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ductive sleeve member and placed coaxially therewith and conductively connected to said ground plane establishing member, a positionable annular conductive disc placed within said second conductive sleeve member for conductively joining the first and second sleeve members, an external energy operative device, transmission line means transferring energy between said first conductive sleeve member and the energy operative device, and means positioning said rod antenna and the annular conductive disc to obtain optimum operation of the rod antenna at a selected frequency.

6. A tunable antenna system operable over a wide frequency range comprising; a ground plane member, a rod antenna adjustable in extension outwards of said ground plane member to a maximum extension position, a capacitive loading member fixedly supported outwards of the tip of said antenna at its maximum extension position, and a conductive collar coaxially aligned with said antenna and extending from said loading member inwards of the tip of said antenna at its maximum extension position, said collar having a bore adapted to enclose an increasing antenna portion with increasing antenna extension, said collar thereby capacitively coupling said loading member and said antenna in controllable degree.

7. A tunable antenna system substantially set forth as in claim 6 in which the collar has a truncated end section inwards of the capacitive loading member.

8. A tunable antenna system operable over a

wide frequency range comprising; a ground plane member, a rod antenna adjustable in extension outwards of said ground plane member to a maximum extension position, a dielectric sleeve mounted on said member and enclosing said antenna, said sleeve extending outwards from said member to an extremity at least flush with the tip of said antenna at its maximum extension position, a capacitive top loading plate affixed to the outer extremity of said sleeve, and a conductive collar coaxially aligned with said antenna and extending from said loading member inwards of the tip of said antenna at its maximum extension position, said collar having a bore adapted to enclose an increasing antenna portion with increasing antenna extension, said collar thereby capacitively coupling said loading plate and said antenna in controllable degree.

9. A tunable antenna system substantially set forth as in claim 8 in which the collar has a truncated end section inwards of the top loading plate.

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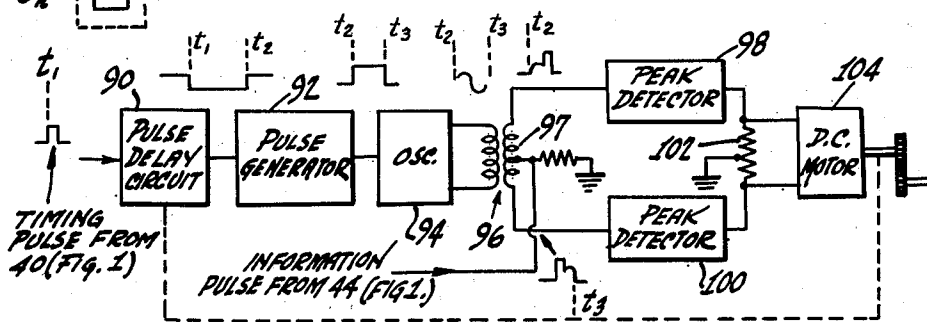
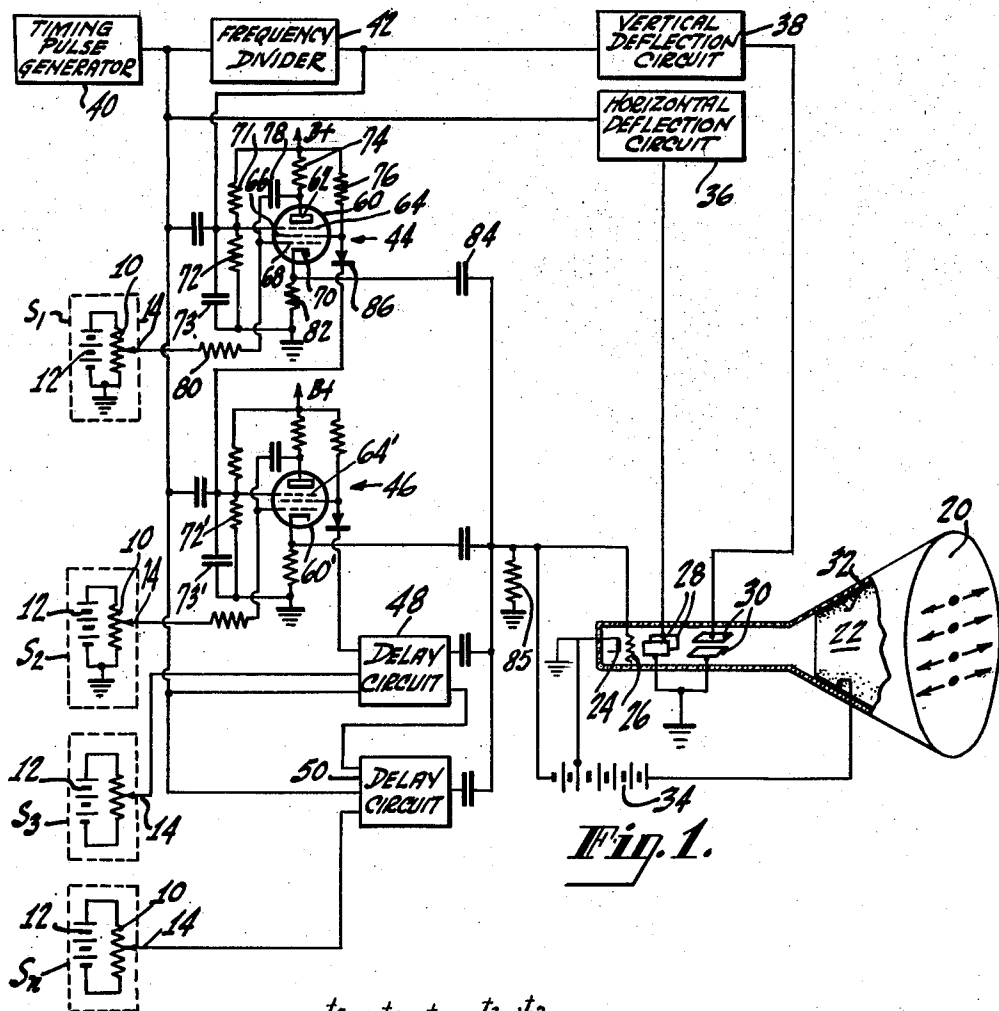
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MULTICHANNEL TELEMETERING
APPARATUS

