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KEYSTONE MODULATION SYSTEM

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Fig. 1.

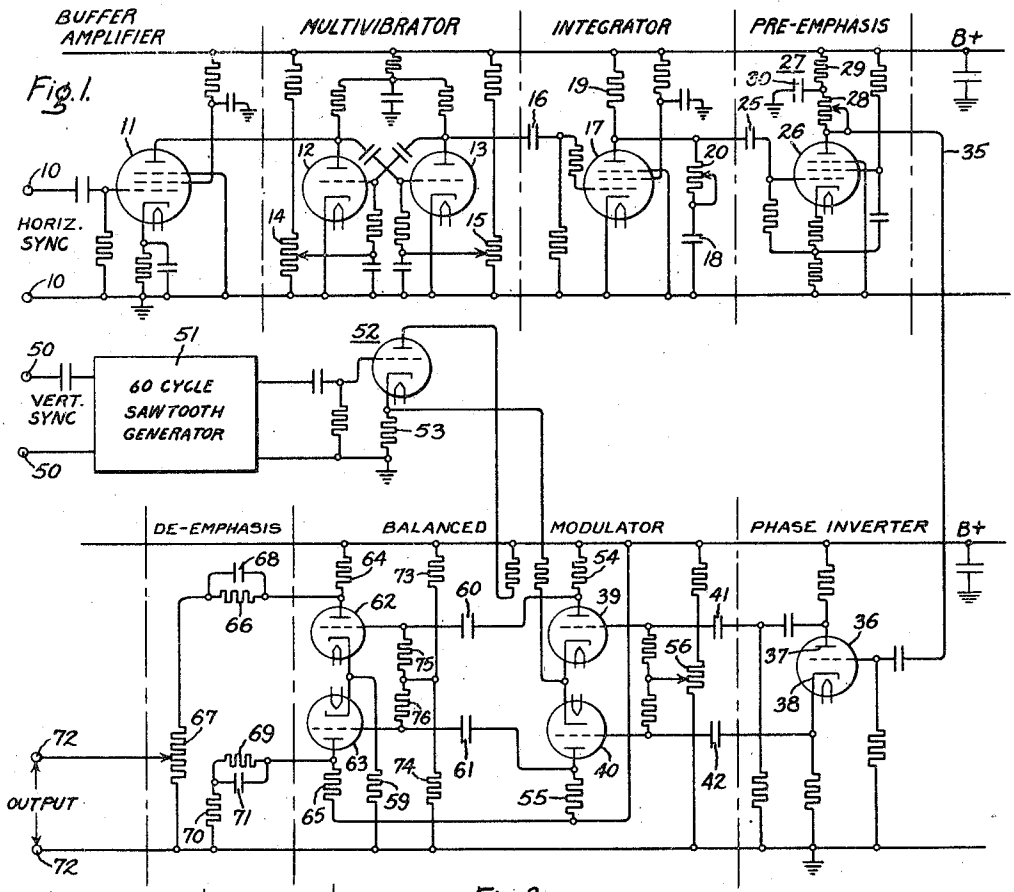
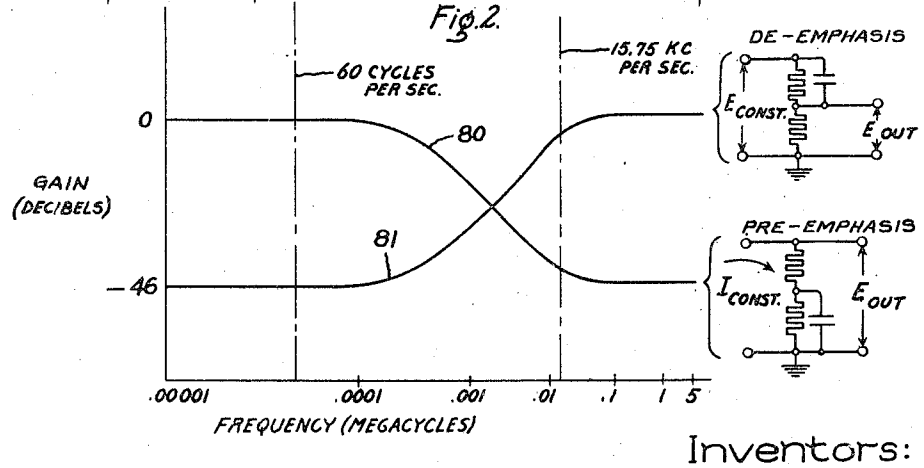


Fig. 2.



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KEYSTONE MODULATION SYSTEM

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6 Claims. (Cl. 332—37)

1

Our invention relates to modulation systems and particularly to a keystone modulation system for use in conjunction with television camera deflection circuits.

