

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 368 878 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **12.01.94** (51) Int. Cl.⁵: **A63B 71/06**

(21) Application number: **88905616.4**

(22) Date of filing: **30.06.88**

(86) International application number:
PCT/AU88/00229

(87) International publication number:
WO 89/00066 (12.01.89 89/02)

(54) **BALL LOCATION SYSTEM.**

(30) Priority: **30.06.87 AU 2801/87**

(43) Date of publication of application:
23.05.90 Bulletin 90/21

(45) Publication of the grant of the patent:
12.01.94 Bulletin 94/02

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(56) References cited:
DE-A- 3 543 679
US-A- 3 774 194
US-A- 4 375 289
US-A- 4 527 152
US-A- 4 664 376

(73) Proprietor: **CALDONE PTY. LIMITED**
26 Fitzroy Avenue
Camden Park, S.A. 5038(AU)

(72) Inventor: **CANDY, Bruce, Halcro**
Blockers Road
Basket Range, S.A. 5138(AU)
Inventor: **BAXTER, John, Robert**
7 Bowey Avenue
Salisbury Heights, S.A. 5109(AU)

(74) Representative: **Kearney, Kevin David**
Nicholas et al
KILBURN & STRODE
30 John Street
London, WC1N 2DD (GB)

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

Description

This invention relates to a ball location arrangement and in particular to means to assess the position of a ball such as a tennis ball when this hits a playing surface in the vicinity of a court marking line.

Background of the Invention

It is a well known problem to which there are several proposed solutions.

Systems utilising balls containing conductive fibres which close circuits when making contact between exposed sensor conductors on the court surface, such as those described in the US Patents 3,883,860 and 4,299,384, have the problem that the balls may have to be of different colour, surface texture, friction coefficient, and moment of inertia than that of the now conventionally used tennis ball, and the court will necessarily be of substantially different texture near the lines. Furthermore the circuits may be closed by any electrical conductor such as an aluminium tennis racket, or conductive fibres which may have fallen out of the ball and lie across the sensing conductors on the court.

Systems utilising electromagnetic interrogation by means of sensing coils buried below the court surface are described in US Patent 3,774,194 and 4,664,376. The precharacterising portion of claim 1 is based on US 3,774,194.

The former Patent describes a radio frequency bridge circuit, one "arm" of which comprises a buried coil, which is used to sense a tennis ball containing a resonant electrical circuit tuned to the said radio frequency transmitted by the said coil.

The latter Patent describes a buried coil which is part of the resonator of an oscillator whose frequency and quality factor are altered by the close presence of a ball of substantially non-zero magnetic permeability.

There are difficulties with such an arrangement in so far that there is susceptibility to external influences. Furthermore, there is great difficulty to assess whether a ball touches the line in cases where the ball is either just "in" or "out", rather, the described systems merely sense the close proximity of the ball to the sensing coils. In addition, the ball described in Us Patent 3,774,194 has physical properties substantially different to the standard ball, such as moment of inertia which necessarily has distinct Eigen axes.

In order to determine whether the ball is "in" or "out", it is necessary to process the received data by means of pattern recognition algorithms or arithmetic algorithms of the data of the received pulse shape generated by the close passage of the ball. Merely measuring the close presence of a ball

as indicated in Patent US 4,664,376 will result in inaccuracies for reasons given later.

It is an object of this invention to at least reduce one or more of the above difficulties

Summary of the Invention

The present invention is characterised by the respective coils being in an overlapping relationship, and the windings of the receive coil being arranged such that the receive coil is substantially nulled with respect to any transmission field from the transmit coil.

In preference the receive coil is adapted by reason of its shape to effect a substantial self-cancelling of signals received from far field sources.

In preference there are two receive coils adjacent the transmit coil.

In preference the receive coil includes a first part wound in a first clockwise direction, and a second part wound in a counter clockwise direction, whereby to provide for substantial self-cancelling of any signals received from far field electromagnetic sources.

According to this invention then there is described an electromagnetic interrogation system in which transmit and receive coils are located below the court surface in the vicinity of the court lines.

An axis of each of these coils is parallel to the court line, and signals from these are used to sense a ball with material with substantially non-zero magnetic permeability.

In preference the ball has some of the latex rubber "filler" additives normally in a tennis ball replaced with powdered particles of high permeable magnetic material such as a ferrite.

In preference there are transmitter means which transmit through the transmit coil an alternating magnetic field with a period selected from within the range 2 micro-seconds to 200 micro-seconds which signal may be received by the receive coil or coils from a ball re-radiating the signal together with extraneous effects.

In preference signals induced in the receive coils are synchronously demodulated and low-pass filtered by detector means. The reference phases of the synchronous demodulators are selected to select magnetic components either in-phase with the ball's magnetic permeability or quadrature components to the ball's permeability. The said low-pass filtered signals are then further processed by effecting a comparison of the signal with a known signal result to yield a final "in" or "out" assessment.

In preference there are a plurality of individual receive coils occupying each a selected long length of a line beneath a playing surface that is a

tennis court and, are preferably of the order of metres in elongate length. These said receive coils are preferably laid end on end below the length of the court lines with a proportion of each end overlapping with it's adjacent coils. The transmit coil may likewise be segmented or extend the length of the lines.

The system described herein can overcome a number of the previously existing problems.

Firstly, physical differences:

The ball and court can be made to be physically indistinguishable from standard.

Secondly, false triggerings can be minimized where detectable objects traverse the line other than the ball.

Thirdly, reduced susceptibility to far field generated electromagnetic interference (E.M.I.).

