Sept. 19, 1933. E. PETERSON 1,927,070

DISTORTION CORRECTION IN WAVE TRANSMISSION SYSTEMS

Filed Feb. 27, 1932

FIG. 1

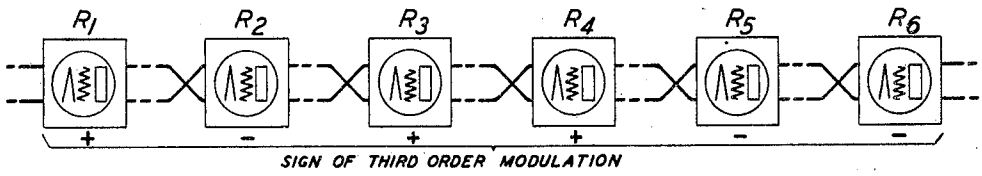


FIG. 2

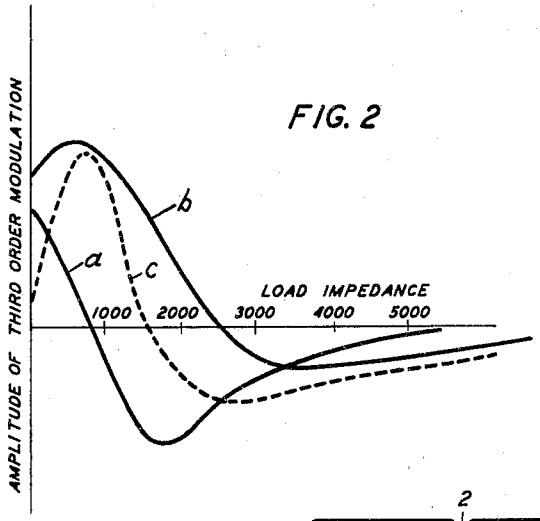
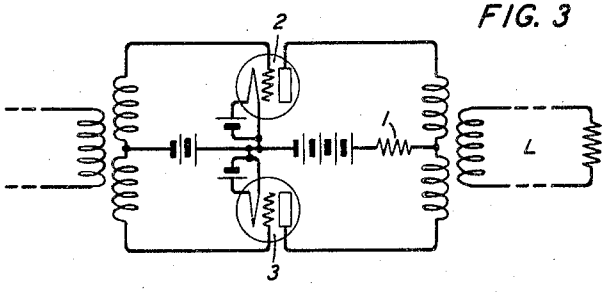


FIG. 3



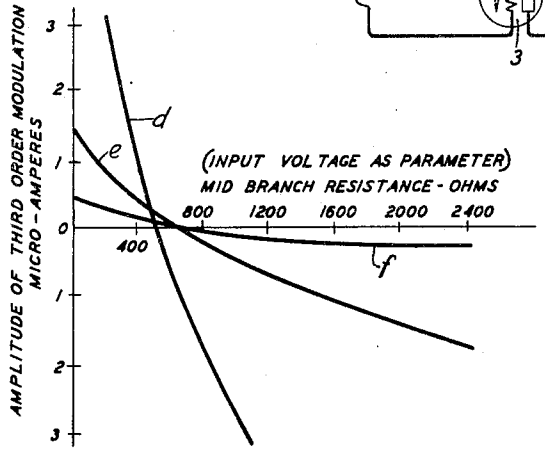


FIG. 4

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DISTORTION CORRECTION IN WAVE TRANSMISSION SYSTEMS

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7 Claims. (Cl. 179—171)

This invention relates to electrical transmission and particularly to the reduction of distortion incident to the transmission of electrical waves over systems employing space discharge devices as transmission elements therein, for example, vacuum tube amplifiers.

It is well known that the electric space discharge devices employed in signaling systems, because of inherent distortion characteristics, produce in their output circuits certain modulation products in addition to the waves of the frequencies which are impressed on their input circuits. Thus, when a wave of a single frequency is impressed on the input circuit of a space discharge device, the output circuit will contain a wave of the fundamental frequency and other waves of frequencies harmonically related to the fundamental. If a complex wave, that is, one composed of a plurality of frequencies, is impressed on the input circuit of the space discharge device, the output circuit of the device will contain waves of frequencies harmonically related to the frequencies of the impressed waves, waves having frequencies equal to the sum and difference of the respective fundamental impressed frequencies, and various higher order modulation components.

When a space discharge device is utilized in a signaling system for a certain purpose, for example, amplification, it is desirable from the standpoint of quality in transmission that the effects of all modulation products produced in the output circuit of the device be minimized. As the effects on quality of transmission of the modulation products of orders higher than the third are usually negligible compared to the effects of the second and third order modulation products, if the third and second order products present are eliminated or reduced to a negligible volume by suitable means, the system for all practical purposes is made distortionless.

