A game court boundary indicator system in which critical zones adjoining the boundary lines have protected and/or concealed sensing means responsive to the proximity of a playing ball having triggering means, said sensing means being unaffected by the presence of the player's body or the tennis racket, and connected to circuit means actuating indicating means.
GAME COURT BOUNDARY INDICATOR SYSTEM

BACKGROUND OF THE INVENTION

This invention relates generally to boundary indication systems for game playing fields or courts and more particularly to structure of the class described in which critical zones adjoining the field or court markers or boundary lines have concealed and protected sensing means responsive to the proximity of the playing ball.

BRIEF DESCRIPTION OF THE PRIOR ART

The U.S. Pat. to Krist, No. 3,415,517 of Dec. 10, 1968 discloses an automatic impact indicator system for tennis which utilizes impact conductor devices which define selected boundaries and areas of a tennis court. Transducers are connected to the conductor devices for converting an impact on a conductor into a signal which operates an indicator-detector to aid an umpire in judging a match. Impact devices and transducers are also associated with the tennis net for detecting and indicating impacts thereon.

The Cornell U.S. Pat. No. 3,645,528 of Feb. 29, 1972 discloses a bowling ball including a tuned loading circuit for purposes of identifying and differentiating between bowling balls of different users for controlling equipment associated with a bowling lane.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

Briefly stated, the present invention contemplates the provision of a tennis court boundary indicator system in which critical zones adjoining the boundary lines have concealed and protected sensing means which are responsive to the presence, proximity and spatial positioning of the playing ball, independently of contact with any sensing means.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

While for purposes of clarity the invention is described principally in connection with the game of tennis, it will be understood that the invention is useful in all games where the position of a ball or playing piece with respect to a zone or boundary line must be objectively determined.

Passing over other aspects of the game of tennis, during play, it is necessary to determine: Is the "serve" a good one or a "fault," and whether the return of any subsequent ball of the volley is a good one or an "out."

For example, in the case of a ball volleyed after initial service, the ball may fall in a critical area between a border line and an imaginary line about 1 foot distant therefrom and its landing point may be disputable. In other words, if the ball strikes the court in an area 1 foot on either side of a boundary line, because of the speed of the ball such areas may be termed dubious areas. Furthermore, since the court may be used for "single" and "double" play, two sets of dubious or critical areas are created. When the ball strikes the court at a point outside of the said critical areas, there is no problem because the visual judgement of the players is easy and unambiguous.

Turning to the first embodiment of the invention as seen in FIGS. 1-7 inclusive, the system generally indicated by reference character 10 comprises broadly: a ball 11; a court 12; boundary lines 14; sensing means 16; indicating means 18; and circuit means 20.

The court 12 from the players' point of view presents a usual appearance except for the "serve" indicating means 13A and 13B which preferably take the form of lights disposed atop net poles 19 therebelow which support the net 21. The two service areas 22 and 23 are defined by lines 24, 25, 26, 27 and 28. Disposed along and adjoining said lines where they define the service areas 22 and 23, and inwardly thereof a suitable distance, for example 1 foot, are oblong critical areas or bands 29 and 30 which are of oblong configuration. Buried beneath the playing surface 15 of the court at said bands, at a suitable depth, for example one-fifth to one-ninth inch, are a plurality of "serve" receiving antenna wires 31 and 32. These wires are preferably arranged in parallel and uniformly spaced, say one-fourth to one-half inch, and are "serve" sensing means.

The boundary lines 24 and 25 delineate the outside longitudinal edges of the "singles" playing area, which includes the above described service areas as well as the areas 33 and 34. Disposed along and adjoining lines 24 and 25 outwardly thereof a suitable distance, for example 1 foot, are longitudinal critical areas or strips 35 and 36. Buried beneath the playing surface of said strips are a plurality of "singles" receiving antenna wires 37 and 38. These are arranged substantially identically to the "serve" antenna wires described above and are "singles" sensing means.

Boundary lines 39 and 40 delineate the outside longitudinal edges of the "doubles" playing area, while boundary lines 41 and 42 at the middle portions thereof delineate the outside end edges of the "singles" and "doubles" playing areas, and at the ends thereof the ends of the "doubles" alleys. Disposed along said adjoining the lines 24 and 25 and outwardly thereof a suitable distance, say 1 foot, is an oblong critical area or annular frame 43 including side portions 45 and 46,
and end portions 47 and 48. Buried beneath the playing surface of said frame are a plurality of “doubles” receiving antenna wires 49, 50, 51 and 52, disposed as described above, and are “doubles” sensing means.

The system 10 includes three receivers, two “service” receivers 53 and 54, and a “singles-doubles” receiver 55. Since they are substantially identical, a description of one will suffice for all. As seen in FIG. 2B the receiver 55 comprises a group of components well known in the art so that detailed descriptions thereof are not considered necessary. The signal as received by a sensing means 16, that is to say — a specific antenna — is fed into a filter 61, to an amplifier 62, to a peak rectifier 63, to a threshold amplifier 64 to a switch or relay 65, and thence to indicating means 18 which may include the sight indicator 66 and a sound indicator 67.

