

[54] **ELECTRONIC LINE INDICATOR APPARATUS**
[75] Inventors: **Fred W. Karsten, Seabrook; James D. Evans; Sam Lee Pool, both of Houston, all of Tex.**
[73] Assignee: **Kewp, Inc., Houston, Tex.**
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[51] Int. Cl. **G08b 23/00**
[58] Field of Search **340/323, 258 B, 421; 250/221, 222; 273/50, 29**

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Primary Examiner—John W. Caldwell
Assistant Examiner—Robert J. Mooney
Attorney, Agent, or Firm—Pravel, Wilson & Matthews

[57] **ABSTRACT**
A new and improved indicator for detecting and indicating the intrusion or presence of objects on a line or boundary being monitored by officials or monitoring personnel, such as a boundary line at a sporting event or contest.

17 Claims, 15 Drawing Figures

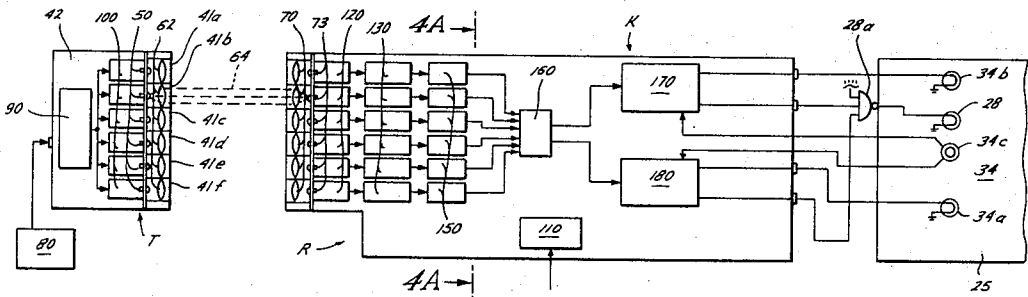


Fig. 1

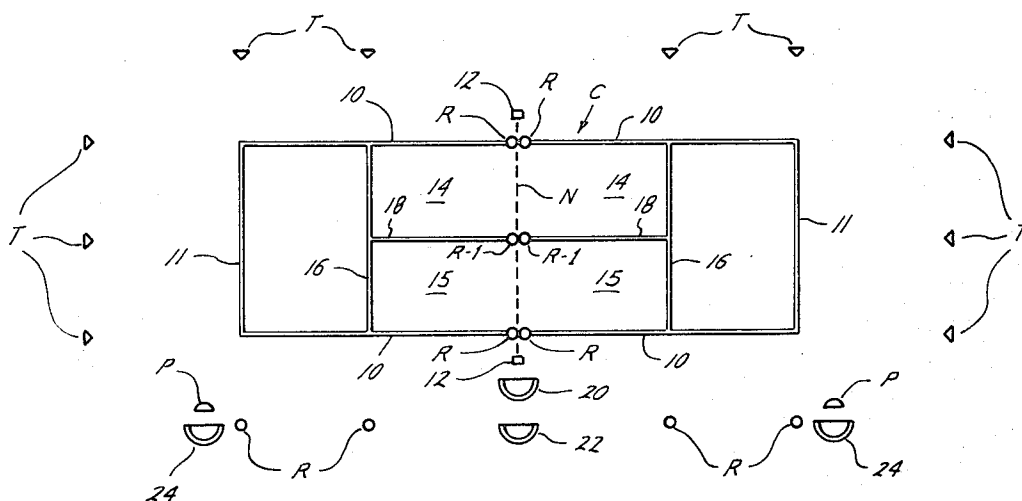


Fig. 2

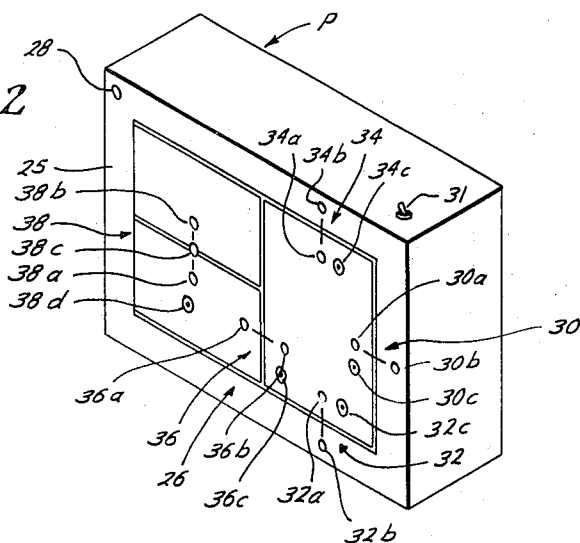
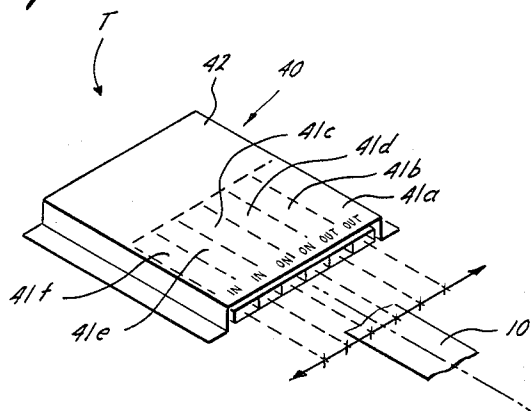
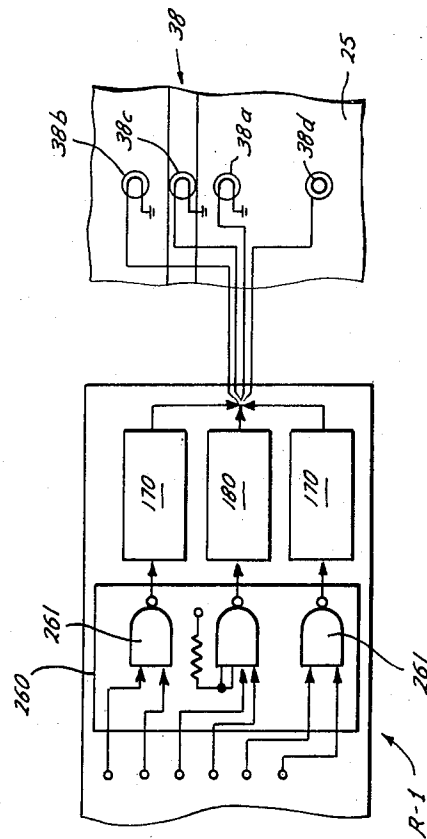
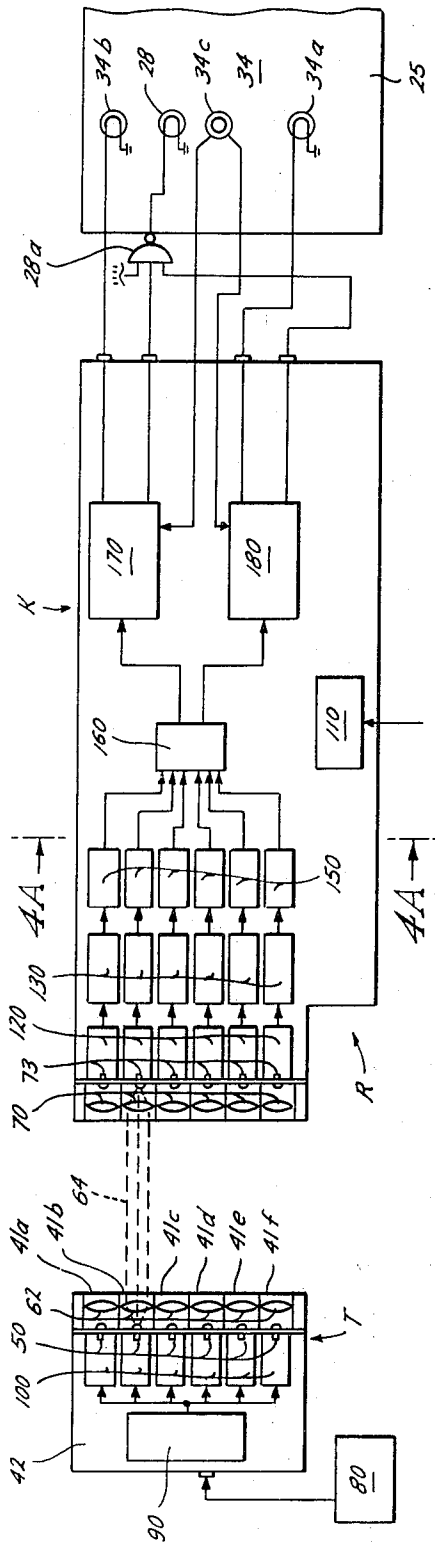