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This invention relates to improvements in multichannel telemetering apparatus, and particularly to apparatus for conveying a plurality of information voltages from a point of origin to a utilization device.

Our present invention is similar in some respects to that disclosed in our copending application, Serial No. 80,848, filed March 11, 1949, and assigned to the same assignee as the present invention. As is described in said copending application, there are many instances in which it is expedient to make continuous measurements of a plurality of varying or variable quantities or conditions within a system or apparatus, and to have a concurrent display of data representing the measured conditions, or to make the measured data available in a form suitable for actuating control devices or the like. Familiar examples of multiple data display systems include aircraft instrument panels, electronic equipment indicators and the like, while equally well known automatic control systems include fuel-flow regulators, voltage control devices, etc.

In the case of electrical equipment, voltages indicative of operation conditions within the apparatus are usually taken at critical points and utilized to actuate indicating, recording, or control devices, while in the case of mechanical equipment, it is common practice to convert such quantities into alternating or unidirectional information voltages (the term "information voltage" being used herein and in the appended claims to designate a voltage which is proportional in magnitude to a varying or variable quantity or condition) which actuate various utilization devices.

Where data display or recording is involved, a separate indicator or recorder is usually provided for each of the information voltages. This is not only inconvenient for an observer, but also requires considerable space where a large number of quantities are involved, and where it is necessary to telemeter the information voltages, individual connections are required between the sending and receiver stations for each information voltage, or an individual frequency must be assigned to each quantity where the telemetering is accomplished by radio means.

In brief, in the majority of prior art methods and systems for handling a plurality of information voltages, each voltage is handled separately throughout the particular operation involved. It is a general object of our present invention to provide an improved apparatus for handling a plurality of information voltages concurrently.

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Another object of our invention is to provide improved apparatus for concurrent visual display of a plurality of information voltages.

According to our invention, the foregoing and other objects and advantages are attained by converting a plurality of information voltages into recurring pulse groups wherein the time-position of each pulse represents the instantaneous magnitude of one of the information voltages. The time position of each information pulse is established with respect to a time-reference pulse from a timing pulse generator, there being one such time reference pulse for each information pulse in any given group of information pulses. As will be described, the time reference pulses and the information pulses can be utilized to actuate an indicator, such as a cathode ray tube indicator, to actuate a recorder, or to actuate automatic control devices.