The ball 11 has an external appearance and playing properties which are substantially identical to an ordinary tennis ball. It carries however inward of the exterior surface thereof three conductive windings, preferably of tough flexible wire. Ball 11 is particularly adapted for lower frequencies and the three windings are seen in FIGS. 4, 5 and 6 of the drawings. Winding L1 is coiled about a first horizontal axis, winding L2 is coiled about a vertical axis, and winding L3 is coiled about a horizontal axis displaced 90° from the axis of winding L1.

The transmitter 70 (FIG. 2A) is located so that its waves may be received by all receiving antennas. It may be of relatively low output power and has a vertically polarized antenna 71.

The ball 11 operates as a primary antenna. The coils L1, L2 and L3 create a quasi homogeneous magnetic field around the ball, the windings having their axes in three rectangularly coordinated directions. Coils L1, L2 and L3 may be connected in series or parallel. In the case of parallel connection, less galvanic loss is involved.

\[ L_2 = L_1 \text{ where } L_1 = L_2 = L_3 \]

Frequency = \( \frac{1}{2} \pi \sqrt{L_2 C} \)

L2 is the result. L1, L2, and L3 are the inductances. Frequency is the resonant frequency.

The C capacity is a layer type capacitance directly connected to the terminals of L2.

The receiving antennas, the sensing means 16, operate as a secondary antenna system, positioned as they are under all the critical zones. The signal from the receiving antennas is fed to the selective filter 61, the amplifier 62 of high input sensitivity, and peak rectifier 63. The threshold amplifier 64 may have an integrated circuit (chip) with output logic “0” or “1” depending upon the input DC level. The switch 65 may be for example transistorized. The visual indicator 66 is positioned so that players and all others may view it or may be in multiple locations. The sound device 67 should be audible to all concerned.

The ball 11 thus has a built-in resonant circuit which is tuned to a predetermined radio frequency, for example 30 Mc. This way no primary source of energy need be located in the ball. The suitably placed transmitting antennas 71, connected to the transmitter 70 create a vertically polarized electromagnetic field at the tuned frequency of the ball of substantially constant strength and uniformity of distribution in the area of the court 12. The horizontally laid receiving antennas only lightly interfere with the established vertically polarized field above the court, the receiving antennas running very close to the playing surface 15, but under it.

The ball, during play, acts as a tuned and constantly moving antenna, uninterruptedly consuming electromagnetic energy from the field, producing oscillation at the above-mentioned frequency in its resonant circuit, and thus constantly building up a magnetic field of the same frequency around the ball. This magnetic field has an effect on the secondary antenna system (the receiving antennas, the sensing means 16) that affects the strength of the induced voltage thereof, which is of reverse quadratic proportion to the distance between the ball 11 and the sensing means 16. By proper adjustment of a threshold in the circuit means 17, the presence of balls 11 at a distance under one-half of an inch which fall into the critical zones having the sensing means 16 may be accurately determined. This results in the closing of the particular switch corresponding to the switch 65 as the case may be.

At the beginning of a game, the switch 77 is closed either in the “double” or “single” position (FIG. 1) so that it brings the requisite critical zones of sensing means into connection with the receiver 55.

If after a serving stroke by a player, a ball 11 falls onto the critical areas 29 or 30 the appropriate sensing corresponding to switch 65 will immediately close in “service” receiver 53 or 54 and connect power to the related indicator 13A or 13B which will become illuminated. This indicates to the players that the “serve” is good. The indicators 13A and 13B are preferably green lights and are maintained illuminated say for 10 seconds by well known delay circuits 75 and 76.

With the switch 77 in the “single” position, if a ball in play comes within a predetermined distance of or lands on the strips 35, 36 or portions 47 or 48, switch 65 will close in receiver 55 and the indicators 66 and 67 will be actuated, showing all present at the match that the ball was outside the boundary lines of the court 12.

Similarly, with the switch 77 in the “double” position if a ball in play comes within a predetermined distance of the critical zones 47, 48, 49 and 50, the indicators 66 and 67 will be actuated.

Turning to the modification of the ball 111 seen in FIG. 7, this is suitable for higher frequencies. Ball 111 is made of a material including the conventional rubber homogeneously mixed with ferromagnetic metal, metal oxide powder, or other magnetic material 180. The energy transmission by the ball (between the field over the court and the secondary antennas or sensing means) is produced by rotation the polarization in the existence of resonant tuning. The ball 111 may also include the windings of ball 11 so that it will be useful at a plurality of frequencies.

Turning to the second embodiment generally indicated by reference character 210 illustrated in FIG. 8, the operation of the system is based exclusively on magnetic fields. A magnetic field of high frequency is built up at the playing surface 215 between two sets of wires 281 and 282 beneath the playing surface 215. The ball 211 may be substantially identical to the ball 111. The wires 281 are connected to a transmitter like 70 (not shown) and wires 282 are connected to a receiver like 55 (not shown). The magnetic coupling is increased when the ball 211 carrying magnetic material 280 falls into the field between wires 281 and 282. The local increase of the coupling increment is proportional.
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to the relative permeability factor of the ball material, and quadratically to the physical closeness. Sensing, amplification and indication can occur in a manner similar to the first embodiment.