Both the said quadrature and in-phase signals are equally susceptible to electromagnetic interference. Thus any significant signal in the quadrature channel indicates a false signal. If further the receive coil circuits are constructed so that far magnetic fields are canceled whereas near fields are not, then the system can be relatively insensitive to electromagnetic interference compared to systems containing coils not nulled to far fields.

Fourthly, accuracy:

The processing can include means for reasonably accurately determining whether any part of the ball touched the line in "just in/out" cases. This can be achieved by means of processing algorithms part of which require certain ratios or comparisons of signal values, not just magnitude comparisons to fixed values.

Furthermore it is best that some of these said ratios or comparisons are between data from different receive coil circuits which are sensitive to the same length of court line but which have different spatial sensitivities across the line. Processing utilizing data from two different coil signals enable the final "in"/"out" assessment to be relatively independent of the depth of the coils or permeability of the ball.

Brief Description of the Drawings:

To assist with the understanding of this invention, reference will now be made to diagrams herein wherein :-

FIG. 1 is a diagram shown according to the preferred embodiment an arrangement of a transmit coil and two receive coils circuits balanced to far fields, and with uniform sensitivity at the ends;

FIG. 2 is a plan view of the arrangement as in Fig 1;

FIG. 3 shows a schematic circuit layout for the embodiment in figs 1 and 2, and

FIG. 4 shows waveforms from balls of different trajectory striking the court above a buried coil system for the configuration shown in FIG. 1, 2 and 3.

Referring in particular to the drawings there is shown a transmit coil 1 and receive coils 2 and 3. The receive coils 2 and 3 are two independent receive coil circuits with windings wound in both clockwise and anti-clockwise senses indicated by the arrows 4, 5 and 6 for coil 2 and 7 and 8 for coil 3. That is, coil 2 effectively consists of three series windings 9, 10 and 11, one in a clock-wise sense at the top of the diagram, followed by an anti-clockwise winding 10 in the centre, and then followed by a clockwise winding at the bottom of the diagram.

Coil 3 effectively consists of two series windings 12 and 13, one of these 12 being wound in a clock-wise sense in the top half of the diagram followed by an anti-clockwise winding 13 in the bottom half of the diagram.

The dimensions and number of turns of each winding are selected such that signals induced in each coil from far magnetic fields at the transmit frequency are substantially canceled or nulled. This substantially reduces the level of electromagnetic interference in the coil circuits. In this specification, reference to "far field" is understood to mean a field generated by a source at least ten times further from a receive coil than the width dimension of the said coil.

The effect of the transmit coil's spatial impedance must be taken into account for the said cancellation to be successful. For example if the coils are symmetrically displaced about the centre of the diagram then coil 3, with the same number of turns in each winding, will be balanced to far fields regardless of the transmit coil's driving impedance, whereas for the same dimensions, the number of turns in coil 2 outer coils 9 and 11 compared to the inner coil 10 is dependent on the transmit coil 1 driving impedance. The sensitivity of the coils to the ball 25 are highest at the ends of the receive coils.

In order to make the sensitivity more uniform, it is necessary to split each coil winding at the ends as shown at 14.

The signals generated by oscillator 15 are amplified through amplifier 16 and when received in coils 2 and 3 are amplified by amplifier 17 then synchronously demodulated at the transmit frequency and then low-pass filtered. The synchronous demodulator reference phases are selected to select both components substantially in-phase with the ball's permeability and at quadrature to it, these being shown in Fig. 3 as synchronous demodulator and low pass filter 18 for in-phase components and synchronous demodulator and low pass filter 19 for quadrature phase components using a quadrature

phase shifter 20.

A quiescent "background" signal is subtracted at 21 and 22 to give a signal whose magnitude is a function of changes in the magnetic environment of the coils. The in-phase components are used for further processing and the quadrature components can be used for discrimination purposes such as identifying materials with reactive-to-resistive ratios different to that of the ball, such as aluminium tennis rackets, metal tacks in tennis shoes etc. traversing the court line, as well as discriminating against electromagnetic interference. Data from receive coil pairs are processed in a "local" micro-processor 25, and the processed information is passed to a "central" microprocessor as indicated by 28. A similar receiving and analogue processing circuitry is used for coil 2, and the corresponding data is passed to the common "local" microprocessor 25 as indicated by 26 and 27.

Accordingly by introducing the concept of providing a transmit coil and a receive coil, it is possible to tailor the receive coil or coils to firstly be less susceptible to electro-magnetic interference from distant sources or far fields, and it is also possible to effect a substantial discrimination in that the received signal can then be examined in relation to its resistive and reactive components and only signals within selected limits can then be accepted.

A ball, and in particular a tennis ball, can have a small quantity of ferrite incorporated within the mixture of the rubber replacing to the same weight, previously existing fillers so that the ball and its handling and bouncing characteristics remain absolutely the same except that it has a substantive magnetic permeability.

The reason for using two receive coils is that if one receive coil only is used, for instance coil 3, if a tennis ball maintained a position exactly along a lateral dividing line of this coil, it would not appear to be detectable and hence one needs a separate further coil set to detect a ball in this situation.

The second receive coil, of course, has to also be wound so as to be essentially balanced or nulled against far field origin electromagnetic interference, but be differently wound from the first coil, that is coil 2, to achieve this.

The coils as aligned specifically in Fig. 2, can be of substantially indefinite lengths but are then appropriately located beneath each of the respective lines, such as at 23, that one might expect on a tennis court.