Fig. 3





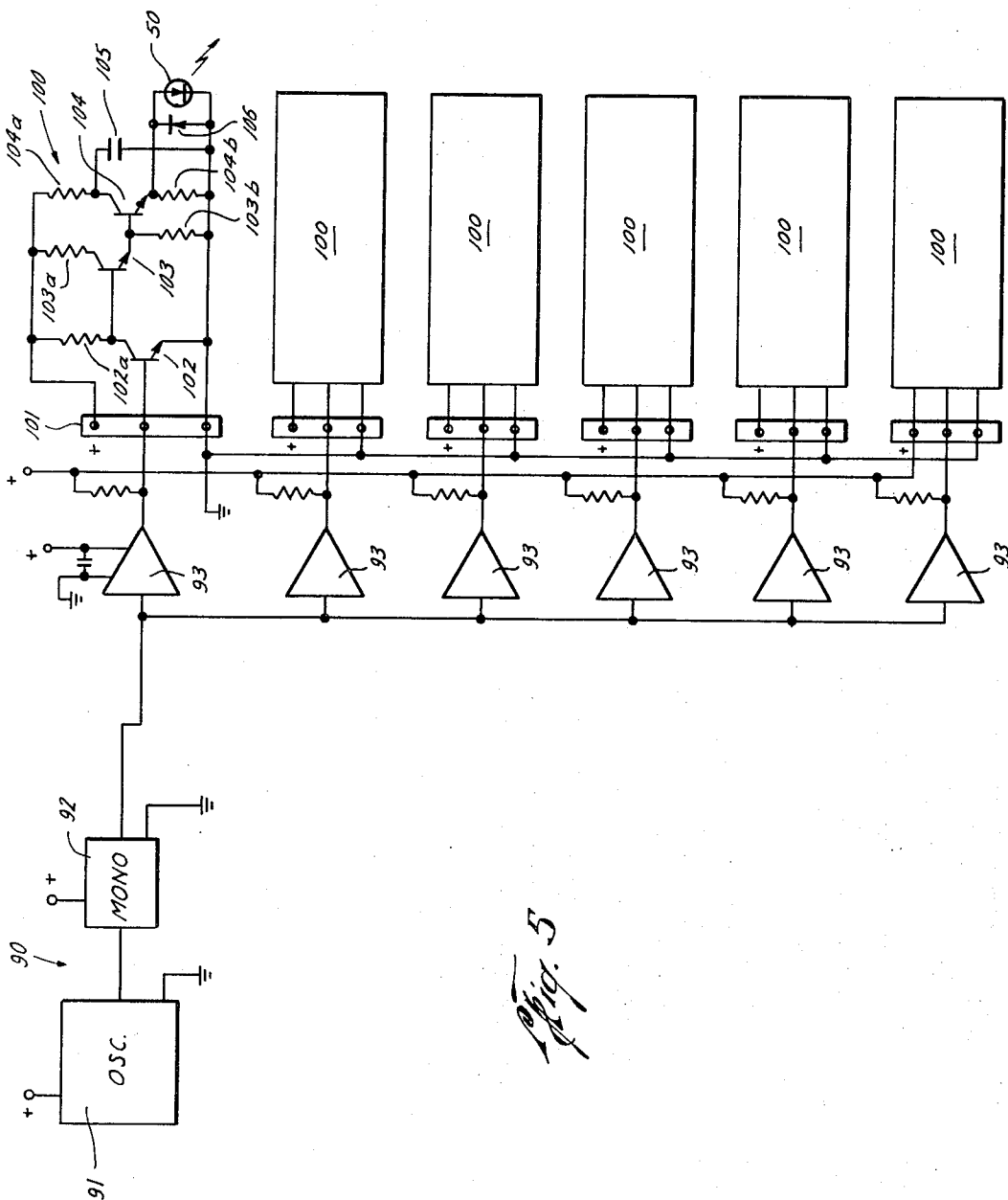
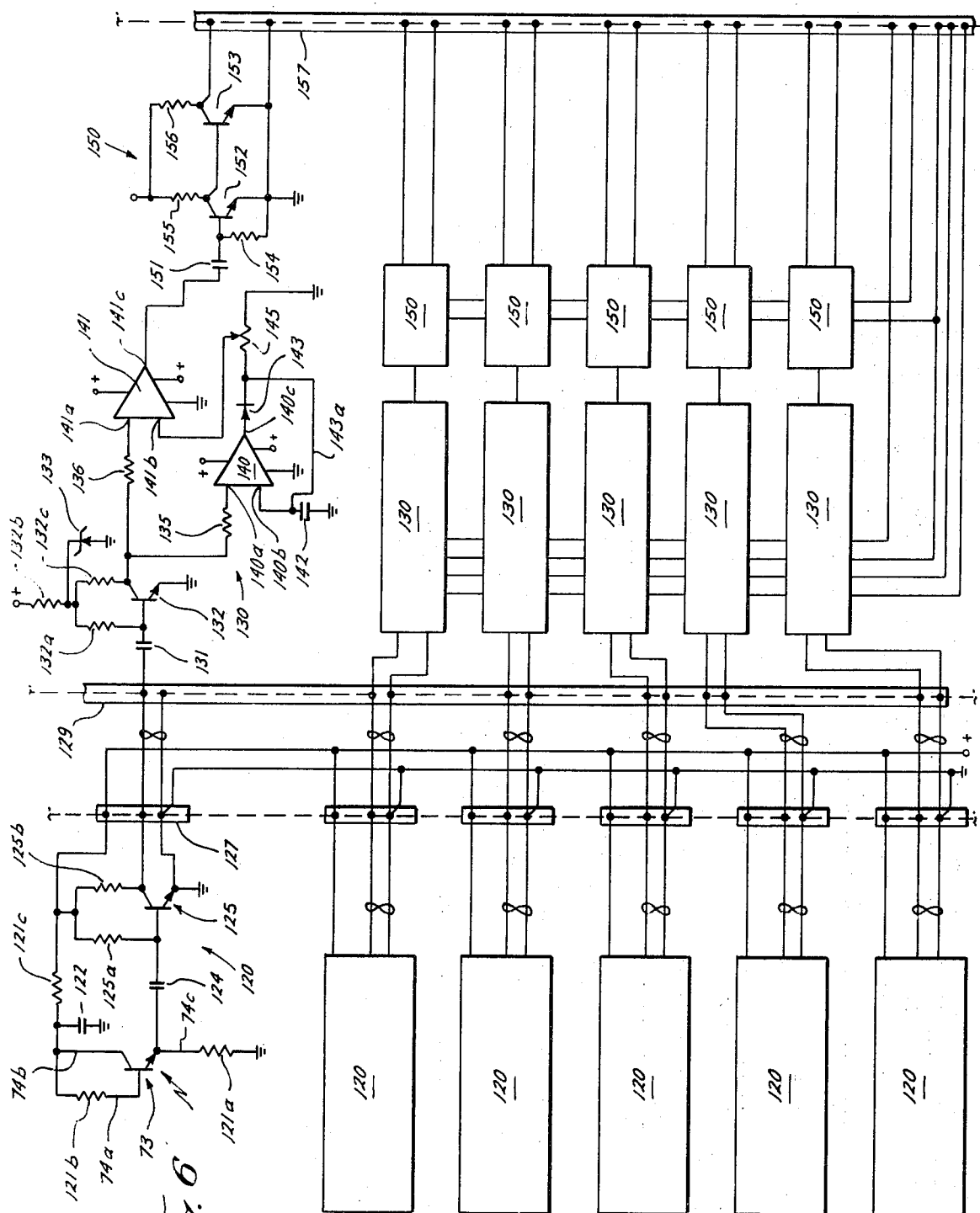