In the third embodiment seen in Figs. 9 and 10 of the invention, here again to avoid unnecessary repetition, certain of the parts corresponding to the above-described embodiments are given the same reference characters with the addition of a prefix "3."

In the third embodiment, high frequency energy is fed from the generator 370 into pairs of spaced conductors 381 and 382, which are placed in the critical zones which it is requisite to monitor for the presence of the ball 311 or comparable moving playing piece. The ball 311 may be of the same type as the ball 11 of the first embodiment.

The conductors 381 and 382 may be regular television lead-in wire having a 300 ohm impedance, buried beneath the playing surface 315.

A relay 365 is hooked into the circuit which when closed activates suitable indicating means, sight or sound, like the first embodiment.

When the ball 311 comes into proximity to the conductors 381 and 382 (depending upon the sensitivity setting of relay 365), said ball acting as a resonant circuit, acts as a large load due to its energy absorption. This increases the current output so that the relay swings to its "on" position.

In the modification shown in FIG. 11 the outer ends of conductors 381a and 382a are interconnected at 383a. This short circuit produces a reflection from the end. Neglecting a consideration of any losses, the ratio of the traveling wave's amplitude and the reflected waves amplitude:

\[ r = \frac{I_F}{I_r} = 1 \]

where \( r \) is the ratio of the standing waves

\( I_F \) is the forward wave

\( I_r \) is the reflected wave

As soon as the ball enters the field created by the cable \( r \neq 1 \).

Thus with the presence of the ball in a critical zone or area in proximity to the conductors 381a and 382a the relay 365a will measure \( r \) and swing to close circuits to suitable indicating means as described above.

The fourth embodiment shown in FIG. 12 utilizes parallel spaced conductors 481 and 482 which are disposed close to and below the playing surface, and utilizes a balanced bridge circuit which may be either of the inductive or capacitive type.

The ball 411 has a thin layer 485 of insulating material over its entire outer surface which may be felt or a comparable material. Immediately inward thereof is a thin layer 486 of metal. For example a deposition from evaporated metal. The body 487 of the ball may be the usual rubber compound.

Here again the presence of the ball 411 in the field of the paired spaced conductors upsets the balance of the bridge circuit 488, activating the relay 465 which closes circuits to indicating means as heretofore described.

In the fifth embodiment again certain corresponding parts are given similar reference characters with the addition of the prefix "5."

In the fifth embodiment, the ball 511 contains a miniature diode type mixer circuit in which the conductors 581 and 582 are radiating two different radio frequencies. The RC circuit 586 in the ball picks up energy from conductors 581 and the RC circuit 587 from conductors 582. The biasing circuit 588 enables circuit 589 to radiate the heterodyne signal which is picked up by the conductor 590 which is connected to receiver 591, relay 592 and indicating device 593.

It may thus be seen that we have provided a system which eliminates doubt as to where a ball lands on the playing surface. Based on experience we have found that a ball falling on a strip about a foot wide outside a boundary line (or inside on a "serve") may be subject to dispute, and our invention enables the ball to give a distinct audible and visual indication of where it lands in these critical or dubious areas. Our system provides instant operation; high accuracy and reliability; full automation; and practicality so that the same may be manufactured at low cost with a consequent wide distribution and use.

We wish it to be understood that we do not consider the invention limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art to which the present invention relates.

We claim:

1. A playing court boundary indicator system comprising: a playing court; a boundary line on said court; a critical zone adjoining said boundary line; sensing means in said critical zone; indicating means; circuit means associating the sensing means with said indicating means; a playing ball; said ball having triggering means; said triggering means in said ball when in said critical zone affecting said sensing means; whereby said indicating means is actuated, providing a definite indication index of the position of said ball with respect to said critical zone.

2. A system as claimed in claim 1 in which the triggering means in the ball has a plurality of conductive windings coiled about different axes.

3. A system as claimed in claim 1 having a transmitter of a predetermined frequency, in which the triggering means in the ball is a tuned circuit corresponding to the frequency of the transmitter.

4. A system as claimed in claim 1 in which the sensing means has an antenna below the surface of the playing court in said critical zone.

5. A system as claimed in claim 1 in which the playing court includes a "single" critical zone, and a "double" critical zone, each having separate sensing means, and a switch in said circuit means to selectively connect the sensing means of both the "single" and "double" critical zones to the indicating means in one position of said switch and the sensing means of only the "double" critical zone in another position of said switch.

6. A system as claimed in claim 1 in which the triggering means in the ball includes a magnetic material.

7. A system as claimed in claim 1 in which radio frequency energy is fed into said sensing means.

8. A system as claimed in claim 1 in which the sensing means is connected to one portion of a balanced bridge circuit, and the indicating means is connected to the remaining position of the said bridge circuit.

9. A system as claimed in claim 1 in which the sensing means radiates two different radio frequencies, and the triggering means in the ball is a mixer circuit.

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