A more complete understanding of the invention can be had by reference to the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawings, wherein:

Figure 1 is a schematic diagram of an apparatus for data display in accordance with the invention, and

Figure 2 illustrates an automatic control device suitable for use with the apparatus shown in Fig. 1.

Our invention will first be described in connection with an apparatus for presenting a concurrent display of a plurality of information voltages on the screen of a cathode ray tube. Referring to Fig. 1, the apparatus includes a plurality of information voltage sources S_1-S_n which, for simplicity, have been shown as a group of potentiometers 10, connected in parallel with batteries 12, and having movable contact arms 14. The position of each of the contact arms 14 is controlled by a condition responsive device (not shown), such as a pressure responsive diaphragm, a temperature responsive bimetallic element, or any similar device. It will be understood that the voltage sources S_1-S_n could as well comprise A. C. voltage sources with rectifier elements for converting A. C. to D. C. voltage, and that if the apparatus shown is being used in connection with an electrical system, the information voltages would ordinarily be obtained from critical points in the equipment itself, without need for the intermediate sources S_1-S_n .

In accordance with the present embodiment of the invention, a concurrent indication of the relative magnitude of each of the information volt-

ages from the sources S_1-S_n is to be made on the screen 20 of a cathode ray tube 22. The tube 22 includes a cathode 24, an intensity control electrode 26, horizontal and vertical beam deflecting plates 28, 30, and an anode 32, with the cathode 24, the control electrode 26, and the anode 32 being connected to an operating voltage source, such as a battery 34. For a reason to be given hereinafter, the bias voltage on the control electrode 26 preferably is made sufficiently negative to normally prevent the beam from producing any indication on the screen 20 of the tube 22.

Horizontal and vertical deflection voltage circuits 36, 38 are connected to the deflecting electrodes 28, 30 in the tube 22 for controlling the deflection of the cathode ray beam. The deflection circuits 36, 38 comprise sawtooth voltage generators, of conventional design, for generating voltages which vary linearly with time to cause the cathode ray beam to scan the screen 20 in two directions at right angles to each other. For convenience, the directions of beam deflection are referred to herein as "horizontal" and "vertical," although it will be understood that the absolute deflection direction will depend on the orientation of the tube 22.

In order to synchronize the operation of the deflection voltage circuits 36, 38, as well as the remaining portions of the apparatus, a timing pulse generator 40 is provided which will generate a continuous train of equally spaced voltage pulses. The pulse generator 40 is connected directly to the horizontal deflection circuit 36, in order to produce one horizontal scan of the cathode ray beam for each pulse from the timing generator 40, while a frequency divider 42 is connected between the pulse generator 40 and the vertical deflection circuit 38 in order that the cathode ray beam will be deflected vertically at a rate sub-harmonically related to the horizontal beam-scanning rate.

As thus far described, the apparatus of Fig. 1 is adapted to produce a multi-line scan of the cathode ray beam in the tube 22, although, as was mentioned, no indication will be produced on the screen 20 of the tube 22 due to the negative voltage on the intensity control electrode 26 of the tube 22. If an intensifying voltage pulse is supplied to the control electrode 26 of the tube 22 during any one horizontal scan of the cathode ray beam, a spot of light will appear on the screen 20 at a distance from the edge of the screen 20 depending on the time interval between the beginning of that particular horizontal scan and the occurrence of the intensifying pulse. In accordance with our invention, each horizontal scan of the cathode ray beam is arbitrarily assigned to one of the information voltages from the sources S_1-S_n . An intensifying pulse is supplied to the control electrode 26, during each horizontal scan, at a time dependent on the magnitude of the information voltage to be presented during that particular scan.

The intensifying pulses for the cathode ray beam are obtained from pulse-output time delay circuits 44, 46, 48, 50 connected one to each of the information voltage sources S_1-S_n . The pulse output time delay circuits 44-50 may comprise so-called "one-shot" or "start-stop" multivibrators, so-called "phantastron" circuits, or any one other type of pulse output time delay circuits, the term pulse-output time delay circuit being used herein and in the appended claims to designate a circuit which will gen-

erate an output pulse of voltage at a controlled time interval after the circuit has been triggered by a time reference pulse of voltage. The delay time of each of the pulse-output time delay circuits is made a function of the magnitude of the information voltage associated therewith.