Fig. 5



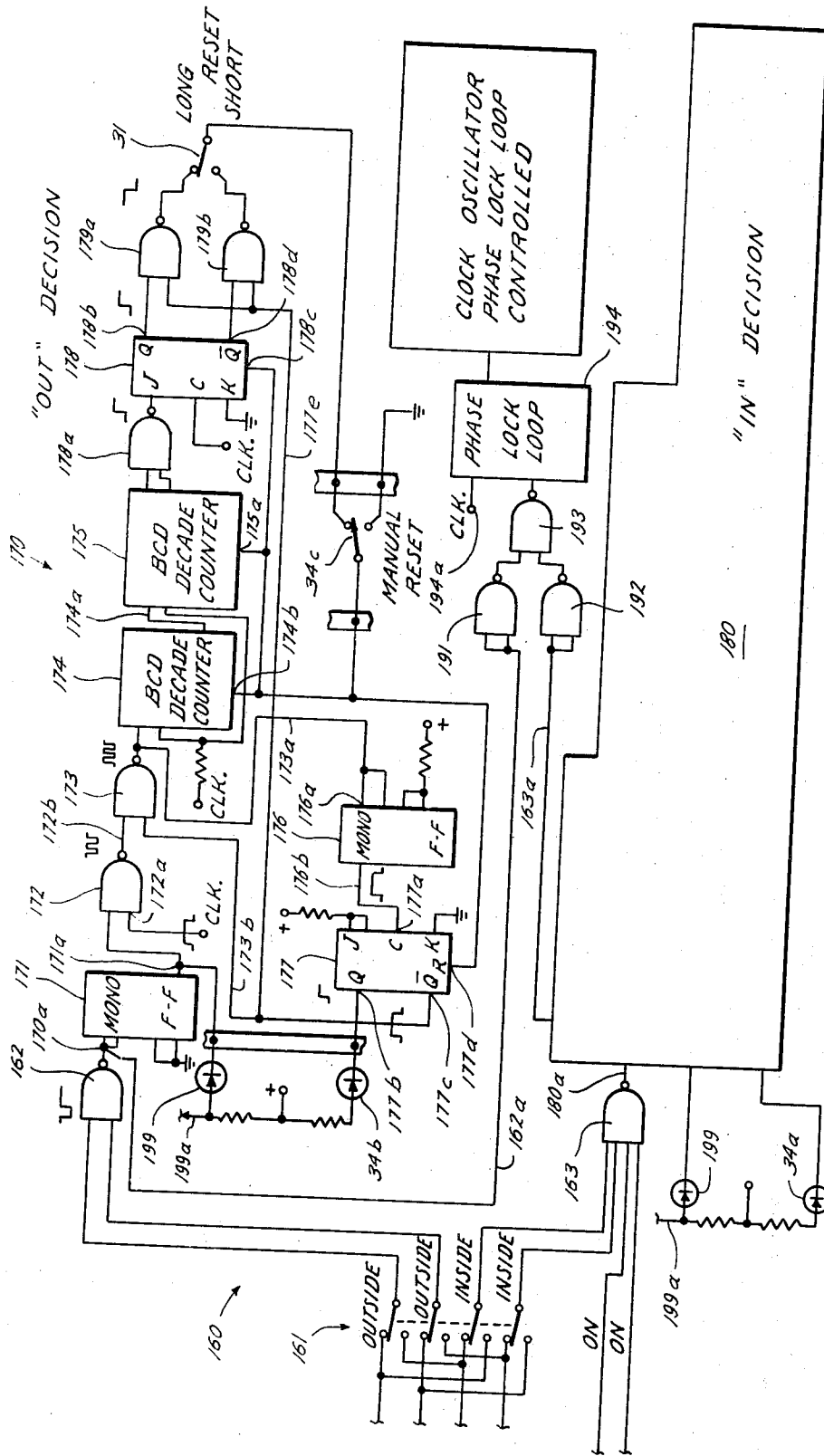


Fig. 7

Fig. 8

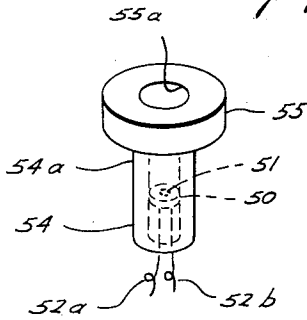


Fig. 9

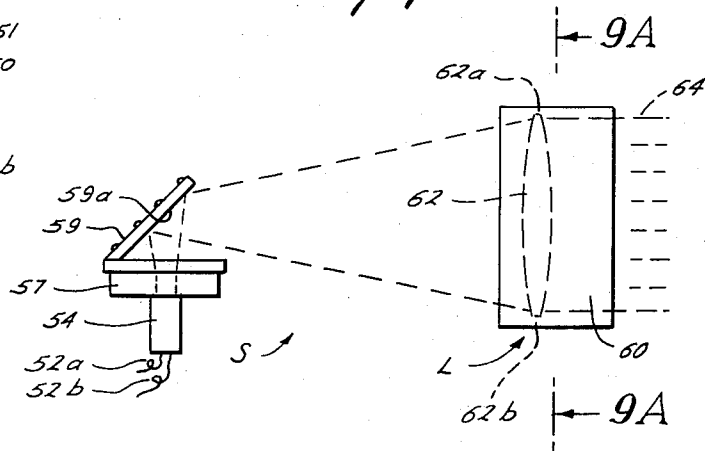


Fig. 9A

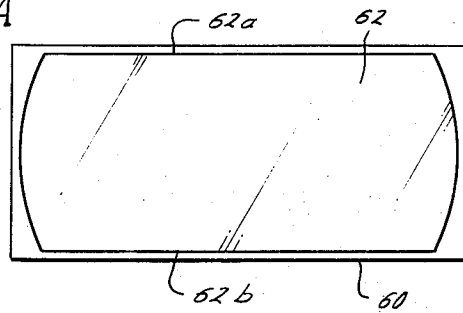


Fig. 10
67

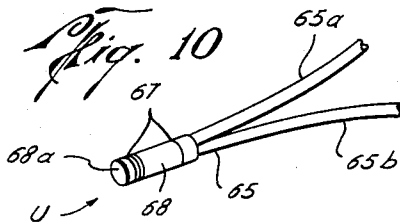


Fig. 12A

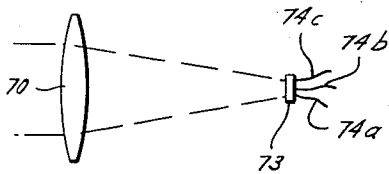
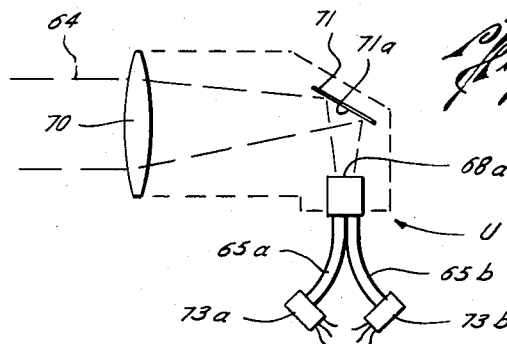