Present television standards require that a rectangular picture area in the television camera tube be scanned at a uniform rate. The horizontal, or line, scanning deflection must be a wave which provides uniform scanning velocity at a fundamental repetition rate of 15,750 cycles per second, with approximately 10% retrace or flyback time; and the vertical, or field, scanning wave must be a wave providing uniform scanning velocity at a fundamental frequency of 60 cycles per second, with approximately 3% retrace or flyback time. In the type of television camera tube commonly known as the iconoscope, the axis of the electron beam which scans the rectangular sensitive target area, is not perpendicular to the target. Therefore, in order to scan each horizontal line at the same rate, it is necessary that the amplitude of the horizontal scanning wave be modulated by the vertical scanning wave. Otherwise, so-called keystone distortion of the image signal results. Therefore, this modulation is commonly called keystone modulation.

The specific problem is thus one of modulating a 15,750-cycle deflection wave by a 60-cycle sawtooth wave. Various systems have heretofore been developed for accomplishing this. However, it has been found that the resultant wave usually contains, besides the modulated 15,750 cycle deflecting wave, some components of the modulating wave including a 60-cycle component and harmonics thereof. As is well known to those skilled in the art, the presence of any such components causes the scanning of the iconoscope target to be distorted from the desired rectangular pattern.

Previous attempts to solve the problem of removing the unwanted 60-cycle component and harmonics thereof have led to the use of either filtering circuits or balancing circuits. The use of filtering circuits alone has been found to be inadequate, due to the nature of the two waves involved. The harmonics of the undesired 60-cycle wave and the sidebands of the desired modulated wave are too close together in frequency for a filter of practical design effectively to eliminate the undesired components and yet avoid phase distortion of the desired frequency components. In the case of balancing circuits, there are serious practical difficulties in maintaining conditions of sufficiently exact balance to eliminate the undesired frequencies.

2

Very briefly stated, our invention combines desirable features of both these types of circuits in a novel manner such that one supplements the other, providing an over-all result which is completely satisfactory. The modulation system embodying our invention utilizes both balanced modulator and coordinated filter circuits. The high frequency wave to be modulated is first passed through a pre-emphasis network of particular frequency and phase shift characteristics, before impressing it on a balanced modulator. The modulator output is then supplied through a de-emphasis network having such frequency and phase characteristics as to just compensate for the effect of the first network on the output waveform. The second filter network is also designed to be particularly effective in attenuating the unwanted fundamental frequency and harmonics of the low frequency modulating wave, so that any slight unbalance in the modulator has only a negligible effect upon the resultant output wave.

Stated in general terms, it is a main object of our invention to provide an improved system for modulating the amplitude of a relatively high frequency wave of complex waveform in accordance with a relatively low frequency wave without introducing either the low frequency wave or disturbing the waveform of the resultant modulated wave.

Still another object of our invention is to provide an improved system for modulation of the high frequency scanning wave supplied a television camera tube in accordance with the low frequency scanning wave.

More specifically, it is an object of our invention to provide an improved system for modulating the amplitude of the horizontal scanning wave, supplied to a television camera tube of the iconoscope type, in accordance with the vertical scanning wave, in order to eliminate keystone distortion.

Another object of our invention is to provide an improved balanced modulator capable of operation over a very wide band of frequencies.

For additional objects and advantages, and for a better understanding of the invention, attention is now directed to the following description and accompanying drawings, and also to the appended claims in which the features of the invention believed to be novel are particularly pointed out.

In the drawings, Fig. 1 is a schematic circuit diagram, partially in simplified block form, of a keystone modulation system embodying our in-

vention; and Fig. 2 illustrates characteristic curves and simplified circuit diagrams relating to certain filter networks employed in the system of Fig. 1.

In the system of Fig. 1, horizontal synchronizing pulses, recurring at the 15,750-cycle rate, are supplied to the input terminals 10 of a buffer amplifier 11 from a suitable master pulse generator or other source, not shown. The amplified synchronizing pulses are applied to synchronize the operation of a conventional multivibrator comprising a pair of triodes 12 and 13. This multivibrator may for example be of the type more fully described in Patent 2,338,395, Bartelink, granted January 4, 1944 and assigned to the same assignee as the present invention. As is well known, this multivibrator may be adjusted to produce a square wave having a desired pulse width by proper adjustments of the positive bias potentials impressed on the respective grid circuits of the devices 12 and 13. These bias potentials are supplied from potentiometers 14 and 15 connected in a circuit across the common power supply source, represented conventionally by the upper bus marked B+ and the lower grounded bus. For example, in accordance with present television standards, the 15,750-cycle positive-going pulses appearing at the anode of device 13 are adjusted to have substantially 10% pulse width.