Each receive coil is "nulled" to the transmitted field, that is the net signal induced by the transmit coil in either receive coil is substantially minimized owing to the selected geometry of the windings in relation to the transmit coil. This is conducive to relatively simple electronics not requiring high

tolerances of stability and large dynamic range.

There will now be discussion as to how to interpret an "in" or "out" assessment which can involve determining for a large number of different bounce positions, the appropriate signature for a ball and then having this stored in the memory of a micro-processor and then having this compare an appropriate signature with an incoming signal signature when the unknown position is to be determined.

While a significant signal is present in the quadrature component of either coil in a receive coil pair, all tennis ball "in" or "out" assessments need be inhibited for data from the said coil pair. Thus occasions may arise when the system is unable to assess whether a ball is "in" or "out", but these should be infrequent.

FIG. 4 shows four waveforms at the low-pass filter output, with the background subtracted, from the in-phase components resulting from balls of different trajectory striking the court above a buried coil system of the configuration shown in FIG. 1 and 2. The "dashed" lines represent the response from coil 2 and the "continuous" lines are for coil 3.

Assume that the "in"/"out" edge is directly above the boundary between the two windings in coil 3's circuit, that is the centre of FIG. 2, and that in each case the projection of the ball is traversing from the bottom of the page to the top where the bottom is on the "in" side and the top on the "out" side.

Trajectories for balls from a "high lob" in which the ball strikes the court from a near vertical approach which land exactly in the centre of the coil system, that is the ball is "in", and a little above centre such that the ball is just "out" are shown in 4(a) and 4(b) respectively.

Waveforms resulting from trajectories of a fast shot which just skims over the net in which the ball strikes the court from a near horizontal approach are shown in 4(c) and 4(d). 4(c) is for such trajectories where the ball's "foot print" is symmetrical about the "in"/"out" edge and 4(d) is for such trajectories where the ball is just "out".

Many algorithms can be employed to determine whether the ball was "in" or "out". All reasonable accurate algorithms require either waveform comparisons with a dictionary of waveforms spanning a range of possible waveforms, or, algorithms in which certain ratios or comparisons of signal values with each other are made, not just magnitude comparisons to fixed values. For example, part of one such latter algorithm determines the value of

$$(\int(S3 + Kabs(S3))dt)/(\int S2dt)$$

where S2 and S3 are the said low-passed signal with the quiescent signals removed from coil 2 and 3 respectively. "abs(S3)" means the absolute value of S3 and K is a constant. If the said value is less than a certain constant, the ball is deemed to be "out", otherwise it is deemed to be "in", so long as certain other criterion are also met. Comparing data from one coil circuit in one pair with data from the other, yields a result relatively independent of the depth of the coils below the surface and ball permeability.

It is also desirable to check that the data is within certain constraints for further discrimination purposes. For example, too big or small a signal, or a pulse shape that could not have been created by an apparently impossible ball trajectory would necessitate an unacceptable assessment.

In cases where the ball lands near the line near the end of a receive coil pair and where part of the ball trajectory is too far outside of the receive coil pair's sensitive zone required for accurate ball position assessment, it is necessary to make an assessment as to whether the ball is "in" or "out" by examining data from the said coil pair in question and the coil pair adjacent to it near which the ball also traverses.

For simplicity and accuracy it is best to overlap the ends of adjacent receive coil pairs so that for the whole region near the line, all ball positions within the near field of the coils induce substantial signals usable for assessment in at least one coil. An assessment need be made to determine whether detected and processed ball signals indicate that the ball is traversing near either end of any coil pair.

A "central micro-processor" is alerted to which processed data from each coil pair are transmitted, such that the said central micro-processor selects or combines the data from all the pair of coils near which the ball 24 traversed to yield a final assessment as to whether the ball 24 was "in" or "out".

In tennis courts containing metallic reinforcing rods, the magnetic field in the vicinity of the rods is substantially altered by the presence of the rods owing to their permeability. Hence the response to a ball traversing areas near the said rods will be different to that of corresponding ball trajectories further from the rods.

In order to avoid this undesirable situation, a metal screen, made of aluminum for example, may be inserted between the rods and the coils. The presence of the screen substantially alters the strength the magnetic field generated by the transmit coil in that it is, compared to the "non-screen" case, relatively weak far from the windings compared to that close to the windings.

In order to make the field more uniform across the sensitive zone, the windings need be wound in

a planar spiraled fashion, such that the number of windings per unit length increases from the centre of the winding to the outside perimeter. This also applies to each receive coil winding, that is it need be distributed in a similar spread out fashion.

Claims

1. A ball location assessment arrangement including, beneath a playing surface, a transmit coil (1), and a receive coil (2,3), the two said coils being located in mutually adjacent alignment beneath a selected part of the playing court, characterised by the respective coils being in an overlapping relationship, and the windings of the receive coil (2,3) being arranged such that the receive coil is substantially nulled with respect to any transmission field from the transmit coil (1).
2. A ball location assessment arrangement as in claim 1, wherein the receive coil (2,3) is adapted by reason of its shape to effect a substantial self-cancelling of signals received from far field sources.
3. A ball location assessment arrangement as claimed in either preceding claim, wherein there are two receive coils (2,3) adjacent the transmit coil (1).
4. A ball location assessment arrangement as claimed in any preceding claim, wherein each receive coil (2,3) includes a first part (9,11,12) wound in a first clockwise direction, and a second part (10,13) wound in a counter clockwise direction, to provide for substantial self-cancelling of any signals received from far field electromagnetic sources.
5. A ball location assessment arrangement as claimed in claim 3 or 4, wherein there are two receive coils (2;3) adjacent the transmit coil (1), and, wherein a first of the receive coils (3) includes two parts (12,13) one of which is wound in a clockwise direction and a second wound in a counter clockwise direction, the second receive coil (2) is wound so as to have three parts (9, 10, 11), two of which are wound in either a clockwise or counter clockwise direction and the third part (10) lying between the said first two parts is wound in the opposite-wise direction than the said first two parts, and a boundary between the said parts of the first said coil (3) is not aligned, when viewed in plan, with a boundary between any of the parts of the said second coil (2).