Fig. 12



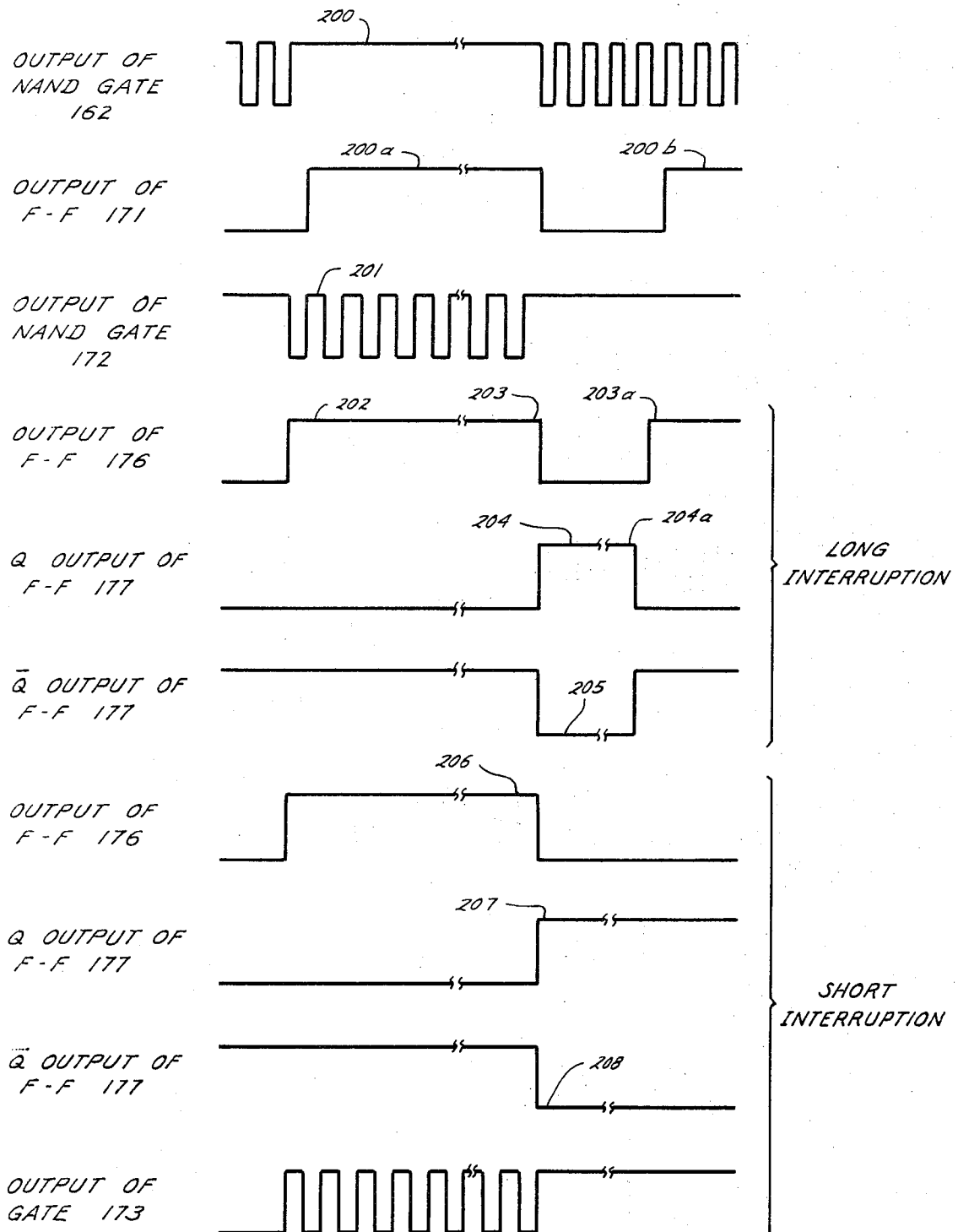


Fig. 11

ELECTRONIC LINE INDICATOR APPARATUS**BACKGROUND OF INVENTION****1. Field of the Invention**

The present invention relates to a new and improved apparatus for an official or monitor who is monitoring lines, for example boundaries at sporting events.

2. Description of Prior Art

Prior art monitoring apparatus, such as those of U.S. Pat. Nos. 3,170,689; 2,650,095; 2,683,602; 3,369,810; and 2,455,909, have generally been used in bowling alleys to detect intrusion of a bowler's foot across a foul line. Such apparatus used one or more continuous light beams sent along the foul line. When the beams were interrupted in a certain sequence, such as by a bowler's foot, a foul or intrusion was indicated.

The continuous light beam was adapted for use only in certain circumstances. Where the line to be monitored was visible to the players or users, the continuous light beam was a distraction. Further, fluctuations in ambient light levels were often not adequately distinguished from intrusions, rendering the prior art systems generally unsatisfactory for outdoor use.

SUMMARY OF THE INVENTION

Briefly the present invention provides a new and improved apparatus for monitoring a boundary or line, such as a boundary or line at a sporting event.

A transmitter sends a pulsed beam of light along the line being monitored, and a receiver senses the pulsed beams. An alarm detects interruptions of the pulsed beam so that intrusions along the line are monitored.

The apparatus of the present invention is adapted for use in assisting an official at a sporting event to determine whether action or play in the sporting event took place on or off the playing area of the event. When so used, a first pulsed beam of light is sent by the transmitter along a boundary of the event, and a second pulsed beam of light is sent along a path adjacent the boundary. The two beams are sensed at the receiver, and the alarm means energized if either or both beams are interrupted, in order that the official may control play of the sporting event.

It is an object of the present invention to provide a new and improved electronic line indicator to detect intrusion of an object along a line being monitored.

It is an object of the present invention to provide a new and improved electronic line indicator which discriminates between types of intruding objects.

It is a further object of the present invention to provide a new and improved apparatus for assisting an official at a sporting event, for example a tennis match, in determining whether action in the event took place on or off the playing area of the event.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a playing area of a sporting event using the present invention;

FIG. 2 is a isometric view of an alarm indicator panel of the apparatus of the present invention;

FIG. 3 is an isometric view of a transmitter of the apparatus of the present invention;

FIG. 4 is a functional block diagram of the apparatus of the present invention;

FIG. 4A is a functional block diagram of a modified apparatus of the present invention;

FIGS. 5, 6 and 7 are schematic electric circuit diagrams of portions of the apparatus shown functionally in FIG. 4;

FIGS. 8 and 10 are isometric views of portions of the transmitter and receiver, respectively, of the apparatus;

FIG. 9A is a view taken along the line 9A—9A of FIG. 9;

FIGS. 9, 12 and 12A are elevation views, partially schematic, of the transmitter and receiver, respectively, of the apparatus; and

FIG. 11 is a voltage waveform diagram of signals occurring at selected locations in the circuit of FIG. 7.

DESCRIPTION OF PREFERRED EMBODIMENT

In the drawings, the letter A designates generally the apparatus of the present invention for monitoring a boundary or line for the presence of an object along the line. The apparatus A may be used for monitoring boundaries or lines in sporting events, in the transportation industry for traffic and cargo counting and control, in the manufacturing and storing industry for product and material counting and handling, selecting and the like, and for safety and security monitoring and crime prevention purposes.

The apparatus A will be described in this preferred embodiment in conjunction with monitoring a sporting event, more specifically a tennis game or match, in order to distinguish between permissible events, such as the tennis ball landing partially or completely on a boundary line on the tennis court or a player placing his foot on a boundary line on the tennis court while returning a serve or volleying, from an impermissible event, such as a tennis ball landing outside a boundary line without contacting a part of the boundary line, or a foot fault when a server places his foot on the end line while serving. It should be understood, however, as set forth above, that the apparatus A may be used to detect intrusions along boundaries of other sporting events, or along other lines or boundaries being monitored for intrusion of objects.

In the drawings (FIG. 1) a tennis court C is shown. The tennis court C has been marked for a singles match, although it should be understood that the apparatus A of the present invention may be used in conjunction with doubles tennis matches.

As is known, the tennis court C, when marked for a singles match is generally rectangular in dimension, having two side lines 10 and two base lines 11 as boundaries, defining the playing area of the tennis match.

A net N divides the tennis court C into two playing areas, one for each player. The playing area of each player is further divided into two service courts 14 and 15 by a service line 16 and a half court line 18 extending between a mid-point of the service lines 16 and connecting same. As is known, the server in the tennis match must place his serve in a particular one of the service courts 14 and 15 on his opponent's half of the playing court C at different serves in accordance with game conditions and rules.

As is known, net court judge's chair 20 and an umpire's chair 22 are provided adjacent the net N in order that the net court judge may observe the net N for let serves, and the umpire may control play of the tennis match.

Using conventional tennis umpiring techniques, ten additional linesmen were required, five for each half of

the playing court C, with two being assigned to the two side lines 10, one assigned to the half court line 18, one assigned to the service line 16 and one assigned to the base line 11.

With the present invention, two linesmen in addition to the net court judge and the umpire are required. These two additional linesmen sit in linesman's chairs 24 and monitor an indicator panel P (FIG. 1 and 2) in order to control play of the tennis match.

The apparatus A of the present invention includes a transmitter T (FIGS. 1 and 3) which sends a pulsed beam of light at periodic intervals along a line of the tennis court C being monitored, and a receiver R which receives the pulsed beam of light sent along the line.

A transmitter-receiver pair, comprising a transmitter T and a receiver R, are placed to transmit the pulsed beams of light, formed in a manner to be set forth below, along the side lines 10, 18, the service line 16 and the base line 11 in each half of the playing court C (FIG. 1). A modified receiver R-1 (FIG. 4A) is used for the half-court lines 18. The transmitters T sending beams of light along the side lines 10 and the half court line 18 are spaced a suitable distance behind the service line 11, and may be, if desired, placed inside a boundary or fence or backdrop so that they do not interfere with play in the tennis match. The receivers R for such transmitters T are placed adjacent the net N. The transmitters T sending pulsed beams of light along the service line 16 and the base line 11 are similarly spaced a suitable distance away from the court C in order not to interfere with play.

Considering the panel P more in detail (FIG. 2), a front face 25 of the panel P has one playing half of a tennis court illustrated schematically thereon, as indicated generally at 26 (FIG. 2). A "Beam Interrupted" indicator light 28 is mounted on the face 25 of the panel P and gives a signal when any one of the pulsed beams being sent between the transmitters T and the receivers R are interrupted by an undesired object being placed in the light path between the transmitter T and the receiver R. Such undesired objects might be a tennis racket, playing equipment, or other undesired articles which obstruct the path for the pulsed beam of light between the transmitter T and the receiver R.

The indicator light 28 is energized through a suitable electronic means, such as a conventional NAND gate 28a receiving input signals from each receiver to indicate when any one of the pulsed light beams between a transmitter-receiver pair of the apparatus A is obstructed by an undesired object.