The output pulses are supplied through coupling capacitor 16 to a well-known form of integrator circuit, or deflection wave generator, comprising a pentode 17 and a sweep capacitor 18. The operation of this circuit will readily be understood by those skilled in the art without detailed description. Suffice it to say that the sweep capacitor 18 is charged from the common power supply source through resistors 19 and 20 and is recurrently discharged by the pentode 17 when it is rendered conductive by the applied 10% pulses. This results in the generation of a 15,750-cycle linear sawtooth wave having a 10% retrace or flyback time, under the assumed conditions. Where the output wave is to be supplied to a magnetic deflection system, a rectangular pulse component is also introduced into the waveform by adjustment of the tap on a resistor 20, for reasons which are well known and which are not material to an understanding of the operation of the present invention. The sweep wave thus developed across the capacitor 18 and resistor 20 is the horizontal or line scanning wave which must be amplitude-modulated before application to the horizontal deflection circuits in order to prevent the keystone distortion previously described.

The output of the integrator is supplied through coupling capacitor 25 to a pentode amplifier 26 having a pre-emphasis network 27 as its anode load impedance. The pre-emphasis network 27 comprises an adjustable resistor 28 and a fixed resistor 29 in series, as well as a capacitor 30, which is connected effectively in parallel to resistor 29 for reasons that will shortly appear.

The output wave appearing across the pre-emphasis network 27 is supplied over conductor 35 to a phase inverter 36 in which it is converted to a pair of push-pull, or out-of-phase, output waves appearing respectively at the anode 37 and cathode 38, as will readily be understood by those skilled in the art. These output waves are then supplied input terminals of a balanced modulator which includes a pair of modulator tubes 39 and 40 having their grid circuits energized in push-pull from the output of the phase inverter 36 through coupling capacitors 41 and 42 respectively.

Vertical synchronizing pulses, supplied from the master pulse generator or other source (not shown), are supplied to the input terminals 50 in Fig. 1. Assuming that the field scanning rate is 60 C. P. S., in accordance with present practice, these vertical synchronizing pulses are utilized to synchronize the operation of a 60-cycle sawtooth generator 51 having approximately a 3% retrace or flyback time. The 60-cycle linear sawtooth waves are impressed upon the input circuits of the modulator tubes 39 and 40 in parallel, through the coupling stage 52. Stage 52 provides a low impedance input to the modulator across a cathode load resistor 53 which is also common to the grid circuits of the devices 39 and 40. The operating bias voltage on the grids of tubes 39 and 40 is determined by the difference in voltage drops across resistor 53 and the lower portion of a bleeder potentiometer 56. Potentiometer 56 is preferably adjusted to provide a net bias negative with respect to ground.

Through the operation of the modulator tubes 39 and 40, push-pull, or out-of-phase, output waves appear across the anode load resistors 54 and 55, having the same form as the 15,750-cycle waves supplied through the capacitors 41 and 42, but modulated in amplitude in accordance with the 60-cycle sawtooth wave supplied across the coupling resistor 53. If the anode voltages were impressed on a push-pull output transformer, those skilled in the art would readily recognize this as a conventional balanced modulator circuit in which the components of the modulating wave may be substantially cancelled out in the transformer output. However, due to the wide band of frequency components present in the complex scanning waves involved, the use of a coupling transformer is not practical. Hence, the balanced modulator also includes a differential amplifier, in accordance with our invention, comprising electron discharge devices 62 and 63 having their grids coupled to the output of devices 39 and 40 through coupling capacitors 60 and 61 respectively. The input coupling networks to the amplifiers 62 and 63 are symmetrical. Suitable grid bias potentials are impressed on amplifiers 62 and 63 from bleeder resistors 73 and 74 through respective resistors 75 and 76.

In the differential amplifier 62, 63, the in-phase components of the 60-cycle modulating wave are almost completely balanced out, due to the action of a relatively large unbypassed cathode resistor 59 which develops a highly degenerative voltage. However, the modulated 15,750-cycle scanning waves are supplied in push-pull, or out-of-phase, relation and hence produce no net degenerative voltage across resistor 59. They, therefore, cause substantial currents to flow in devices 62 and 63, resulting in the development of voltages across the respective anode resistors 64 and 65.

The modulated waves are impressed on respective de-emphasis networks which are electrically identical to provide properly balanced loads for amplifier 62, 63. One network comprises series resistors 66 and 67, in shunt to load resistor 64 and the internal plate resistance of tube 62, and a capacitor 68 in shunt to resistor 66. The other network comprises series resistors 69 and 70, in shunt to load resistor 65 and the internal plate resistance of tube 63, and a capacitor 71 in shunt to resistor 69.

