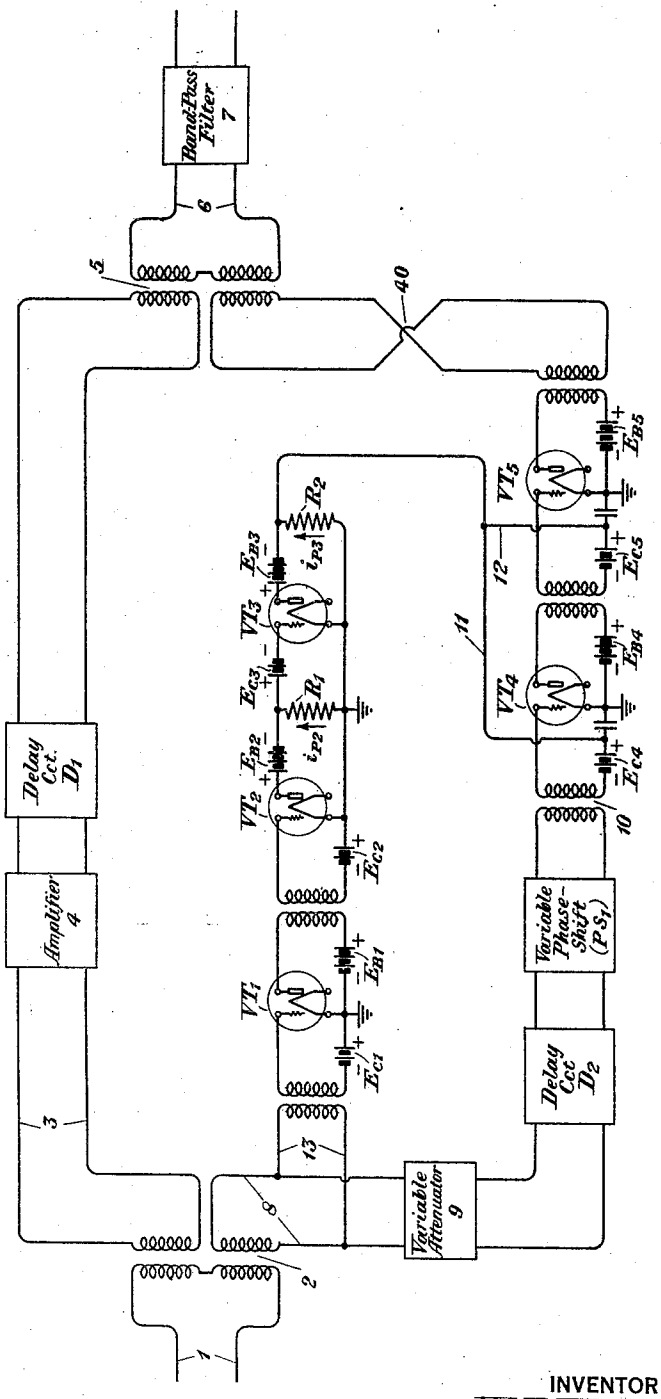
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POWER LIMITING APPARATUS

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## POWER LIMITING APPARATUS

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This invention relates to communication systems, and more particularly to a method of and means for limiting power or voltages applied to apparatus included in such systems.

A problem, which is of general occurrence in the communication art, particularly where high powered amplifiers are concerned, as in a radio transmitting station, is that of preventing overload of vacuum tube or other devices in the circuit, which causes distortion of the signals and may cause breakdown of tubes due to excessive voltages. This invention presents a novel method of and means for the solution of problems of the above general type.

In a transmission system utilizing the power limiting method and arrangements of this invention, the signal transmission path will be divided into two branches. Through one of these branches, provided with an amplifier and a delay circuit, the signals pass in the ordinary way. The other path is so arranged by means of vacuum tube circuits that for values of signals below the desired cut-off point, little or no power is transmitted through it, thereby leaving the first path to be normally the dominant one. The vacuum tube arrangement of the second branch is such that when the signalling power approaches the point at which cut-off is desired, the transmission effectiveness of the second branch increases. By placing the output circuits of the two branch paths in opposition, this transmission at the higher levels through the second branch is made to oppose the normal transmission through the first branch, thereby effecting a limiting value of the overall transmission through the circuit.

In a number of the voltage limiting methods of the prior art, the main transmission path is through the limiting element of the circuit. One of the outstanding differences in principle between methods and arrangements of the prior art and the method and arrangements of this invention lies in the fact that the main transmission path in the arrangements of this invention is distinct from the variable circuit elements. This fundamental difference between the voltage limiting methods of the prior art and those herein described makes it possible in the utilization of this method to greatly reduce the tendency for the voltage limiting arrangements to introduce distortion in the signals. Other features and objects of the invention will appear more fully from the detailed description thereof hereinafter given.

The invention may be more fully understood from the following detailed description thereof, together with the accompanying drawing in the figure of which is shown a circuit diagram embodying a preferred form of the invention.