A base line indicator group 30 including an "In" indicator light 30a and an "Out" indicator light 30b are mounted with the face 25 of the panel P. The indicator lights 30a and 30b are energized by electronic circuitry in the apparatus A to indicate whether a tennis ball landing adjacent the base line 11 on the tennis court C landed in play or out of play during the match. A reset button 30c permits the linesman to reset the apparatus A after the "In" light 30a or the "Out" light 30b is de-energized.

A control switch 31 permits the linesman to adjust electronic circuitry in the apparatus A and monitor for foot faults by a server, in a manner to be set forth below.

A side line indicator group 32 including an "In" indicator lamp 32a, and "Out" indicator lamp 32b and a reset button 32c permit the linesman observing the

panel P to determine whether a tennis ball landing adjacent a side line 10 landed in play or out of play. The reset button 32c permits the linesman to reset the apparatus A after the lamp 32a or the lamp 32b is de-energized.

A second side line indicator group 34 including an "In" indicator lamp 34a, and "Out" indicator lamp 34b and a reset button 34c permit the linesman to determine whether a tennis ball landing adjacent the second side line 10 of the tennis court C landed in play or out of play, with the reset button 32c used to reset the apparatus A after the lamp 34a or 34b has been de-energized in a manner to be set forth below.

A service line indicator group 36 on the face 25 of the panel P includes an "In" indicator lamp 36a, and "Out" indicator lamp 36b and a reset button 36c permitting the linesman to monitor whether a tennis ball landing adjacent the service line 16 on the tennis court C landed in play or out of play.

A half court line indicator group 38 on the base 25 of the panel P includes a first service court indicator lamp 38a, and "On Line" indicator lamp 38c and a reset button 38d. The lamps 38a, 38b and 38c are energized in a manner to be set forth below to indicate to the linesmen whether a tennis ball landed in the proper service court during play of the match. The reset button 38d permits the linesman to re-energize the indicator lamps when such lamps have de-energized to indicate an interruption.

Considering the transmitters T more in detail (FIG. 3), each of the transmitters T includes a plurality of sources of pulsed beams of light. The pulsed beams of light are furnished at periodic intervals along the line being monitored. In the preferred embodiment, each of the transmitters T has six sources S (FIG. 9) mounted in an individual housing 40 (FIGS. 3 and 9). A rear portion 42 of the transmitter T (FIG. 3) contain electronics (FIGS. 4 and 5) to drive the sources S in the transmitter T.

The sources S in the front portion 40 of the transmitter T are aligned and send the pulsed beams of light to photosensitive receiver units U, of a type to be set forth below, in the receivers R. In the preferred embodiment of the present invention, two of the sources S, indicated at 41a and 41b (FIG. 3) send pulsed beams of light along a line adjacent to, and outside of the line on the tennis court being monitored. In the accompanying drawings, the line is indicated as a side line 10, although it should be understood that as set forth above, each of the lines in the tennis court C are monitored by individual transmitters T and receivers R, with the half-court lines 18 having receivers R-1.

Two further sources S, indicated at 41c and 41d (FIG. 3) are aligned so that the pulsed beams of light from such sources are transmitted substantially along the line 10 being monitored. Two further sources, indicated at 41e and 41f are aligned to transmit pulsed beams of light adjacent to, and inside of, the line 10 being monitored. In this manner, pulsed beams of light are sent along the line 10 and adjacent to and both inside and outside of, the line 10 being monitored. As has been set forth above, each of the transmitters T preferably has six sources S so aligned, and each of the receivers R has six photosensitive units therein to receive the pulsed beams of light sent from the transmitter T.

Considering the sources S of the transmitter T more in detail (FIGS. 8 and 9), a light-emitting diode 50,

having a light emitting portion 51 for emitting a light beam when energized, is electrically connected to the electronic circuitry of the transmitter T by electrical conductors 52a and 52b. The light-emitting diode 50 is mounted in a tubular or cylindrical member 54 by potting or other suitable mounting techniques. The interior of the cylinder 54 adjacent the diode 50 is preferably painted or otherwise suitably colored black in order to decrease stray reflectance from the output of the diode 50.

A mounting cap 55 is formed at an upper end 54a of the cylinder 54 and permits the diode 50 to be mounted in a receiving plate member 57 (FIG. 9). An aperture or opening is formed through the mounting plate 55 adjacent a surface 55a in order that the light beam from the diode 50 may pass therethrough.

A mirror 59 having a reflective front surface 59a formed thereon is mounted with the receiving plate member 57. The mirror 59 reflects the light passing from the diode 50 through the mounting member 55 onto a lens L (FIG. 9).

The lens L includes a lens mounting socket 60 in which a collimating lens 62 is mounted. The collimating lens 62 receives the light reflected from the surface 59a of the mirror 59 and focuses and forms such light into a parallel light beam, indicated by phantom lines 64 (FIG. 9). The collimating lens 62 is preferably truncated along an upper surface 62a and a lower surface 62b (FIG. 9A) in order that the light beam 64 focused and formed by the lens 62 is substantially rectangular when travelling between the transmitter T and the receiver R.

It should be understood that the light-emitting diode 50 may be mounted in the source S to shine the light emitted therefrom directly onto the lens 62, if desired.

The receivers R of the apparatus A are contained within housings of like configuration to the housing 40 of the transmitter T (FIG. 3). As has been set forth above, each of the receivers R in the preferred embodiment has six photosensitive receptor units U (FIGS. 10 and 12) which receive the pulsed beams of light sent from the transmitter T along the line being monitored. A photosensitive receptor unit U (FIGS. 10 and 12) includes a plurality of fiberoptic bundles 65 grouped into a first group 65a and a second group 65b to adjust for variations in ambient light levels. A plurality of wrapping wires 67 bind the ends of the fiberoptic rods, and such ends are coated with an epoxy or other suitable synthetic resin coating 68. An end portion 68a of the epoxy coating 68 is ground off to form a flat surface, which is polished with suitable grinding compounds to form an optically transparent surface. The synthetic resin capping solution acts as an impedance matching element between the air and the glass in the fiberoptic bundles.

A condensing lens 70 in the receiver R receives the beams of light 64 sent from the source S in the transmitter T. The condensing lens 70 focuses the beams of light so received onto a reflective surface 71a of a mirror 71 (FIG. 12). The reflective surface 71a of the mirror 71 transfers the light from the condensing lens 70 onto the surface 68a of the photosensitive receptor unit U. The light received at the photosensitive receptor unit U is conveyed by the fiberoptic groups 65a and 65b to a corresponding pair of photosensitive transistors, or phototransistors 73a and 73b. With the two groupings 65a and 65b of fiberoptic rods and the corre-

sponding phototransistors 73a and 73b, the signal level sensed at one of the phototransistors 73a and 73b is fed to a low pass filter to sense slowly varying light levels. The output of the other phototransistors and the low pass filter are compared, for example in a differential amplifier, with each other and used to compensate for variations in the ambient light at the tennis court C.

It should be further understood that the single phototransistor 73 may be mounted to receive light directly from the focusing lens 70 (FIG. 12A), if desired. The single phototransistor 73 is electrically connected by conductor 74a, 74b and 74c to the remaining electronic circuitry of the apparatus A, to be set forth below. The electronic circuitry of the apparatus A distinguishes for fluctuations in the ambient light, and permits use of the single phototransistor 73.

Each of the transmitters T of the apparatus A includes a power supply 80 (FIG. 4), which may be a conventional direct current power supply such as a battery or a rectifier energized by an alternating current source to provide a direct current output. A pulse generator 90 forms pulses to periodically energize the light-emitting diodes or sources 50 in order that pulsed beams of light are sent at periodic intervals along the line or boundary being monitored. A driver circuit 100 is associated with each of the diodes 50 to energize the associated diode 50 to provide an output light pulse of sufficient amplitude when energized by the pulse generator 90.

As has been set forth above the electronics of the transmitter T are contained in a rear portion 42 (FIGS. 3 and 4) and energize the light source 50 for each of a plurality of light beams 41a through 41f to provide a plurality of pulsed beams of light transmitted along the line.

Considering the pulse generator 90 more in detail (FIG. 5), an oscillator 91, which may be a conventional integrated circuit square wave function generator, provides a square wave output signal when energized by the power supply 80.

The square wave output from the oscillator 91 is furnished to a monostable re-triggerable flip-flop 92. The flip-flop 92 provides a square wave pulse of a predetermined duration, for example two microseconds, at a predetermined pulse rate. A suitable pulse rate for the present invention is 500 Hertz, so that the pulse beams of light from the transmitter T are not at a harmonic frequency of 60 Hertz electrical power. The pulse rate is selected in accordance with the particular use of the apparatus A, and may be synchronized to an external source, if desired.