The amplitude-modulated line-frequency scanning waves appear across both de-emphasis networks, so the output may be taken from either or both of them. Since only a "single-ended" output is desired in the illustrated embodiment of the invention, the ressitor 67 is illustrated as a potentiometer connected to output terminals 72. The terminals 72 may be connected to the horizontal deflection amplifier for an iconoscope camera tube (not shown) in conventional manner.

If the balanced modulator 39, 40, 62, 63 could be maintained perfectly balanced at all times, the output waveform would not contain the 60-cycle component or any harmonic present in the 60-cycle sawtooth modulating wave. However, in any practical balanced modulator system the amplitude of the modulating wave must be relatively great as compared to the amplitudes of the sideband components in the output wave. Therefore, even a very slight unbalance in the modulator will cause undesired components of relatively large magnitude to appear at the output. In most keystone correction systems, this produces a skew component in the scanning pattern, distorting it.

The manner in which the pre-emphasis and de-emphasis networks cooperate with the balanced modulator to eliminate the unwanted frequency components, and to reduce distortion to a negligible value, will be better understood by reference to the characteristic curves and equivalent network diagrams of Fig. 2.

The gain-frequency characteristics of the pre-emphasis network 28, 29, 30 is represented by the curve 80 in Fig. 2. The gain in decibels (neglecting the insertion loss) is plotted as ordinate against frequency as abscissa. A logarithmic frequency scale is used in view of the wide range of frequencies involved.

The pre-emphasis network is supplied with the high frequency deflection wave at substantial constant current, since the internal impedance of the pentode amplifier 26 is very high as compared to its load impedance. The network constants are suitably proportioned so that at low frequencies, of the order of the fundamental frequency of the vertical sweep, the capacitor 30 has substantially no effect and the output voltage of the network is substantially equal to the input voltage. However, at high frequencies of the order of the fundamental frequency of the horizontal sweep wave, the output voltage is substantially proportional to the resistance of resistor 28. The network also introduces a predetermined amount of phase distortion, that is, there is decreasing phase shift, or time delay, at the higher frequencies. This phase shift is, of course, modified slightly by the effect of stray circuit capacities at very high frequencies, but the shift is approximately linear over the necessary operating range of frequencies so that no harmful effect results from this condition.

The balanced modulator 39, 40, 62, 63 eliminates most of the 60-cycle component of the modulating wave, as well as harmonics thereof, in the manner previously described. The modulator does not substantially distort the high frequency wave. The potentiometer 56 is preferably adjusted for class AB_1 operation of tubes 39 and 40, that is, each tube operates within limits of grid current and grid cutoff.

The de-emphasis networks are each proportioned to have a gain-frequency characteristic as represented by curve 81 in Fig. 2. It will be observed that this curve is exactly complementary to curve 80. In each network, the internal impedance of the triode 62 or 63, shunted by load resistance 64 or 65, must also be taken into account in the network design. The network characteristics are adjusted to be the inverse of those of the pre-emphasis network associated with pentode 26. At low frequencies, output voltage across resistor 68 is substantially proportional to the ratio of the resistance of resistor 68 to the sum of the resistances of the resistors 68 and 69. However, for the higher frequency components of the deflecting wave, the capacitor 70 effectively short-circuits resistor 69 so that the output voltage is substantially equal to the input voltage. It can also easily be shown that the phase shift characteristics of the entire network are the inverse of those of the pre-emphasis network. For further details on the general design and characteristics of such networks per se, reference may be made to Reissue Patent 22,306, granted April 27, 1943, to Donald E. Norgaard, and assigned to the same assignee as the present invention.

The de-emphasis network is therefore very effective in attenuating any residual components of the 60-cycle modulating wave appearing at the modulator output, and it also restores the waveform of the resultant modulated wave substantially to the same form that it had at the input to the pentode 26 which drives the pre-emphasis network.

A number of significant circuit constants are given in the table below which have been found satisfactory in a practical keystone modulation system embodying our invention. These values, of course, are to be regarded as purely illustrative, and not as limiting.