6. A ball location assessment arrangement as claimed in any preceding claim, wherein the transmit coil (1) is of elongate proportions and aligned to extend substantially beneath a line (23) on the playing surface, and the receive coil or coils (2,3) are in each case aligned symmetrically about the transmit coil (1) and extending substantially coincident with the same elongate dimensions as the transmit coil (1). 5
7. A ball location assessment arrangement as claimed in any preceding claim, wherein there are transmission means (15,16) adapted to effect an alternating electro-magnetic signal coupled to the transmit coil (1) and there are detector means (17-22,25,28) coupled to the receive coil or coils and adapted to detect signals re-radiated from a ball (24) having magnetic permeability within a near field vicinity of both the transmit coil (1) and corresponding receive coil (2,3). 10 15 20
8. A ball location assessment arrangement as claimed in claim 7, wherein the detector means (17-22,25,28) include means (18,19,20) to effect synchronous demodulation of the detected signal in relation to the transmitted signal in the transmit coil. 25 30
9. A ball location assessment arrangement as claimed in any preceding claim, wherein the said detector means include synchronous demodulators followed by low-pass filters. 35
10. A ball location assessment arrangement as claimed in any preceding claim, wherein the detector means (17-22,25,28) further include processing means (25,28) for determining a ball position and include algorithms including means providing a process of determining the ratio or comparison between the amplitude of the signals received in each receive coil circuit of each said pair. 40 45
11. A ball location assessment arrangement as claimed in any preceding claim, wherein the said transmitted magnetic field is substantially sinusoidal, and such that the synchronous detectors are synchronous with the transmitted magnetic field and the phases selected to be either in-phase or at quadrature with the ball magnetic permeability at the transmitted frequency, and includes means for discrimination to reject false signals arising from materials with reactive ratios different to that of the ball. 50 55
12. A ball location assessment arrangement as claimed in any preceding claim further including a microprocessor (25,28) as part of the said processing means which contains software algorithms which contain constraining parameters for discrimination purposes and assessments as to the apparent trajectory of the ball (24).
13. A ball location assessment arrangement as claimed in claim 12, including a microprocessor (25) containing a software algorithm by which an assessment can be made to determine whether detected and processed ball signals indicate that the ball (24) has traversed near either end of any coil pair and including a central microprocessor (28) to which processed data from each coil pair is transmitted, such that the said central microprocessor (28) selects or combines the data from all the pair of coils near which a ball (24) traversed to yield a final assessment as to whether the ball was "in" or "out".
14. A ball location assessment arrangement as claimed in any preceding claim, wherein the individual turns at the ends of the receive and transmit coil circuits are spread out, where the said spreading may consist of single strands of a coil circuit being substantially spatially separated or individual turns of the said coil circuit may be grouped together in more than one group and the said groups may be substantially spatially separated from each other, such that the said spatial separations are selected such that the sensitivity of the coils to the ball at the said ends are not substantially higher than that of the corresponding ball position with respect to the court line near the centre of the said receive coil pair.
15. A ball location assessment arrangement as claimed in any preceding claim in which a metal screen is located below the coils and where each winding of each coil is wound in a planar spiralled fashion, such that the number of windings per unit length increases from the centre of each said winding to the outside perimeter, the geometry and conductor density being selected to make the field reasonably uniform across the coils sensitive zone.
16. A ball location assessment arrangement as claimed in any preceding claim, wherein there is included a tennis ball (24) having within its body a substance providing substantive magnetic permeability.

Patentansprüche

1. Einrichtung zur Bestimmung einer Ballposition umfassend unter einer Spielfläche eine Übertragungsspule (1) und eine Empfangsspule (2,3), wobei die beiden Spulen nebeneinander unter einem ausgewählten Teil eines Spielplatzes angeordnet sind, **dadurch gekennzeichnet, daß** die Spulen in einer überlappenden Beziehung stehen, und daß die Windungen der Empfangsspule (2,3) so angeordnet sind, daß die Empfangsspule mit Bezug auf jegliches Übertragungsfeld der Übertragungsspule (1) im wesentlichen auf Null gestellt ist.

5
10
15
2. Einrichtung zur Bestimmung einer Ballposition nach Anspruch 1, worin die Empfangsspule (2,3) aufgrund ihrer Form geeignet ist, eine im wesentlichen Selbstlöschung von Signalen auszuüben, die von entfernten Feldquellen empfangen werden.

20
3. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin es zwei Empfangsspulen (2,3) nahe der Übertragungsspule (1) vorgesehen sind.

25
4. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin jede Empfangsspule (2,3) einen ersten Teil (9,11,12), der in einer ersten Uhrzeigersinn-Richtung gewickelt ist, und einen zweiten Teil (10,13) umfaßt, der in einer Gegenuhrzeigersinn-Richtung gewickelt ist, um die im wesentlichen Selbstlöschung jeglicher Signale zu liefern, die von fernen elektromagnetischen Feldquellen empfangen werden.