The pulse output of the flip-flop 92 is furnished to a plurality of inverting buffer operational amplifiers 93 which amplify and invert the pulse output from the flip-flop 92 and provide such pulses to the driver circuits 100.

It should be understood that although the flip-flop 92 is shown as driving the six driver circuits 100 simultaneously, a conventional multiplexing switch could be electrically connected between the flip-flop 92 and the buffer amplifiers 93 so that the driver circuits 100 sequentially receive pulses from the pulse generator 90.

As has been set forth above, the driver circuits 100 are like in number to the emitting diodes 50 and provide power to drive the diodes 50 when pulses are received from the pulse generator 91. Since the driver circuits 100 are of like construction to each other, only

one is shown in detail in the accompanying drawings to preserve clarity therein.

The driver circuits 100 receive operating power from a connector 101 as indicated in the accompanying drawings. An amplifier transistor 102 receives bias power through a bias resistor 102a from the connector 101. The amplifier transistor 102 receives the output of the buffer amplifier 93 and provides such signal to drive a Darlington-connected pair of transistors 103 and 104. The transistor 103 is biased by bias resistors 103a and 103b from the connector 101, while the transistor 104 is biased by resistors 104a and 104b from the connector 101. The resistance value of the resistor 104a is chosen so that the charge time for a charge storage capacitor 105 is substantially less than the time lapse between two output pulses.

The capacitor 105 stores electrical charge from the flow of current through the resistor 104a. When the transistor 104 is conducting, the charge in the capacitor 105 flows into the light-emitting diode 50 and energizes the diode 50 causing a pulsed beam of light to be sent therefrom.

A protective diode 106 is connected in parallel with the light-emitting diode 50 across the resistor 104b in order to protect the light-emitting diode 50 from reverse voltage surges.

The electronic circuitry for the receiver R includes a power supply 110 (FIG. 4) which may be a battery or other conventional direct current bias power source. As has been set forth above, a plurality of phototransistors 73, like in number to the number of source diodes 50 in the transmitter T, and each receiving pulsed beams of light focused thereon by a corresponding condensing lens 70, are mounted in the receiver R.

A preamplifier 120 is provided for each of the phototransistors 73. Each of the preamplifiers 120 has a signal conditioner circuit 130 associated therewith. The signal conditioners 130 are connected through individually associated voltage scaler circuits 150 to a switch unit 160 when the receiver R is used in conjunction with a side line, service line or base line on the tennis court C.

A control unit K including an "Out" decision unit 170 and an "In" decision unit 180 receives the output signals from the switch unit 160 and energizes an indicator group on the face 25 of the indicator panel P. In the accompanying drawings, the control circuit K is illustrated as energizing the side line indicator group 34. However, it should be understood that the control unit K for the receivers R associated with the side line 10 having indicator group 32 assigned thereto, and the service line 16 having indicator group 36 associated therewith each have control circuits K including an "Out" decision circuit 170 and an "In" decision circuit 180 therein.

The "Out" decision unit 170 in the control unit K de-energizes, in a manner to be set forth below, the "Out" indicator lamp 34b when a tennis ball lands adjacent the side line 10 but outside the playing court C. The "In" indicator lamp 34a is de-energized by the "In" decision unit 180 when a tennis ball lands either on the line or in the playing court C. The reset button 34c resets the "Out" decision unit 170 and the "In" decision unit 180 after de-energization of either the "In" indicator lamp 34a or the "Out" indicator lamp 34b.

As has been set forth above, the "Beam Interrupted" lamp 28, electrically connected through the NAND

gate 28a, is energized when one of the beams being monitored by the five receivers R is interrupted by an undesired object.

An alternate switch unit 260 is used in the receiver R-1 monitoring the half-court line 18 on the playing court C. For this half-court receiver R-1, the control unit K includes two "Out" decision units 170 and one "In" decision unit 180. The "Out" decision units 170 individually energize the two "Out" indicator lamps 38a and 38b (FIG. 4A) of the half-court line indicator group 38. The "In" indicator group 180 energizes the "On" indicator lamp 38c of the indicator group 38. The reset button 38d provides a control signal to each of the "Out" decision units 170 and to the "In" decision unit 180 resetting same, as will be set forth below.

Each of the phototransistors 73 has a preamplifier circuit 120 connected therewith, as has been set forth. Bias resistors 121a, 121b and 121c are connected to the photo-transistor 73 (FIG. 6) to bias same into the desired operating region so that the pulsed beams of light focused onto the photo-transistor 73 by the condensing lens 70 are converted into electrical signals. A capacitor 122 is provided to protect the phototransistor 73 from high frequency transients.

A coupling capacitor 124 electrically connects the phototransistor 73 to an amplifying transistor 125. The capacitance of the coupling capacitor 124 is chosen in order to attenuate low frequency signals and thus minimize the response of the receivers R to 60 Hertz light and to slowly varying ambient light.

The amplifier transistor 125 receives operating bias from bias resistors 125a and 125b. The amplified output of the transistor 125 is provided through connectors 127 and 129 to the associated signal conditioner circuit 130.

A single one of the signal conditioner units 130 is shown in detail in the accompanying drawings (FIG. 6), since the signal conditioner units 130 are of like structure to each other, in order to preserve clarity in the drawings. A coupling capacitor 131 of the signal conditioner unit 130 electrically connects an amplifier transistor 132 to the connector 129. The capacitance of the coupling capacitor 131 is chosen, in a like manner to the coupling capacitor 124, in the preamplifier 120 to minimize the effects of 60 Hertz light and of slowly changing ambient light on the receiver R.

Bias resistors 132a, 132b and 132c bias the amplifier transistor 132 into the desired operating range. A voltage regulating Zener diode 133 is connected in parallel with bias resistors 132a and 132c and the transistor 132 to regulate the voltage applied to the amplifier transistor 132.

The amplifier transistor 132 is electrically connected through input resistors 135 and 136 to first input terminals 140a and 141a of comparator operational amplifiers 140 and 141, respectively. A capacitor 142 is connected to a second input 140b of the comparator 140.

A diode 143 and a feedback connector 143a connect an output 140c of the comparator 140 to the second input 140b of the comparator 140.

The capacitance value of the capacitor 142 is chosen (e.g., 2 microfarads) so that the discharge time thereof is relatively long compared with the time duration between the pulsed light beams received by the phototransistor 73. In this manner, the capacitor 142 forms an automatic threshold circuit which establishes a threshold level in accordance with the peak intensity of

the pulsed beam of light at the receiver R so that the receiver R is adjusted for fluctuations and changes in the ambient light level, and in the voltage output levels of the power supply of the receiver.

A potentiometer 145 is electrically connected between a second input 141b at the comparator 141 and the capacitor 142. The resistance value of the potentiometer 145 is adjusted so that the voltage level applied from the capacitor 142, representing the peak threshold level of the received pulsed beam, when applied to the second input 141b of the comparator 141 is a predetermined fraction of the peak voltage level so sensed. A suitable value would be, for example, two-thirds the level stored on the capacitor 142.

Accordingly, the comparator 141 compares the input signal received at the first input terminal 141a, representing the signal level being received currently by the phototransistor 73, with a predetermined fractional value of the maximum signal level as determined by the automatic threshold capacitor 142. When the signal at the input terminal 141a exceeds the predetermined fractional value of the maximum signal level, an output terminal 141c of the comparator 141 provides a positive direct current output signal level. When the input signal at the terminal 141a is less than the predetermined fractional value of the threshold level, indicating that the amplitude of the pulsed beams of light sensed by the phototransistor 73 are below acceptable limits established by the threshold circuit 142, the output terminal 141c of the comparator 141 is substantially 0 volts. During this time, the charge stored on the threshold capacitor 142 is discharged through the potentiometer 145 to ground and to the comparator 141. The diode 143 prevents the amplifier 140 from discharging the capacitor 142 once the peak voltage has been received and electrically decouples the amplifier once the input is zero volts. The time constant established by the resistance of potentiometer 145 and the capacitance of the capacitor 142 is chosen so that the time required for this discharge to take place is relatively long compared with a temporary interruption such as a tennis ball interrupting the pulsed beams of light. In this manner, pulsed beams of light are restored before the charge on the capacitor 142 is dissipated unless the interruption of the pulsed beams of light is caused by a player interrupting such beam, an unwanted object being placed in the path along which the pulsed beams are transmitted, or a circuit failure in the electronics in the transmitter T providing such beam.

Further, since a tennis ball often lands only in a portion of the beam so that only a portion of the beam is interrupted, the comparison of the predetermined fractional value of the peak signal level, established by the potentiometer 145, with the signal level currently received permits the signal conditioner 130 to detect when at least a predetermined fraction, in this embodiment one-third, of the pulsed beam of light is interrupted. Accordingly, interruption of at least one-third of the pulsed beam of light is detected in the same manner as interruption of the complete beam of light by the signal conditioner unit 130.

