

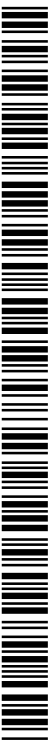


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(54) Title: SCANNING DETECTOR AND CONTROL METHOD

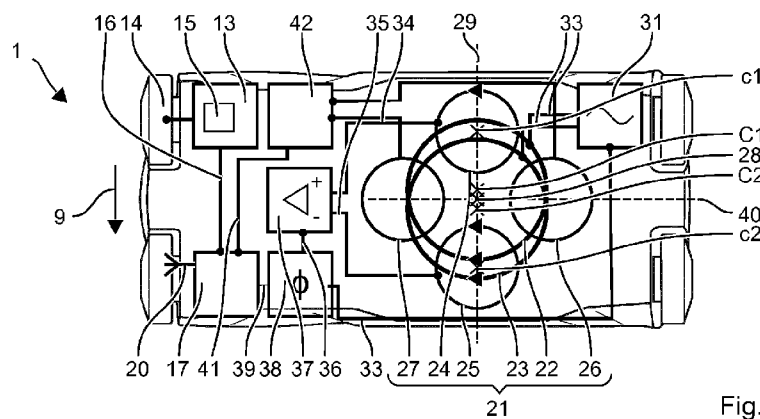


Fig. 3

(57) Abstract: The scanning detector (1) is designed to detect and to identify first structures (2) only made of iron-based objects (7) and second structures (6) comprising iron-based objects (7) and non-magnetic and highly conductive metallic objects (8). The structures are below a surface, for instance embedded in masonry. A movement sensor (13) determines a movement of the scanning detector (1) along a measuring-direction (9). A field-sensor (13) comprises a pair of primary pickup-coils (24, 25) along the measuring-direction (9) and an excitation-coil arrangement (22, 23) arranged between the primary pickup-coils (24, 25). A current source (31) injects an alternating excitation-current (33) in the excitation-coil arrangement (22, 23). Thus, the excitation-coils are emitting a corresponding alternating magnetic field. A phase-analyser (38) determines a phase (phi) between the alternating excitation-current (33) and a difference (36) of induced voltage-signal (34) in the primary pickup-coils (24, 25). An interpretation unit (17) determines a slope of the phase (phi). The interpretation unit (17) identifies a structure by discriminating among the first structures (2) and the second structures (6) based on whether the slope is increasing or decreasing. A display (18) or a transceiver (20) is used to inform the user about the identified structure.

Scanning Detector and Control Method

BACKGROUND OF THE INVENTION

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The present invention relates to a handheld scanning detector, particularly for detecting structures embedded in concrete or masonry.

10 A scanning detector is known from US 7,355,410. The scanning detector recognizes and localizes iron reinforcement bars in concrete. The scanning detector cannot distinguish different materials, in particular, if different materials are in close vicinity.

SUMMARY OF THE INVENTION

15 The scanning detector is designed to detect and to identify first structures only made of iron-based objects and second structures comprising iron-based objects and non-magnetic and highly conductive metallic objects. The structures are below a surface, for instance embedded in masonry. A movement sensor determines a movement of the scanning detector along a measuring-direction. A field-sensor comprises a pair of primary pickup-coils, along the measuring-direction and an excitation-coil arrangement, arranged between
20 the primary pickup-coils. A current source injects an alternating excitation-current in the excitation-coil arrangement. Thus, the excitation-coils are emitting a corresponding alternating magnetic field. A phase-analyser determines a phase (ϕ) between the alternating excitation-current and a difference of induced voltage-signals in the primary
25 pickup-coils. An interpretation unit determines a slope of the phase. The interpretation unit identifies the structure by discriminating among the first structures and the second structures based on whether the slope is increasing or decreasing. A display or a transceiver is used to inform the user about the identified structure.