In a long, non-loaded signal transmission line having small phase distortion, comprising N identical, equally spaced repeaters, the third order modulation output is made up of the arithmetical sum of the modulation in the N repeaters. The third order modulation output at the end of the line is, therefore, N times as large, with respect to the fundamental, as it is in a single one of the repeaters. The same holds true for second order and for other orders of modulation. This factor obviously imposes stringent modulation requirements in the design of the individual repeaters, which requirements are more and more difficult to meet as the number of repeaters in the line increases.

An object of the present invention is to control modulation in signal wave transmission systems.

A related and more specific object is to reduce the effects of modulation, including both odd and even orders, in a signaling system comprising a plurality of vacuum tube transmission devices, for example, vacuum tube repeaters.

In accordance with the invention, modulation distortion in a signaling system comprising a plurality of vacuum tube transmission devices, is minimized by so selecting the vacuum tubes therein and adjusting their circuit characteristics as to produce randomness in sign of both third order and even order modulation outputs of the individual transmission devices.

The invention will be better understood from the following detailed description thereof when read in connection with the accompanying drawing in which:

Fig. 1 shows diagrammatically a long signaling system comprising a plurality of vacuum tube repeaters connected in tandem and embodying the invention;

Fig. 3 shows schematically one type of vacuum tube repeater which is adapted to be used in the system of Fig. 1 to accomplish the objects of the invention; and

Figs. 2 and 4 show characteristic curves of typical vacuum tube amplifiers illustrating the invention.

The U. S. patent to Nyquist No. 1,570,770, issued January 26, 1926 discloses a method which has been found practical for reducing even order modulation in a system comprising a plurality of vacuum tube repeaters connected in tandem. This is accomplished by poling successive repeaters in the system oppositely. Because the even order distortion components have a phase angle which is an even multiple of the phase of the fundamentals, the even order components retain their original phase when the fundamentals are reversed in phase. Thus, if the polarity of a repeater is reversed, for example, by reversing the input or output leads to the repeater tubes, as indicated by the crossed leads between the successive vacuum tube repeaters R_1, R_2, R_3, etc. in the system of Fig. 1, the phase of the even order modulation products with respect to the fundamental changes by 180 degrees. By properly poling all of the repeaters R_1, R_2, . . . R_N, half may be made to have even order modulation of one sign and the other half even order modulation of the opposite sign, so that a random distribu-

tion of signs exists. If this is done, the even order modulation output, for example, the second order modulation output at the end of the line will be only $\sqrt{N}$ times larger than the probable even order output of a single one of the repeaters. However, the odd order modulation products are not affected by the poling of the repeaters.

Heretofore, in connection with a study of modulation in vacuum tubes, due to the variation of the amplification factor, μ, and of the internal plate resistance, Ro, it has been found that the characteristics of certain types of vacuum tubes are such that the sign of the third order modulation changes as the load impedance is varied from small to large values due to the summation of μ and Ro modulations of opposite sign. In some tubes, the point of zero third order modulation was found to be not far from the matching resistance of the tube. The variation in the amplitude of third order modulation for the two space discharge devices of this general type in a balanced vacuum tube amplifier, with load impedance is shown in curves *a* and *b*, respectively, in Fig. 2. The summation of the currents represented by these two curves is shown by a curve *c* which passes through the zero axis at a load resistance of approximately 1500 ohms indicating that the third order products of the two tubes are of opposite phases. The curves of Fig. 2 were taken from Landeen Patent 1,722,099, issued July 23, 1929.

In a batch of tubes having the above mentioned characteristics, manufacturing variations inevitably occur so that it may not always be feasible to set the operating point of each tube or pair of tubes in a balanced amplifier for zero third order modulation output. However, an operating point can be readily chosen for all of the tubes in the batch such that the distribution of third order modulation among them is approximately random in sign and amplitude. If tubes of the type described are used in the repeaters R_1, R_2, R_3, . . . R_N, in the system of Fig. 1 and the load impedances thereof are adjusted properly so that the sign of the third order modulation products of approximately half of them is opposite to that of the other half, the third order modulation output of the system may be reduced by $\sqrt{N}$, where N is the number of repeaters, compared to that obtained by the use of other tubes having the same absolute value of modulation but lacking the randomness in sign. If then the even order modulation output of the system is reduced to a negligible value by poling the successive repeaters oppositely so that the even order modulation produced by half of the repeaters is balanced by the even order modulation of opposite sign produced by the other half of the repeaters, the modulation output of the system is greatly reduced.

The invention is not limited to the use of tubes of the characteristics described above for obtaining the randomness in sign and amplitude of the third order modulation products, which impose certain limitations on the load impedance, which in some cases may be undesirable. Other methods of obtaining the randomness in sign and amplitude of the third order modulation products which are independent of the load impedances and which apply to all types of tubes may be used. For example, the method used may be that shown in the copending application of J. G. Kreer, Jr., Serial No. 595,502, filed February 27, 1932 which discloses that the sign of the third order modulation produced in any three-electrode space discharge device may be made to change from positive to negative sign by merely changing the value of an impedance element or elements in the external circuits connecting the electrodes (not the load circuit) of the device.