30
35
5. Einrichtung zur Bestimmung einer Ballposition nach Anspruch 3 oder 4, worin zwei Empfangsspulen (2,3) nahe der Übertragungsspule (1) vorgesehen sind, und worin eine erste Empfangsspule (3) zwei Teile (12,13) umfaßt, von denen einer in einer Uhrzeigersinn-Richtung und ein zweiter in einer Gegenuhrzeigersinn-Richtung gewickelt ist, wobei die zweite Empfangsspule (2) so gewickelt ist, daß sie drei Teile (9,10,11) aufweist, von denen zwei entweder in Uhrzeigersinn oder Gegenuhrzeigersinn-Richtung gewickelt sind, und der dritte Teil (10), der zwischen den ersten zwei Teilen liegt, in der entgegengesetzten Richtung wie die ersten zwei Teile gewickelt ist, und wobei eine Grenzlinie zwischen den Teilen der ersten Spule (3) in Draufsicht gesehen nicht ausgerichtet ist mit einer Grenzlinie zwischen beliebigen Teilen der zweiten Spule (2).

40
45
50
55
6. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin die Übertragungsspule (1) längliche Proportionen hat und so ausgerichtet ist, daß sie sich im wesentlichen unterhalb einer Linie (23) auf der Spielfläche erstreckt, und wobei die Empfangsspule oder Empfangsspulen (2,3) in jedem Falle symmetrisch über der Übertragungsspule (1) ausgerichtet ist/sind und sich im wesentlichen übereinstimmend mit den gleichen Längsdimensionen wie die Übertragungsspule (1) erstreckt/erstrecken.

10
7. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin es eine Übertragungseinrichtung (15,16) gibt, die geeignet ist, ein alternierendes elektromagnetisches Signal zu erzeugen, das mit der Übertragungsspule (1) gekoppelt ist und worin es eine Detektoreinrichtung (17-22,25,28) gibt, die mit der Empfangsspule oder den Empfangsspulen gekoppelt und geeignet ist, Signale zu detektieren, die von einem Ball (24) zurück abgestrahlt werden, der eine magnetische Permeabilität innerhalb eines Nahfeldbereichs sowohl der Übertragungsspule (1) als auch der entsprechenden Empfangsspule (2,3) aufweist.

15
20
8. Einrichtung zur Bestimmung einer Ballposition nach Anspruch 7, worin die Detektoreinrichtung (17-22,25,28) eine Einrichtung (18,19,20) einschließt, um eine synchrone Demodulation des detektierten Signals in Beziehung zu dem übertragenen Signal in der Übertragungsspule zu bewirken.

30
35
9. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin die Detektorvorrichtung synchrone Demodulatoren mit anschließenden Tiefpaßfiltern einschließt.

40
10. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin die Detektorvorrichtung (17-22,25,28) weiterhin eine Verarbeitungseinrichtung (25,28) zum Bestimmen einer Ballposition und einen Algorithmus einschließt, der Mittel umfaßt, die ein Verfahren zum Bestimmen des Verhältnisses oder eines Vergleichs zwischen der Amplitude der Signale liefern, die in jedem Empfangsspulenschaltkreis von jedem Paar empfangen werden.

45
50
55
11. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin das übertragene magnetische Feld im

55

wesentlichen sinusförmig und so ist, daß die Synchrondetektoren synchron mit dem übertragenen Magnetfeld sind und die Phasen so ausgewählt sind, daß sie entweder in Phase oder Quadratur mit der magnetischen Permeabilität des Balls bei der übertragenen Frequenz sind, und eine Diskriminatoreinrichtung zum Zurückweisen von falschen Signalen umfaßt ist, die von Materialien mit reaktiven Verhältnissen verschieden zu denen des Balls sind.

5

10

12. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, weiterhin umfassend einen Mikroprozessor (25,28) als Teil der Verarbeitungseinrichtung, welcher Software-Algorithmen einschließt, die einschränkende Parameter zu Unterscheidungszwecken und zur Feststellung der auftretenden Bahn des Balls (24) enthält.

15

20

13. Einrichtung zur Bestimmung einer Ballposition nach Anspruch 12, mit einem Mikroprozessor (25), der einen Software-Algorithmus enthält, mit welchem eine Feststellung getroffen werden kann, um festzustellen, ob detektierende und verarbeitete Ballsignale anzeigen, daß der Ball (24) sich nahe bei irgendeinem Ende eines Spulenpaares vorbeibewegt hat, und mit einem zentralen Mikroprozessor (28), an welchen verarbeitete Daten von jedem Spulenpaar übertragen werden, so daß der zentrale Mikroprozessor (28) die Daten aus allen Spulenpaaren auswählt oder kombiniert, in deren Nähe sich ein Ball (24) vorbeibewegt hat, um eine endgültige Feststellung zu treffen, ob der Ball "in" oder "out" war.

25

30

35

14. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin die einzelnen Windungen an den Enden der Empfangs- und der Übertragungsspulenschaltkreise aufgeweitet sind, wobei das Ausweiten darin besteht, daß einzelne Stränge eines Spulenschaltkreises im wesentlichen räumlich getrennt sind oder einzelne Windungen des Spulenschaltkreises in mehr als einer Gruppe zu Gruppen zusammengefaßt sein können und die Gruppen im wesentlichen räumlich voneinander getrennt sein können, sodaß die räumlichen Trennungen so gewählt sind, daß die Empfindlichkeit der Spulen für den Ball an den genannten Enden im wesentlichen nicht höher sind als die an der entsprechenden Ballposition mit Bezug auf die Spielfeldlinie nahe der Mitte des Empfangsspulenpaares.