30 The phase is a good indicator about the material composition. For a given scanning detector the slope of the phase will be always one of falling or rising when the detector is moved towards the first structure. The same scanning detector will have the opposite slope when the scanning detector is moved towards the second structure.

35

The non-magnetic and highly conductive metallic objects can have a specific conductivity at least of 250 nS/m. In a most preferred example the objects are copper-based or made of pure copper. In a further example, the objects can be made of aluminium.

5 An embodiment can have the primary pickup-coils, in an overlapping arrangement with the excitation-coil arrangement,. The overlap may such that at least a third of the area of each of the pickup-coils, is overlapping with the excitation-coil arrangement, and at least a half of each of the pickup-coils, is not overlapping with the excitation-coil arrangement,. This overlapping arrangement significantly improves the signal-to-noise ratio for the phase
10 measurement.

In an embodiment the excitation-coil can comprise two circular or elliptical excitation-coils, which are displaced to each other along the measurement-direction. The field-sensor is sensitive on misalignment of the coils. The separation of the excitation coil arrangement in
15 two coils reduces the sensitivity.

An embodiment comprises a pair of secondary pickup-coils, arranged on an axis perpendicular to the measurement-direction. A magnitude-analyser may determine a magnitude of eddy currents in the primary pickup-coils, or the secondary pickup-coils,. The
20 identification unit can identify the structure as third structure only made of copper-based objects based on a flat slope of the phase (ϕ) and the magnitude exceeding a threshold. The additional measurement of the magnitude allows for correctly identifying nearly all metallic subwall structures.

25 An embodiment uses a frequency of the alternating current in the range of 8 kHz and 25 kHz.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention are described below with reference to the
30 drawings. The drawings do not necessarily illustrate the exemplary embodiments to scale, but, rather, are depicted in schematic and/or slightly distorted form when this is useful for the explanation. With respect to additions to the teaching which are directly apparent from the drawings, reference is made to the relevant related art. In this regard it is noted that a variety of modifications and alterations regarding the form and the detail of a specific embodiment
35 may be made without departing from the general concept of the present invention. The features of the present invention disclosed in the description, the drawings, and the claims

may be important to the refinement of the present invention, taken alone as well as in any given combination.

In addition, any combination composed of at least two of the features disclosed in the description, the drawings, and/or the claims fall within the scope of the present invention. The general concept of the present invention is not limited to the exact form or the detail of the preferred specific embodiment illustrated and described below or is not limited to a subject matter which would be delimited in comparison to the subject matter claimed in the claims. For given dimension ranges, values within the stated limits are also intended to be disclosed as limiting values, and may be used and claimed as desired. For the sake of simplicity, the same reference numerals are used below for identical or similar parts or parts having an identical or similar function.

Fig. 1 shows a scanning detector for subsurface structures

Fig. 2 shows the scanning detector hovering above subsurface structures

Fig. 3 shows a field-sensor of the scanning detector

Fig. 4 shows a scanning result for an iron rod under a wall surface

Fig. 5 shows a scanning result for a copper rod under a wall surface

Fig. 6 shows a scanning result for an iron rod and a copper rod under a wall surface

DETAILED DESCRIPTION

Fig. 1 shows a scanning detector (1) according to the present invention for detecting and identifying a subsurface structure (2) hidden below a surface (3). The surface (3) is in particular a surface of a building, like a wall (4), a ceiling, a floor. The surface (3) is made of non-magnetic and non-metallic materials used in constructing buildings, like concrete, stone, brick, wood, carpet, paper, etc.. The subsurface structure may contain metallic supporting structures like armouring irons made of steel (2), etc.; electric installations like power lines made of copper (5), etc.; or other installations like water tubes, gas tubes, etc. or the subsurface structure (6) may contain more than one type. The different structure types may in close proximity, even touching.