Since the voltage scaler units 150 are of like structure and function to each other, the details of one are shown in the accompanying drawings (FIG. 6) in order to preserve clarity therein. A coupling capacitor 151 electrically connects an output 141c of the comparator 141 to amplifying transistors 152 and 153. The capacitor

151 isolates the transistors 152 and 153 from the positive direct current voltage present at the output 141c of the comparator 141 when the pulsed beams of light are not interrupted. The transistor 152 and 153 are biased into the desired operating region by bias resistors 154, 155 and 156.

The voltage scaler units 150 (FIG. 6) are used to adjust the voltage level present at the output of the comparator 141 to a level compatible with the logic levels of the switch unit 160 and the decision units 170 and 180. A connector 157 electrically connects the voltage scaler units 150 to the switch unit 160.

The switch unit 160 includes a two position, four contact switch 161 and NAND gates 162 and 163. The switch unit 160 controls the application of signals from the voltage scaler units 150 so that the "Out" decision unit 170 and the "In" decision unit 180 receive signals from the proper photo-transistors 73.

The switch 161 and the NAND gate 162 furnish the "Out" decision unit 170 with signals from the phototransistors 73 receiving beams sent along the line (FIG. 3) and adjacent to and inside the line (FIG. 3). The switch 161 is reversible in position so that the receiver R may be used on lines where the "In" and "Out" positions are reversed, by reversing the position thereof.

The NAND gates 162 and 163 are further connected by conductors 162a and 163a, respectively, to inverting NAND gates 191 and 192. A NAND gate 193 connects the output of the inverting NAND gates 191 and 192 to a conventional phase lock loop circuit 194.

The phase lock loop circuit 194 further receives clock pulses from a clock oscillator 195. As is known, the phase lock loop circuit 194 maintains synchronism between the pulse outputs of the clock oscillator 195 and the pulse outputs of the NAND gates 162 and 163 as provided by the NAND gate 193. As has been set forth, the outputs of the gates 162 and 163 represent the pulsed beams sent between the transmitter T and the receiver R. The synchronized output signal from the phase lock loop circuit 194 is furnished at an output terminal 194a to selected terminals indicated "CLK" in the drawings (FIG. 7).

The "Out" decision unit 170 receives an input signal at a terminal 170a from the NAND gate 162 and responds to interruption of at least one of the two outside beams being sent between the transmitter T and the receiver R. The "Out" decision unit 170 determines the time duration of the interruption of the beam and indicates the nature of such interruption based on the time duration thereof. In a like manner, the "In" decision unit 180 receives an input signal at a terminal 180a from the NAND gate 163 and responds to interruption of at least one of the two inside beams or the two on-line beams being sent between the transmitter T and the receiver R. The "In" decision unit 180 determines the nature of the interruption by determining the time duration of such interruption.

Accordingly, the "Out" decision unit 170 and the "In" decision unit 180 contain like circuit elements and operate in a like manner. To preserve clarity in the drawings, the components of the "Out" decision unit 170 are shown in detail (FIG. 7), it being understood that the "In" decision unit 180 contains like circuit elements.

The NAND gate 162 responds to the interruption of at least one of the two pulsed beams between the transmitter T and the receiver R by assuming a logic 1 level

as indicated at 200 (FIG. 11) and maintaining such level for the duration of the beam interruption, holding the input terminal 170a of the decision unit 170 at the logic 1 level. As long as pulsed beams are received within a time limit of one and one-half the time duration between pulses, a re-triggerable monostable flip-flop 171 maintains a 0 at a $\bar{Q}$ output terminal 171a.

Interruption of one or both of the two outside beams causes the NAND gate 162 to permit the retriggerable monostable flip-flop 171 to assume a logic 1 level at a $\bar{Q}$ output terminal 171a thereof (FIG. 11). The $\bar{Q}$ output terminal 171a maintains the logic 1 level until receipt of the pulsed beams resumes, at which time it is driven to a logic 0 state by the NAND gate 162. A NAND gate 172 is connected to the terminal 171a. NAND gate 172 further receives clock pulses at an input terminal 172a thereof so that synchronized pulses are provided at an output 172b during the interruption of one or both of the outside beams between the transmitter T and the receiver R, as indicated at 201 (FIG. 11). A "Beam On" indicator lamp 199 is electrically connected between a positive power supply terminal and the $\bar{Q}$ output terminal 171a. When the $\bar{Q}$ output terminal is a logic 1 while at least one of the out beams is interrupted, the lamp 199 is de-energized.

The indicator lamp 199 is connected by a conductor 199a to the NAND gate 28a, which further is connected to the indicator lamps from the other receivers R, and to the indicator lamp 28 on the panel P (FIGS. 3 and 4). In this manner interruption of one of the beams energizes the lamp 28 to indicate obstruction of the beam by undesirable objects. For short term interruptions by a moving ball, energization of the lamp 28 is not of noticeable duration. When the lamp 28 is energized for a noticeable interval, the linesman is notified that at least one of the beams is obstructed. The linesman may determine which beam is obstructed by removing the face 25 of panel P and looking for the de-energized lamp 199.

A control NAND gate 173 inverts the synchronized pulses from the NAND gate 172 and provides such pulses to a first BCD decade counter 174. The decade counter 174 counts the first 10 pulses from the NAND gate 173 and over a conductor 174a advances or carries a second BCD decade counter 175 once for each ten pulses received from NAND gate 173. The BCD decade counter 175 counts each pulse carried by the counter 174 over the output conductor 174a. Thus, the two-stage counters 174 and 175 count up to 100 pulses from the NAND gate 173. When the count reaches 100, the counters 174 and 175 recycle and again begin counting from zero.

The pulse output of the NAND gate 173 is further provided over a conductor 173a to an input terminal 176a of a retriggerable monostable flip-flop 176. The flip-flop 176 responds to the presence of pulses at the output of the NAND gate 173 by maintaining an output terminal 176b at a logical 1 level, as indicated at 202 (FIG. 11). When the NAND gate 173 no longer provides pulses at the output thereof, due to resumption of the receipt of pulses at the input terminal 170a of the decision unit 170 or a reset signal, formed in a manner to be set forth below, the output conductor 176b is driven to a logical 0 level indicated at 203, triggering a J-K flip-flop 177 at a clock input terminal 177a thereof.

The J-K flip-flop 177 responds to the change of logic levels on the conductor 176b by driving the Q output terminal 177b to a logical 1 level as indicated at 204 due to the presence of a logical 1 at the J input, and the $\bar{Q}$ output terminal 177c to a logical 0 level as indicated at 205 due to the presence of a ground at the K input.

The $\bar{Q}$ output terminal 177c of the flip-flop 177 is connected by a conductor 173b to an input terminal 173c of the control NAND gate 173. The control NAND gate 173 responds to the transition to a logical 0 of the output terminal 177c and blocks further pulses from passing therethrough and being counted by the counters 174 and 175.

A reset input terminal 177d of the flip-flop 177 is connected to the reset button 34c (FIGS. 2 and 7) permitting resetting of the apparatus A and driving the $\bar{Q}$ output terminal 177c to a logic 1 level, after the outside beams between the transmitter T and the receiver R are interrupted.

The "Out" indicator lamp 34b is electrically connected to the Q output terminal 177b of the flip-flop 177. The indicator lamp, which may be a light-emitting diode, if desired, or other suitable indicator lamp, receives electrical current therethrough from a positive power supply terminal when the Q output terminal 177b of the flip-flop 177 is at a logical 0 or ground state. When the beam is interrupted by a moving tennis ball, the Q output terminal is driven to a logic 1 level, de-energizing the lamp 34b, indicating that the ball was out.

A coding NAND gate 178a electrically connects the second decade counter 175 to a J-K flip-flop 178. The coding NAND gate 178a receives selected outputs from the second decade counter 175. The outputs from the decade counter 175 connected to the coding NAND gate 178a indicate a time limit set by a predetermined number of pulses counted by the counters 174 and 175. This time limit is longer than the interruption of pulsed beams between the transmitter T and the receiver R taking place when a tennis ball passes therethrough. However, this limit is shorter than the time duration of the interruption of the pulsed beams by a player's foot or other permissible interruptions.

Accordingly, when the NAND gate 178a is driven to a logical 1 level in response to the predetermined time limit elapsing, the interruption of the pulsed beams was by a permissible event.