40

45

50

55

15. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, in welchen ein Metallschirm unter den Spulen angeordnet ist und wo jede Wicklung jeder Spule in einer planaren spiralförmigen Weise gewickelt ist, so daß die Anzahl der Windungen pro Längeneinheit von der Mitte jeder Wicklung zum äußeren Rand zunimmt, wobei die Geometrie und die Leiterdichte so gewählt sind, daß das Feld über der Spulenempfindlichkeitszone hinreichend einheitlich gemacht wird.

16. Einrichtung zur Bestimmung einer Ballposition nach einem der vorangegangenen Ansprüche, worin ein Tennisball (24) eingeschlossen ist, der in seinem Körper eine Substanz aufweist, die eine wesentliche magnetische Permeabilität liefert.

Revendications

1. Agencement d'évaluation du point d'impact d'une balle incluant, au-dessous d'une surface de jeu, une bobine d'émission (1) et une bobine de réception (2, 3), les deux dites bobines étant positionnées selon un alignement mutuellement adjacent au-dessous d'une partie sélectionnée du cours de jeu, caractérisé en ce que les bobines respectives sont en chevauchement et en ce que les enroulements de la bobine de réception (2, 3) sont agencés de telle sorte que la bobine de réception soit sensiblement annulée vis-à-vis d'un quelconque champ d'émission en provenance de la bobine d'émission (1).
2. Agencement d'évaluation du point d'impact d'une balle selon la revendication 1, dans lequel la bobine de réception (2, 3) est conçue en raison de sa conformation de manière à réaliser une auto-annulation significative de signaux reçus depuis des sources de champ lointain.
3. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel il y a deux bobines de réception (2, 3) adjacentes à la bobine d'émission (1).
4. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel chaque bobine de réception (2, 3) inclut une première partie (9, 11, 12) enroulée selon le sens des aiguilles d'une montre et une seconde partie (10, 13) enroulée selon le sens inverse des

aiguilles d'une montre afin d'assurer une autoannulation significative de quelconques signaux reçus depuis des sources électromagnétiques de champ lointain.

5. Agencement d'évaluation du point d'impact d'une balle selon la revendication 3 ou 4, dans lequel il a deux bobines de réception (2 ; 3) adjacentes à la bobine d'émission (1) et dans lequel une première des bobines de réception (3) inclut deux parties (12, 13) dont une première est enroulée selon le sens des aiguilles d'une montre et dont une seconde est enroulée selon le sens inverse des aiguilles d'une montre, la seconde bobine de réception (2) est enroulée de manière à comporter trois parties (9, 10, 11) dont deux sont enroulées selon soit le sens des aiguilles d'une montre soit le sens inverse des aiguilles d'une montre et dont la troisième partie (10) qui s'étend entre lesdites deux premières parties est enroulée selon le sens opposé auxdites deux premières parties et une frontière entre lesdites parties de ladite première bobine (3) n'est pas alignée selon une vue en plan avec une frontière entre l'une quelconque des parties de ladite seconde bobine (2).
6. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel la bobine d'émission (1) présente des proportions allongées et est alignée de manière à s'étendre sensiblement au-dessous d'une ligne (23) située sur la surface de jeu et la bobine de réception ou les bobines de réception (2, 3) sont dans chaque cas alignées de façon symétrique par rapport à la bobine d'émission (1) et s'étendent de manière à coïncider significativement avec les mêmes dimensions allongées que la bobine d'émission (1).
7. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel il y a un moyen d'émission (15, 16) conçu pour produire un signal électromagnétique alternatif couplé à la bobine d'émission (1) et un moyen de détecteur (17-22, 25, 28) couplé à la bobine de réception ou aux bobines de réception et conçu pour détecter des signaux reirradiés depuis une balle (24) présentant une perméabilité magnétique dans un champ proche voisin à la fois de la bobine d'émission (1) et d'une bobine de réception correspondante (2, 3).
8. Agencement d'évaluation du point d'impact d'une balle selon la revendication 7, dans le-

quel le moyen de détecteur (17-22, 25, 28) inclut un moyen (18, 19, 20) pour réaliser une démodulation synchrone du signal détecté en relation avec le signal émis dans la bobine d'émission.

9. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel ledit moyen de détecteur inclut des démodulateurs synchrones suivis par des filtres passe-bas.
10. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel le moyen de détecteur (17-22, 25, 28) inclut en outre un moyen de traitement (25, 28) pour déterminer une position de balle et comprend des algorithmes incluant un moyen produisant un processus de détermination du rapport ou de la comparaison entre l'amplitude des signaux reçus dans chaque circuit de bobine de réception de chaque dite paire de bobines.
11. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel ledit champ magnétique émis est sensiblement sinusoïdal de telle sorte que les détecteurs synchrones soient synchrones avec le champ magnétique émis et que les phases sélectionnées soient soit en phase soit en quadrature de phase avec la perméabilité magnétique à la fréquence d'émission, et il inclut un moyen pour effectuer une discrimination afin de rejeter des signaux provenant de matériaux présentant des rapports de réaction différents de ceux de la balle.
12. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, incluant en outre un microprocesseur (25, 28) en tant que partie dudit moyen de traitement qui contient des algorithmes de logiciel qui contiennent des paramètres de contrainte à des fins de discrimination et d'évaluation de la trajectoire apparente de la balle (24).
13. Agencement d'évaluation du point d'impact d'une balle selon la revendication 12, incluant un microprocesseur (25) contenant un algorithme de logiciel au moyen duquel une évaluation peut être effectuée pour déterminer si oui ou non des signaux de balle détectés et traités indiquent que la balle (24) est passée près de l'une quelconque des extrémités d'une quelconque paire de bobines et incluant un micro-

processeur central (28) auquel des données traitées en provenance de chaque paire de bobines sont transmises de telle sorte que ledit microprocesseur central (28) sélectionne ou combine les données en provenance de toutes les paires de bobines à proximité desquelles une balle (24) est passée pour obtenir une évaluation finale consistant à savoir si la balle était bonne ou mauvaise.