The scanning detector (1) is moved along a linear path or a curved path on the surface (3). The movement leads to a spatial shift of the scanning detector (1) with respect to the structure (2) and a related change in a detected electromagnetic signal. The correlation between the spatial shift and the change in the signal is used for an identification of the position of the structure (2) and its metallic composition within the scanning detector's visual

range. Even though the over-all subsurface structure (2) is most likely larger than the visual range and the subsurface structures (2) may have a different composition inside and outside of the visual range the description only considers the composition visible to the scanning detector (1), i.e. the part of the structures within the visual range.

5

The scanning detector (1) can distinguish between subsurface structures (2) made only of iron-based objects (7) and subsurface structures (6) made of iron-based objects (7) and copper-based objects (8). Iron-based objects have a high content of at least 50 %, preferably 75 % of iron, e.g. steel. The magnetic and electric properties of the object are dominated by the iron content. The Iron-based objects (7) have a very high relative magnetic permeability (> 100) and for a metal moderate electric conductivity, typically less than 100 nS/m (nano Siemens per meter). Steel-based objects (8) have a conductivity in the range of 10 nS/m to 50 nS/m. Copper-based objects have a high content of at least 50 %, e.g. 75 %, preferably 90 % of copper. The magnetic and electric properties of the object are dominated by the copper content. Copper has a very weak response to magnetic fields. The relative magnetic permeability has a value of 0.999'994, thus nearly 1 and significantly lower than iron or steel. The electric conductivity is high, about 600 nS/m, and significantly higher than iron or steel. Aluminium has some similarity to copper regarding these properties, i.e. a feeble response to magnetic fields (1.000'022) and a high electric conductivity (350 nS/m). Copper and Aluminium are members of a group of non-magnetic (about 1.00) and highly conductive metals (>250 nS/m). Both copper and aluminium are the typical materials for power lines (5) because of their high conductivity. Coatings of polymers, paper, fabric or other electrically isolating materials are disregarded and do not contribute to the content of the copper-based object or iron-based object. The objects (7, 8) are preferably massive or hollow rods.

The scanning detector (1) may be manually moved by a user along a direction (9). The illustrated hand-held scanning detector has a housing (10) with a handle section (11). The user can grasp the handle section (11) and slide the scanning detector (1) along the surface (3). Thereby, a bottom surface (12) of the housing (10) preferably moves in parallel to the surface (3). A movement sensor (13) detects the movement of the scanning detector (1) along the surface (3). The illustrated scanning detector (1) uses wheel-shaped rollers (14) and a speedometer (15) to measure the movement relative to the wall (4). The rollers (14) may be ball-shaped allowing for movements along a curved path. The movement sensor (13) can be based on an optical sensor as known from an optical mouse for computers. The position of the scanning detector (1) can be tracked by an external tracker and receiving its

position by the tracker. Further techniques for measuring the movement of the scanning detector (1) can be employed.

5 The movement sensor (13) delivers continuously or in intervals a movement-signal (16). The movement-signal (16) may contain information on position (x), velocity, acceleration, etc. of the scanning detector (1). An interpretation unit (17) derives the present position (x) based on the movement-signal (16). The user preferably moves the scanning detector (1) continuously in one measuring-direction (9) but can as well move the scanning detector (1) back and forth, in particular in areas where the user assumes a structure (2). The
10 interpretation unit (17) distinguishes movements to the left and right and derives by the movements the actual position (x). Preferably, the interpretation unit (17) identifies movements in the plane, i.e. from left to right and vice versa as well as up and down.

The scanning detector (1) has a display (18) for displaying the position of hidden subsurface
15 structure (2) and its material composition. The scanning detector (1) may comprise input elements (19) for starting the scanning process, recalibrating the scanning detector (1), changing display settings etc. The display (18) and the input elements (19) may be incorporated in the housing (10) of the scanning detector (1). The scanning detector (1) may be equipped with a transceiver (20) for communicating with a detachable display, a
20 detachable input device, a mobile device, a computer or other equipment. The transceiver (20) may transmit information to be illustrated on the external display instead or in addition to the display (18) and receive input parameter for controlling the scanning detector (1) instead or in addition to the input elements (19). The transceiver (20) may incorporate a short range wireless communication protocol like bluetooth or a long range communication protocol like
25 GSM.