The flip-flop 178 provides a logical 1 at a Q output terminal 178b in response to a permissible interruption of the light beams. A coupling NAND gate 179a is connected by a conductor 177e to the Q output 177b of the flip-flop 177 and to the output terminal 178b. As long as the Q output 177b is logic 1, the gate 179a is driven to a logical 0 level when terminal 178b is driven to logic 1. The logical 0 level at the output of the NAND gate 179a is coupled through the switch 31 and the switch 34c to reset the flip-flop 177 at the reset input 177d, the decade counter 174 at a reset input 174b, the decade counter 175 at a reset input 175a and the flip-flop 178 at a reset input 178c. In this manner, the "Out" decision unit 170 senses a permissible interruption of the pulsed beams of light due to the count exceeding a predetermined number and resets itself automatically as indicated at 204a. As the interruption is generally of a relatively long duration, the counters 174 and 175 repetitively recycle during the long duration interruption caused by a player's foot as indicated by waveforms

200b and 203a (FIG. 11). The indicator lamp 34b flickering off and then on for a brief interval indicated by waveform 204 is not noticed by the linesman observing the panel P.

As has been set forth, the counters 174 and 175 count the number of pulses during the time that the beams between the transmitter T and receiver R are interrupted.

In the event that the interruption of the beam is a relatively short one indicating a tennis ball or other rapidly moving object interrupting the beam, the control gate 173 causes the flip-flop 176 to energize the flip-flop 177 before the counters 174 and 175 cause the coding gate 178a to energize the flip-flop 178 in response to the limit count.

When receipt of beams resumes, monostable flip-flop 176 is triggered, as indicated at 206, and drives Q output 177b of J-K flip-flop 177 to logic 1, and the $\bar{Q}$ output 177c to logic 0 as indicated at 207 and 208, respectively, inhibiting the control gate 173. In this event, the reset pulse is not formed by the gate 179a and thus the reset signal is not furnished to the flip-flop 177, the counters 174 and 175 and the flip-flop 178. When flip-flop 176 resets as indicated at 206, the outputs of flip-flop 177 are driven to the states indicated by the waveforms 207 and 208. The output of gate 173 is inhibited as indicated at 209. Since the predetermined count has not been reached, the gate 179a does not form the reset pulse, and "Out" decision unit 170 is locked out. The "Out" decision unit 170 is thus locked out and the "Out" indicator lamp 34b remains de-energized after the relatively short duration interruption of the beam. In this manner, the linesman is notified that the interruption was an impermissible event and that the ball landed outside the court play.

After announcing his decision, the linesman then depresses the manual reset button 34c resetting the "Out" decision unit 170 so that play may begin once more.

When the ball lands inside or on the line, the "In" decision unit 180, operating in a like manner to the "Out" decision unit 170, de-energizes the lamp 34a indicating that the ball landed in the playing court.

As has been set forth above, the reset switch 31 may be adjusted so that the linesman monitoring the service line may distinguish between a relatively long duration impermissible event, such as a server's foot on the service line, as contrasted to a permissible short-term event, such as a tennis ball landing on the line.

When the switch 31 is so adjusted, a NAND gate 179b, connected to a $\bar{Q}$ output 178d of the flip-flop 178, and further connected by the connector 177e to the Q output 177b of the flip-flop 177 provides a reset signal to the "Out" decision unit 170. The $\bar{Q}$ output 178d energizes the NAND gate 179b when the time limit of counters 174 and 175 is exceeded. Thus, the "Out" decision logic unit may also be used to distinguish between permissible short term events occurring within the time limit established by the counters 174 and 175, and impermissible relatively long term events, indicated by the counters 174 and 175 reaching the predetermined limit.

With the switch unit 260 for the receiver R-1 (FIG. 4A), a pair of NAND gates 261 are connected to signal conditioner units 130 responsive to the two pairs of beams being sent adjacent to and on either side of the half-court line. The NAND gates 261 are electrically connected to "Out" decision units 170 so that the deci-

sion units 170 may determine whether the tennis ball landed adjacent to the line, but not on the line. The linesman monitoring the receiver R-1 can determine whether the service landed in the proper service court by observing the position of the server and observing the indicator lamps 38a, 38b and 38c to determine on which side of the half-court line the served tennis ball landed.

A NAND gate 262 is electrically connected to the signal conditioner units 130 responsive to the pulsed beam sent along the half-court line. The NAND gate 262 provides an output signal to a "In" decision unit 180 when either or both of the pulsed beams along the half-court line is interrupted, indicating that the ball landed at least in part on the half-court line.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, materials, components, circuit elements, wiring connections and contacts as well as in the details of the illustrated circuitry and construction may be made without departing from the spirit of the invention.

We claim:

1. An apparatus for monitoring the occurrence of permissible and impermissible events along a boundary or line, comprising:

- a. transmitter means for sending a pulsed beam of light at periodic intervals along the line;
- b. receiver means for receiving the pulsed beam of light sent along the line; and
- c. control means for detecting interruption of the pulsed beam of light and discriminating between interruptions caused by a permissible event and interruptions caused by an impermissible event.

2. The structure of claim 1, wherein said transmitter means comprises:

- a. emitter means for emitting a light beam when energized; and
- b. lens means for focusing the light beam from said emitter means along the line.

3. The structure of claim 2, wherein said lens means comprises:

- a. collimating lens means for forming a parallel light beam; and
- b. said collimating lens means further focusing the parallel light beam along the line.

4. The structure of claim 1, wherein said receiver means comprises:

- a. photosensitive means for forming an electrical signal in response to light received from said transmitter means; and
- b. lens means for focusing onto said photo-sensitive means the light beam received from said transmitter means.

5. The structure of claim 4, wherein said lens means comprises:

- a. condensing lens means for receiving the beam of light from said transmitter means.

6. An apparatus for assisting an official at a sporting event by monitoring action in the sporting event comprising:

- a. transmitter means for sending a pulsed beam of light at periodic intervals along a boundary of the sporting event;
- b. receiver means for receiving the pulsed beam of light sent along the boundary; and

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- c. control means for detecting interruption of the pulsed beam of light along the boundary and determining the nature of the interruption wherein action adjacent the boundary is monitored to assist the official in controlling play in the sporting event.
7. The structure of claim 6, wherein said transmitter means comprises:
- a. source means for emitting beams of light when energized; and
 - b. pulse generator means for periodically energizing said source means wherein pulsed beams of light are sent at periodic intervals along the boundary.
8. The structure of claim 6, further including:
- a. said transmitter means including means for sending a second pulsed beam of light along a path adjacent the boundary; and
 - b. said receiver means including means for receiving the second pulsed beam of light sent along the path adjacent the boundary; and
 - c. said control means including means for detecting interruption of the second pulsed beam.
9. The structure of claim 8, wherein said control means includes indicator means, said indicator means comprising:
- a. first indicator means for indicating interruption of the first pulsed beam; and
 - b. second indicator means for indicating interruption of the second pulsed beam.
10. The structure of claim 6, wherein the sporting event is a tennis game and wherein the action may be either a player's foot or a tennis ball on the boundary and wherein said control means comprises:
- a. counter means for measuring the duration of the interruption of the pulsed beam of light; and
 - b. decision means for determining the cause of the interruption based on the duration of the interruption measured by said counter means.
11. The structure of claim 6, wherein the action in the sporting event includes permissible and impermissible events occurring adjacent a boundary of the sporting event, and wherein said control means comprises:
- a. first indicator means for indicating interruption of the pulsed beam; and

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- b. lens means for focusing onto said photo-sensitive means the light beam received from said transmitter means.
12. The structure of claim 10, wherein said decision means comprises:
- a. means for interrupting the operation of said counter means in response to the occurrence of the impermissible event; and
 - b. means for indicating occurrence of the impermissible event.
13. The structure of claim 12, further including: reset means for re-energizing said counter means.
14. The structure of claim 10, wherein said decision means comprises:
- a. means for interrupting the operation of said counter means in response to the occurrence of the permissible event; and
 - b. means for indicating occurrence of the permissible event.
15. The structure of claim 14, further including: means for automatically re-energizing said counter means in response to occurrence of a permissible event.
16. The structure of claim 6, further including signal conditioner means in said receiver means, said signal conditioner means, comprising:
- a. peak detector means for detecting the maximum signal level at said receiver means; and
 - b. comparator means for comparing the input signal received with the signal level detected by said peak detector means wherein partial interruptions of the pulsed beam of light and obstructions on the boundary are detected.
17. The structure of claim 6, further including signal conditioner means in said receiver means, said signal conditioner means comprising:
- automatic threshold means for establishing a threshold level in accordance with the peak intensity of the pulsed beam of light at said receiver means, wherein said receiver means is adjusted for fluctuations and changes in the ambient light level.

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