5

10

14. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel les spires individuelles au niveau des extrémités des circuits de bobine de réception et d'émission sont étalées, ledit étalement pouvant être constitué par des uniques torons d'un circuit de bobine qui sont séparés spatialement de façon significative ou par des spires individuelles dudit circuit de bobine qui peuvent être groupées ensemble selon plus d'un groupe et lesdits groupes peuvent être séparés spatialement de manière significative les uns des autres de telle sorte que lesdites séparations spatiales soient choisies de telle sorte que la sensibilité des bobines vis-à-vis de la balle au niveau desdites extrémités ne soit pas significativement supérieure à celle de la position de balle correspondante par rapport à la ligne de cours située à proximité du centre de ladite paire de bobines de réception.

15

20

25

30

15. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel un écran en métal est placé au-dessous des bobines et où chaque enroulement de chaque bobine est enroulé en spirale plane de telle sorte que le nombre d'enroulements par longueur unitaire croisse depuis le centre de chaque dit enroulement jusqu'au périmètre extérieur, la géométrie et la densité de conducteur étant choisies de manière à rendre le champ raisonnablement uniforme autour de la zone sensible aux bobines.

35

40

45

16. Agencement d'évaluation du point d'impact d'une balle selon l'une quelconque des revendications précédentes, dans lequel une balle (24) comportant à l'intérieur de son corps une substance assurant une perméabilité magnétique significative est incluse.

50

55

fig 1

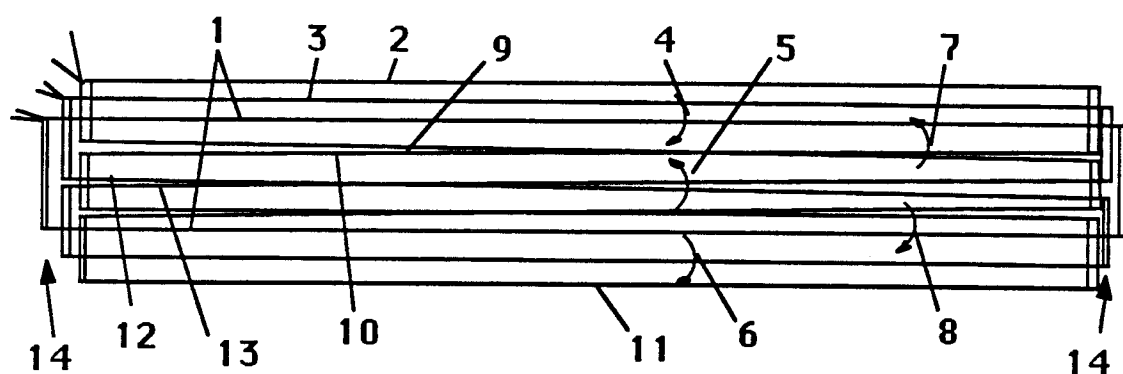
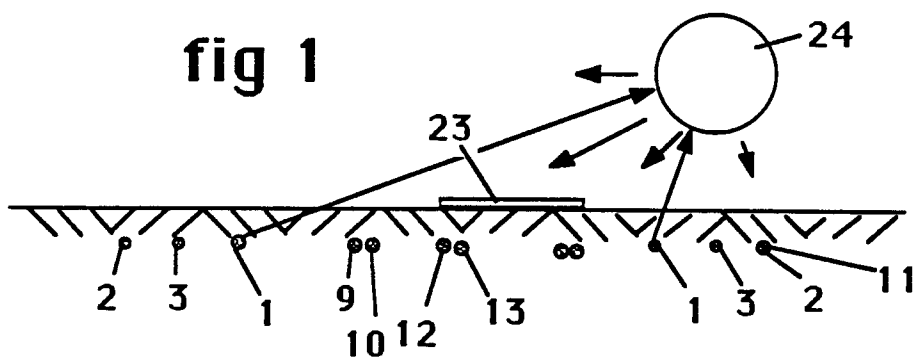