In the drawing is shown a section 1 of a transmission line. This line section is divided by transformer 2 into two branch sections 3 and 8. Line section 3 is the main transmission path and includes an amplifier 4 and a delay circuit $D_1$. It is connected through transformer 5 to an out-put line section 6 which may include filter apparatus 7. The line section 8 includes a variable attenuator 9, a delay circuit $D_2$, a variable phase shifter $PS_1$, a transformer 10 and an amplifier comprising the vacuum tubes $VT_4$ and $VT_5$. The output of this amplifier is connected through transformer 5 to the output circuit 6. It is pointed out that at a point such as 40 in the output of the amplifier the conductors will be turned over. This is to secure phase opposition in transformer 5 between the currents in circuits 3 and 8. The gain through this branch path 8 is variable, its value being low and substantially constant for all input signals less than the predetermined safe value, and increasing as the input signal increases above this safe value. By suitable adjustments of the variable phase shift device $PS_1$, the signals from this branch path 8 add to the signals from the main path 3 at exact phase opposition in transformer 5, so that the combined signals in the output path 6 will increase as the input increases up to a safe value, and remain substantially constant or decrease for further increases of the input.

The gain of the amplifier containing tubes

$VT_4$ and $VT_5$ is varied by changing the grid bias on these tubes. The grid bias is supplied in part from the detector-amplifier system comprising detector tube $VT_2$ and amplifier tube $VT_3$. This detector-amplifier is connected by the tube $VT_1$ and the circuit 13 in parallel with the input circuit 8 of tube $VT_4$ and $VT_5$.

If we write the plate current of $VT_2$

$$i_{P2}=I_{P2}+\triangle i_{P2}$$

where $I_{P2}$ is the plate current of this tube under the condition of no input signal, and $\triangle i_{P2}$ the increase in current due to the rectification of the signal, the voltage at the grid of $VT_3$ is

$$e_{g3}=-[E_{c3}+I_{P2}R_1+\triangle i_{2}R_1]$$

The plate current of $VT_3$ is

$$i_{P3}=I_{P3}-\triangle i_{P3}$$

where $I_{P3}$ is the plate current of $VT_3$ when its grid voltage is $-[E_{c3}+I_{P2}R_1]$ and $\triangle i_{P3}$ is the change in plate current caused by the change in grid voltage by the amount $\triangle i_{P2}R_1$. The biasing voltage at the grid $VT_4$ is

$$e_{g4}=-[E_{c4}+I_{P3}R_2-\triangle i_{P3}R_2]$$

and at the grid of $VT_5$

$$e_{g5}=-[E_{c5}+I_{P3}R_2-\triangle i_{3}R_2]$$

Accordingly, it is evident that the bias on the tubes $VT_4$ and $VT_5$ is large with no signal at the input of this device and that it decreases as the signal is increased. It is possible then to so apportion the battery potentials and the resistances in these circuits so that the gain of the amplifier comprising in part tubes $VT_4$ and $VT_5$ is small for signal inputs below a definite value and increases for increase in input thereafter. By this method and means the power or voltage applied to the output line section 6 may be limited to a desired value.

The delay circuit $D_2$ is included between the rectifier input and the amplifier input circuits so that a large peak of voltage may change the gain of the amplifier comprising tubes $VT_4$ and $VT_5$ before it is transmitted through this amplifier. The delay circuit $D_1$ retards this same voltage peak by the amount of the total delay in the other branch path so that it reaches the transformer 5 at the same instant through both paths. The variable phase shifter $PS_1$ allows small variations in the transmission time so that the phase difference between the two paths actually is 180 degrees so that the signals through the two paths substract. The amplifier 4 is included in the path 3 to prevent singing in the circuit.

Using the specific method of this invention for changing the gain of the variable gain amplifier $VT_4$, $VT_5$, the distortion produced in this amplifier is large when its gain is small and small when its gain is large. When the distortion of this amplifier is large, however, the output from it is small compared to the signal in the other transmission path. Accordingly, the overall distortion produced by these arrangements is comparatively small. The band-pass filter 7 in the output circuit serves to remove all these components of the resultant distortion which do not fall back into the transmitted band.

Since the limiting action in the voltage limiting device of this invention is produced by a difference method, it is evident that the distortion in the output signal is materially less when the limiting is accomplished by the method of this invention rather than with former methods heretofore referred to. To further illustrate this fact, suppose that the input signal is 10 per cent. greater than the safe value (say 1.10 $E_s$, where $E_s$ is the safe voltage). The limiting circuit must supply a bucking voltage equal to .10$E_s$ to reduce the output to the safe value. Even if the limiting branch of the circuit distorts the applied signal very badly, so much so that its output contains 50 per cent. distortion components, the actual distortion in the output is only .10$E_s$ x .5 or 5 per cent. As the limiting branch is called upon to supply an increasing bucking voltage, the distortion in it as a circuit element decreases, so that the overall distortion over the entire limiting range is low. The use of the method of the invention greatly decreases the residual distortion by virtue of the differential principle no matter what is the means used to reduce distortion in the non-linear amplifying portion of the voltage limiter.