In order that any given information pulse will always occur during the proper horizontal scan of the cathode ray beam, it is necessary that the time delay circuits be triggered in a predetermined sequence, in synchronism with the sequentially related horizontal scanning lines of the cathode ray beam. In the modification of the invention shown in Fig. 1, this is accomplished by utilizing phantastron circuits as pulse-output time delay circuits, and coupling the phantastron circuits in cascade in a novel manner so that no one delay circuit can be triggered until after triggering of the preceding delay circuit. Since the general principles of operation of an individual phantastron circuits are well known (see e. g. Handbook of Industrial Electronic Circuits—Markus and Zeluff, 1948, pg. 243), and since the circuits 44-50 are substantially identical, the following description will be limited to a discussion of these details of one phantastron circuit 44 relating to the effect of the cascade coupling between the first and second phantastron circuits, 44 and 46, respectively.

The first phantastron circuit 44 contains a pentode tube 60 having an anode 62, a suppressor grid 64, a screen grid 66, a control grid 68, and a cathode 70. The suppressor grid 64 is connected to the voltage supply source (not shown-designated "B+") through a voltage divider network 71, 72, the anode 62 is connected to the voltage supply through a load resistor 74, and the screen grid is connected to the voltage supply through a load resistor 76. The control grid 68 is connected to the anode 62 through a coupling capacitor 78, and is also connected to the information voltage source S_1 through an isolating resistor 80, while the cathode 70 is returned to ground through a resistor 82. A capacitor 73 is connected across the resistor 72 to stabilize the voltage on the suppressor grid 64. The circuit 44 has a stable condition of operation in which current flows from the cathode 70 to the screen grid 66. Current is prevented from reaching the anode 62 due to the fact that the suppressor grid voltage is more negative than the cathode voltage. Consequently, when the circuit 44 is in this stable condition, the voltage at the anode 62 is equal to the B+ voltage for the apparatus, while the voltage on the screen grid 66 is considerably lower than the anode voltage due to the voltage drop across the screen load resistor 76. However, if the suppressor grid voltage is raised suddenly, as by applying a positive voltage pulse of sufficient magnitude thereto, current will be allowed to flow from the cathode 70 to the anode 62, switching the circuit 44 from a stable to an unstable condition, and causing an abrupt increase in the screen grid voltage and an abrupt decrease in the anode voltage. During the time that the circuit 44 is in the stable condition, the coupling capacitor 78 will acquire a charge equal to the difference between the voltage at the anode 62 and the voltage at the cathode 70. When the circuit switches from the stable to the unstable condition, the sudden drop in anode voltage will be passed through the coupling capacitor 78 and will be applied to the control grid 68, thereby causing a decrease in current flow from the

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cathode 70 and a corresponding decrease in the voltage drop across the cathode load resistor 82. This drop in cathode voltage will tend to increase the positive suppressor-grid-to-cathode voltage, thereby aiding the foregoing switching action. The capacitor 78 will then begin to discharge through the resistor 80 and the potentiometer 10 in the information voltage source S_1 , allowing the cathode voltage to increase until the suppressor-to-cathode voltage is again negative, whereupon the tube current will be diverted from the anode 62 to the suppressor 64, and the circuit 44 again will be in the stable condition.

The length of time that the circuit 44 will remain in the unstable condition (i. e. "anode current flow") will depend on the magnitude of the so-called R-C time constant of the circuit including the capacitor 78, the isolating resistor 80, and the potentiometer 10, as well as on the magnitude of the voltage supplied to the circuit from the information voltage source S_1 . Accordingly, the time between the triggering of the circuit 44 and the return thereof to stable operating condition will be a function of, and a measure of, the magnitude of the information voltage from the source S_1 .