fig 2

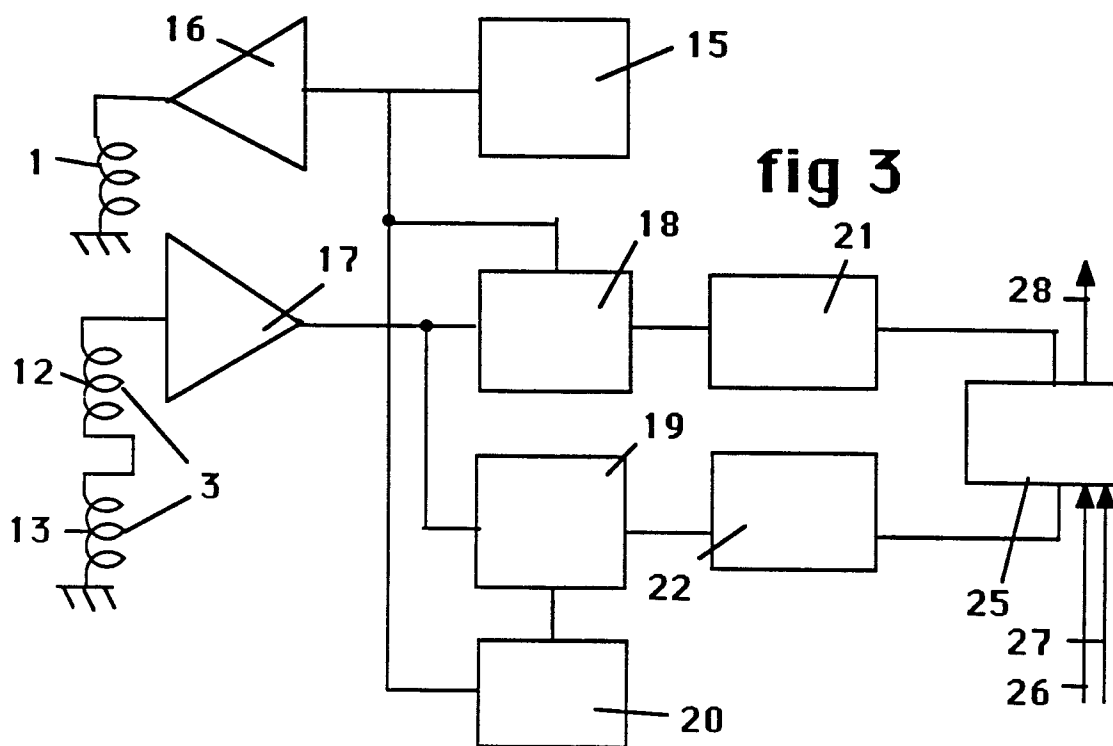


fig 3

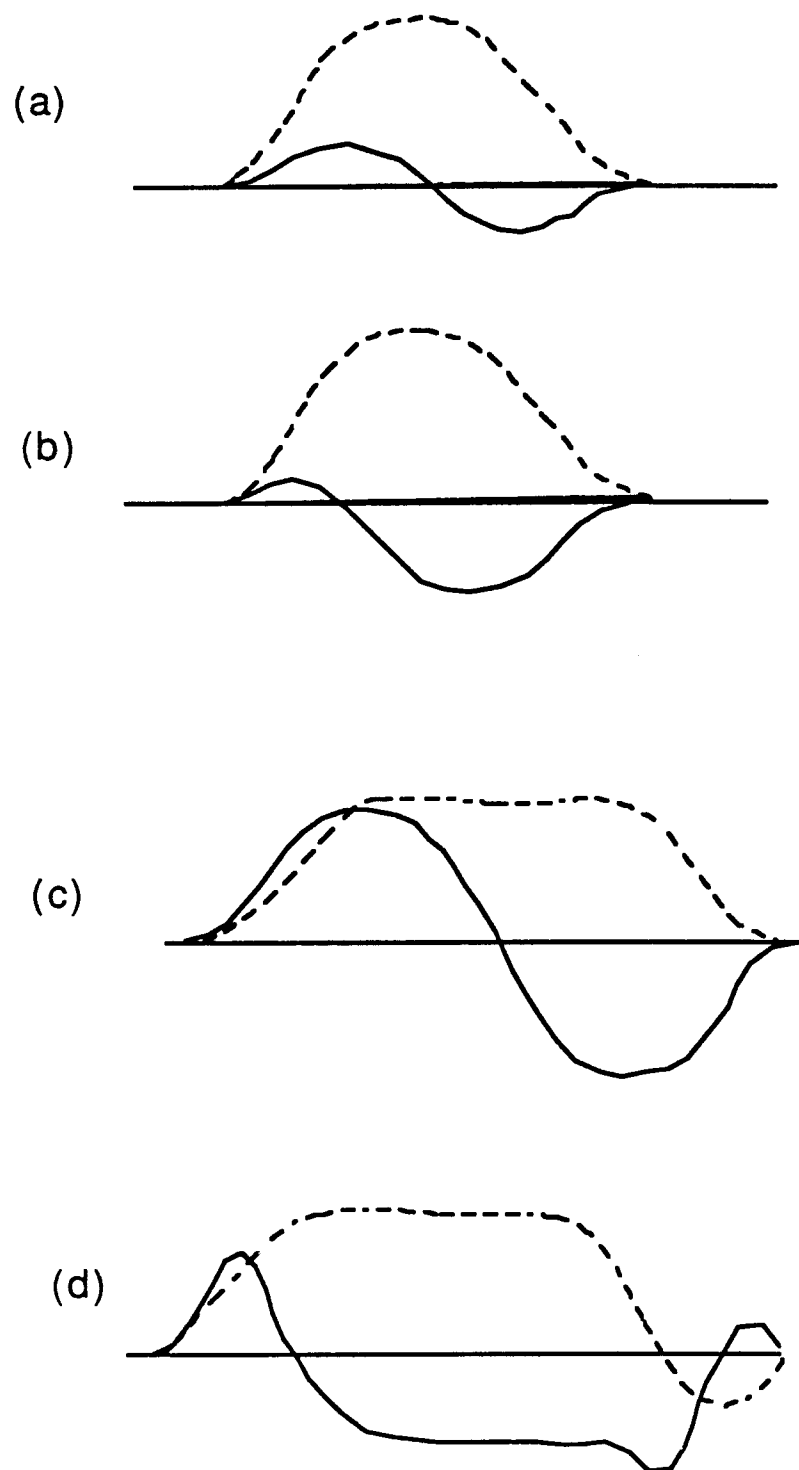


fig 4