While the arrangements of the invention have been referred to as applicable to a high frequency radio system, it is pointed out that they are applicable to other types of transmission systems. For example, they might be applied to volume control in voice frequency circuits, provided a proper network were provided in the rectifier circuit so that the change in gain would be delayed by an amount greater than the syllable period preventing operation on any except permanent changes in volume. Accordingly, while the invention has been disclosed as embodied in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many other forms without departing from the spirit of the invention as defined by the appended claims.

What is claimed is:

1. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be lim-

ited, one of said branch circuits transmitting waves of all amplitudes applied to the system without substantial distortion, and means to substantially prevent transmission over the other branch until the applied potentials bear a predetermined relation to the potential to which the outgoing circuit is to be limited, whereby when the applied potentials are below the predetermined potential transmission to the outgoing circuit takes place exclusively from said first branch and when the applied potential exceeds said predetermined potential the resultant waves transmitted over the second branch substantially compensate for the wave excess transmitted over said first branch.

2. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branch circuits transmitting waves of all amplitudes applied to the system without substantial distortion, means to substantially prevent transmission over the other branch until the applied potentials bear a predetermined relation to the potential to which the outgoing circuit is to be limited, and means to cause the waves in said second branch to be opposite in phase to the waves in said first branch, whereby when the applied potentials are below the predetermined potential transmission to the outgoing circuit takes place exclusively from said first branch and when the applied potential exceeds said predetermined potential the resultant waves transmitted over the second branch substantially compensate for the wave excess transmitted over said first branch.

3. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branch circuits including an amplifier having uniform gain for waves of all amplitudes applied to the system, and an amplifier in the other branch circuit having means controlled by the voltage applied thereto so that transmission over the second branch is substantially prevented until the potentials applied to the second amplifier bear a predetermined relation to the potential to which the outgoing circuit is to be limited, whereby when the applied potentials are below the predetermined potential transmission to the outgoing circuit takes place exclusively from said first branch and when the applied potential exceeds said predetermined potential the resultant waves transmitted over the second branch substantially compensate for the wave excess transmitted over said first branch.

4. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branch circuits including an amplifier having the same gain for waves for all amplitudes applied to the system, a vacuum tube amplifier in the second branch, and means for changing the grid bias of said second amplifier in accordance with the input voltage of said second amplifier to substantially prevent transmission over said branch until the applied potentials bear a predetermined relation to the potential to which the outgoing circuit is to be limited, whereby when the applied potentials are below the predetermined potential transmission to the outgoing circuit takes place exclusively from said first branch and when the applied potential exceeds said predetermined potential the resultant waves transmitted over the second branch substantially compensate for the wave excess transmitted over said first branch.

5. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branches including an amplifier having substantially the same gain for waves of all amplitudes applied to the system, an amplifier in the second branch, a rectifier circuit in parallel with said second branch, and means for connecting the rectifier output to the amplifier in said second branch to so control the gain thereof as to substantially prevent transmission over said second branch until the applied potentials bear a predetermined relation to the potential to which the outgoing circuit is to be limited, whereby when the applied potentials are below the predetermined potential transmission to the outgoing circuit takes place exclusively from said first branch and when the applied potential exceeds said predetermined potential the resultant waves transmitted over the second branch substantially compensate for the wave excess transmitted over said first branch.

6. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branches including an amplifier having the same gain for waves of all amplitudes applied to the system, an amplifier in said second branch having its grid normally so biased as to substantially prevent transmission until the applied potentials bear a predetermined relation to the potential to which the outgoing circuit is to be limited, a rectifier circuit in parallel to the second branch, said rectifier circuit being so associated with the amplifier in said second branch as to change the grid bias of said amplifier in response to the applied

waves to render said amplifier effective to produce in its output waves whose amplitude is equivalent to the excess amplitude of the input waves applied to the system, whereby when the applied potentials are below the predetermined potential transmission to the outgoing circuit takes place exclusively from said first branch and when the applied potential exceeds said predetermined potential the resultant waves transmitted over the second branch substantially compensate for the wave excess transmitted over said first branch.

7. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branch circuits including an amplifier having the same gain for waves of all amplitude applied to the system, an amplifier in the second branch, and means associated with said second amplifier and responsive to applied waves to render the gain of said second amplifier high when the voltage applied thereto is high, and low when the voltage applied thereto is low.

8. A voltage limiting apparatus comprising two branch circuits having their outputs connected in opposing relation to an outgoing circuit in which the voltage is to be limited, one of said branch circuits including an amplifier having the same gain for waves of all amplitude applied to the system, an amplifier in the second branch, and means associated with the amplifier in said second branch and responsive to applied waves to control the gain of said amplifier so that the gain of said amplifier will be high when the voltage applied thereto is substantially above a limiting voltage, and low when the voltage applied thereto is substantially below a limiting voltage.

In testimony whereof, I have signed my name to this specification this 13th day of May, 1929.

WILLIAM T. WINTRINGHAM.