Triggering voltage for the circuit 44 is derived from two sources, namely, from the timing pulse generator 40, and from the frequency divider 42. The relative magnitudes of the resistors in the voltage divider 71, 72 and the other parameters of the circuit 44 are so adjusted that the circuit 44 will not be triggered either by a pulse from the timing generator 40 or by a pulse from the frequency divider 42 occurring alone, but will be triggered only when pulses from both the circuits 40, 42 occur simultaneously. Accordingly, the circuit 44 will be triggered simultaneously with the beginning of the first horizontal scan of the cathode ray beam in the tube 22. At some time during the first horizontal scan (determined by the magnitude of the information voltage from the source S_1), the circuit 44 will revert to the stable operating condition, at which time the voltage at the cathode 70 of the tube 60 will rise abruptly, and a positive pulse of voltage will be developed by the differentiating action of a coupling capacitor 84 and a resistor 85. This positive pulse will appear on the intensity control electrode 26 in the cathode ray tube 22, and will increase the intensity of the cathode ray beam sufficiently to cause a bright spot to appear on the screen 20 of the cathode ray tube 22, and it is apparent that the position of the spot on the screen 20 will be a function of the magnitude of the information voltage from the source S_1 .

The second phantastron delay circuit 46 is generally similar to the first delay circuit 44, and contains a pentode tube 60' and circuit elements identical with the tube 60 and the elements 71-84 in the circuit 44. However, the suppressor grid 64' in the tube 60' is not connected to the frequency divider 42, but is coupled to the screen grid 66 in the tube 60 through a rectifier element 86.

During the time that the circuit 44 is in the unstable condition, the voltage at the screen grid 66 will be relatively high, due to the lack of tube current through the screen resistor 76. During this period, current will flow through the screen resistor 76 and the rectifier 86, charging the capacitor 73' to a voltage somewhat above the normal voltage across the resistor 72'. Although the circuit 44 may switch from the unstable to the stable condition well before the occurrence of the next pulse from the timing generator 40, the time

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constant of the RC network 72', 73' is made sufficiently large to hold the voltage on the suppressor grid 64' in the tube 60' above its normal level long enough for the next pulse from the timing generator 40 to trigger the circuit 46. Consequently, the circuit 46 will be triggered by the next pulse from the timing generator 40 after the pulse which aids in triggering the first delay circuit 44. It will be understood that each of the remaining delay circuits 48, 50 is similarly coupled to be triggered in proper sequence by pulses from the timing generator 40 when accompanied by a priming voltage from the preceding delay circuit.

In summarizing the operation of the apparatus shown in Fig. 1, it will be assumed that the frequency divider has a "count-down" factor of four-to-one, so that the cathode ray beam in the tube 22 will make four vertically spaced horizontal scans of the screen 20 in each cycle of operation of the system. During the first scan in each cycle, the beam will be intensified and a spot will appear on the screen 20 at some time determined by the output voltage of the source S_1 ; during the second scan the position of the spot on the screen will be controlled by the output voltage of the source S_2 , etc. These spots will move from side to side on the tube screen 20, as indicated, when the information voltages change. If desired, a permanent record can be made of the information presented on the screen 20 by conventional photographic techniques. Also, it will be understood that the number of information voltages that can be displayed concurrently in the foregoing manner is limited only by the space limitations of the tube screen, and that a very large number of information channels could be handled without interference or overlap. The screen 20 can be indexed in any desired manner to designate the different information voltage sources. Moreover, the space limitation imposed by the tube screen can be avoided by using pulse counting techniques for the display of any given information voltage.

For long distance telemetering applications, it is apparent that the timing and information pulses can be transmitted by standard television techniques, with the information voltage pulses constituting the "video" portion of the television signal, as, for example, in the manner shown in our above-identified copending application.

The information voltage pulses also can be used for automatic control applications by means of so-called "follow-up systems," an example of which is shown schematically in Fig. 2. The system of Fig. 2 is adapted to provide control movements regulated by any one of the information voltage sources, say the source S_1 , in Fig. 1, in place of or in addition to the indications provided by the tube 22 in Fig. 1.

In the system of Fig. 2, a pulse output time delay circuit 90 is adapted to receive triggering pulses from the timing pulse generator 40 of Fig. 1, say at a time t_1 . At the end of the delay period of the circuit 90 (at time t_2), determined in a manner to be described hereinafter, the circuit 90 triggers a pulse generator 92 which produces a pulse of fixed time duration or width, say t_2-t_3 . This pulse, in turn, is used to shock excite an oscillator 94 to produce one cycle of operation. The one-cycle output wave of the oscillator 94 is applied through a transformer 96 to a pair of peak detector circuits 98, 100. Also, the information voltage pulse from one of the delay circuits in Fig. 1, say from the circuit 44, is applied to a center tap of the transformer secondary wind-