Fig. 3 shows a preferred embodiment of this method applied to a balanced vacuum tube amplifier circuit, taken from the Kreer application. As described in detail in the Kreer application, by suitable choice of the value of the resistance element 1 in the common branch of the output circuit of the balanced amplifying tubes 2 and 3 the sign and amplitude of the third order modulation products transmitted to the load circuit L may be controlled in the desired manner.

The curves *d*, *e* and *f* in Fig. 4, taken from the Kreer application, show the variation in amplitude and sign of third order modulation with variation in the mid-branch resistance for three different input voltages in a balanced vacuum tube amplifier circuit corresponding to that of Fig. 3 employing Western Electric Company No. 104–D vacuum tubes. Similar curves may be obtained by using any other types of tubes.

In the operation of the system of Fig. 3, the impedance of the load circuit L may be set at the optimum value from the standpoint of maximum power output or other considerations and then the value of the resistance 1 in the mid-branch may be chosen so as to give the desired magnitude and sign to the third order modulation products transmitted to the load circuit. It is apparent that if amplifier circuits such as shown in Fig. 3 are used in the repeaters R_1, R_2, . . . R_N in the system of Fig. 1 a simple adjustment of the output mid-branch resistance in the several repeaters will give the desired randomness in sign and amplitude of the third order modulation products.

Although this invention has been described in connection with particular types of vacuum tubes, and with specific types of repeater circuits, it is not limited to these types of tubes or circuits but is capable of broad application and is to be limited only by the scope of the appended claims.

What is claimed is:

1. In a wave transmission system comprising a plurality of wave transmission devices including one or more electric space discharge tubes, the method of reducing the effects of modulation due to the distortion characteristics of said tubes which consists in so selecting the constants of the circuits associated with said space discharge tubes that the odd order modulation outputs of certain of said devices are of opposite sign and of approximately the same order of magnitude and poling said devices so that at least a portion of the even order modulation products of certain of said tubes is effectively neutralized by those of other tubes.

2. In a signal wave transmission system comprising a plurality of wave transmission devices including one or more electric space discharge tubes, the method of reducing the effect of modulation components of the transmitted signals produced by said tubes, which consists in selecting for the tubes in certain of said devices ones of the types in which the third order modulation changes sign for different values of load impedance, and adjusting the load impedances for the various tubes of that type so that the third order modulation of certain tubes are ef-

fectively neutralized by the third order modulation of others.

3. A high quality signal wave transmission system comprising a plurality of wave changing devices certain of which contain one or more electric space discharge tubes, certain of said tubes being of the type in which the sign and magnitude of the odd order modulation changes for certain different values of load impedance, and the respective load impedances of said certain tubes being selected so that the certain odd order modulation products of some tubes are effectively neutralized by those of others.

4. A high quality signaling system comprising a plurality of vacuum tube repeaters connected in tandem, certain vacuum tubes in a plurality of said repeaters being of the type in which the sign and magnitude of the third order modulation output depends on the value of the associated load impedance, and the values of the load impedances of said certain tubes being such as to produce such distribution of signs and magnitudes in their third order modulation outputs that the third order modulation of certain repeaters is effectively neutralized by that of others and means for poling said repeaters so that at least a portion of the second order modulation products of certain repeaters is effectively neutralized by those of other repeaters.

5. A high quality signal wave transmission system comprising a plurality of wave repeating devices connected in tandem certain of which devices include one or more space discharge tube amplifying elements comprising input and output circuits, the impedance of at least one of said circuits for at least one of said elements being chosen to make the third order modulation produced thereby of such sign and amplitude as to neutralize effectively the third order modulation produced by other elements.

6. A signal wave transmission system comprising a signal line and wave repeating devices at various points along said line, each device comprising two space discharge devices having portions of their input and output circuits in common and a resistance element in the common portion of the output circuits of the two tubes for each device, the values of the resistance elements being chosen so as to make the third order modulation outputs of a portion of said devices effectively opposite in sign to those of the remaining portion and of such magnitude relative to the magnitudes of the third order modulation outputs of said remaining portion as to reduce the third order modulation at the output of said line to a negligible amount.

7. A signal wave transmission system comprising a signal line and wave repeating devices at various points along said line, each of said repeating devices comprising two space discharge amplifying tubes having their input and output circuits connected in push-pull relation, a resistance element in the common portion of the output circuits of the two tubes in each repeating device, the value of the resistance elements being chosen of such value to make the third order modulation outputs of a portion of said repeating devices effectively opposite in sign to those of the remaining portion and of such magnitude relative to the magnitudes of the third order modulation outputs of said remaining portion as to reduce the third order modulation at the end of said line to a negligible amount, and said repeaters being poled with respect to said line so that at least a portion of the even order modulation products generated by the space discharge tubes in certain repeaters is effectively neutralized by those generated by the tubes in other repeaters.

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