Tube 26: Type 6SJ7
Tubes 62, 63: Type 6SN7GT
Resistor 28=2,200 ohms (adjustable)
Resistor 29=56,000 ohms
Capacitor 30=.01 microfarad
Resistors 64 and 65=18,000 ohms
Resistor 68=4,700 ohms (potentiometer)
Resistor 69=1 megohm
Capacitor 70=.001 microfarad

While a specific embodiment has been shown and described, it will, of course, be understood that various modifications may be made without departing from the invention. The appended claims are therefore intended to cover any such modifications within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A system for modulating the amplitude of a first complex wave of relatively high frequency in accordance with a second complex wave of relatively low frequency, comprising a first frequency-selective translating network having an input supplied with said first wave, said network providing at its output a low attenuation at said low frequency and a substantially greater attenuation at said high frequency, a balanced modulator having carrier wave input terminals, modulation wave input terminals and modulated wave output terminals, means supplying the output of said network to said carrier wave input terminals, means supplying said second wave to said modulation wave input terminals, and a second frequency-selective translating network having an input supplied from said modulator output terminals, said second network having in-

verse attenuation characteristics at said two frequencies substantially complementary to those of said first network.

2. A system for modulating the amplitude of a first wave of relatively high frequency in accordance with a second wave of relatively low frequency, comprising a first frequency-selective translating network having an input supplied with said first wave, said network having a decreasing gain-frequency characteristic over a range between said two frequencies, a balanced modulator having carrier wave input terminals, modulation wave input terminals and modulated wave output terminals, means coupling the output of said network to said carrier wave input terminals, means supplying said second wave to said modulation wave input terminals, and a second frequency-selective translating network having an input supplied from said modulator output terminals, said second network having an increasing gain-frequency characteristic over said range.

3. A system for modulating the amplitude of a first wave of relatively high fundamental frequency in accordance with a second wave of relatively low fundamental frequency, comprising a pre-emphasis network supplied with said first wave, said network consisting of linear resistance and capacitance elements and providing at its output a decreasing phase shift and increasing attenuation with increasing frequency, a balanced modulator having carrier wave input terminals, modulation wave input terminals and modulated wave output terminals, means supplying said output to said carrier wave input terminals, means supplying said second wave to said modulation wave input terminals, a de-emphasis network supplied from said modulated wave output terminals, said de-emphasis network consisting of linear resistance and capacitance elements and providing at a pair of load terminals an increasing phase shift and decreasing attenuation with increasing frequency, whereby said low frequency and principal harmonics thereof are substantially prevented from appearing at said load terminals.

4. A keystone modulation system for the line scanning circuits of a television camera tube, comprising a first source of sawtooth waves of line frequency, a second source of sawtooth waves of field frequency, a pre-emphasis network consisting of linear resistance and capacitance elements, said network being coupled to said first source and providing at its output a decreasing phase shift and increasing attenuation over a frequency range extending from said field frequency to said line frequency, a balanced modulator having carrier wave input terminals, modulation wave input terminals and modulated wave output terminals, means coupling said output to said carrier wave input terminals, means coupling said second source to said modulation wave input terminals, a de-emphasis network consisting of linear resistance and capacitance elements, said de-emphasis network being coupled to said modulated wave output terminals and providing at its output an increasing phase shift and decreasing attenuation over said frequency range substantially complementary to the phase shift and attenuation of said pre-emphasis network, whereby said field frequency and principal harmonics thereof are substantially eliminated from said modulated wave, and means coupling the output of said de-emphasis network to said line scanning circuits.

5. A keystone modulation system for the high frequency deflection circuits of a television camera tube, comprising a first source of high frequency waves, a second source of low frequency sawtooth waves, a balanced modulator comprising a pair of grid-controlled electron discharge devices, a pre-emphasis network having substantial attenuation at said high frequency, means for impressing waves from said first source through said pre-emphasis network on the inputs of said devices in push-pull, means for impressing waves from said second source directly upon said inputs in parallel, means for deriving high frequency sawtooth waves from the outputs of said devices, said last waves being amplitude-modulated by said low-frequency sawtooth waves, a de-emphasis network having substantial attenuation at said low frequency, and means for supplying said modulated waves through said de-emphasis network to said high-frequency deflection circuits.

6. A balanced modulator for operation over a wide band of signal frequencies, comprising a first pair of electron discharge devices having grid and anode circuits, means for impressing symmetrical, out-of-phase, carrier waves upon the respective grid circuits, means for impressing a modulating wave upon said grid circuits in the same phase, whereby out-of-phase components of the amplitude-modulated carrier wave and also in-phase components of the modulating wave appear in the respective anode circuits, a second pair of electron discharge devices having control electrode and output circuits, and means comprising symmetrical coupling networks for coupling each of said anode circuits to one of said control electrode circuits, said second devices having individual symmetrical load impedances in said output circuits and having an unbypassed common cathode resistor, whereby said in-phase components are substantially cancelled by degeneration and only said out-of-phase components appear in said output circuits.

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No references cited.