The illustrated scanning detector (1) has an electromagnetic field-sensor (21) comprising an arrangement of two excitation-coils (22, 23) and four pickup-coils (24, 25, 26, 27). All six
30 coils are arranged in parallel to the bottom surface (12) of the scanning detector (1). The coils are essentially flat. The height of the coils is by at least a magnitude smaller than a diameter of the coils. The vertical arrangement of the coils can be safely ignored in the ongoing description. Preferably, the four pickup-coils are arranged in one plane.

The excitation-coils (22, 23) are designed to generate identical magnetic fields while
35 powered by identical currents. The design parameters like outer shape, diameter, number of windings, wire cross-section can be identical for both excitation-coils (22, 23) or be adopted such that one or more parameters compensate for other parameters to achieve the identical

magnetic fields. The pair of excitation-coils (22, 23) is arranged symmetrically with respect to a centre (28) of the electromagnetic field-sensor (21).

5 The excitation-coils (22, 23) are aligned on an axis (29) parallel to the measuring-direction (9). A preferred example uses elliptic or circular excitation-coils (22, 23). Their respective centres (C1, C2) are located on the axis (29).

10 The excitation-coils (22, 23) are slightly displaced to each other along the axis (29), i.e. their respective centres (C1, C2) are offset to the centres (28). A first excitation-coil (22) is advancing the second excitation-coil (23) along the measuring-direction (9). The offsets (30) of both centres (C1, C2) to the centres (28) are preferably equal. The excitation-coils (22, 23) are overlapping. The respective radii (R1, R2) of the excitation-coils (22, 23) are significantly larger than the offsets (30). The radius (R1) may be at least five times larger than the offset. Preferably, the radii (R1, R2) are equal.

15

The pair-wise configuration of the excitation-coils (22, 23) is beneficial in terms of higher robustness and lower sensitivity of misalignment. Further, circular coils are easier to be manufactured. The pair of separate excitation-coils (22, 23) may be substituted by a single excitation-coil. The single excitation-coil may be designed based on the superposition of the
20 above pair of excitation-coils (22, 23).

A pair of pickup-coils (24, 25) is located on the axis (29). These pickup-coils (24, 25) are called primary pickup-coils (24, 25). The primary pickup-coils (24, 25) are equally designed and generate the same eddy-current in amplitude and in phase when subjected to the same
25 changing magnetic field. The design parameters comprise shape of the coil, diameter, number of windings, and cross-section of the wire. The pair of primary pickup-coils (24, 25) is arranged symmetrically with respect to the centre (28). The first primary pickup-coil (24) is located before the sensor centre (28); the second primary pickup-coil (25) is located behind the electromagnetic field-sensor (21) centre (28) as seen by the measuring-direction (9).

30

The primary pickup-coils (24, 25) are overlapping with the excitation-coils (22, 23), but are not overlapping with each other. The first primary pickup-coil (24) overlaps with the first excitation-coil (22) and may overlap with the second excitation-coil (23); the second primary pickup-coil (25) overlaps with the second excitation-coil (23) and may overlap with the first
35 excitation-coil (22). The overlap is chosen such that no eddy current is generated in each of the primary pickup-coils (24, 25) in the only presence of air or in vacuum even though the excitation-coils (22, 23) are powered by the current source (31). The excitation-coils (22, 23)

generate a magnetic flux perpendicular to the coils, at least in good approximation near the coils. The magnetic flux flows in opposite directions in the area inside the pair of excitation-coils (22, 23) compared to the magnetic flux in the area outside the pair of excitation-coils (22, 23). Each of the primary pickup-coils (24, 25) is located overlapping with the inside area and the outside area such that equal amounts of magnetic flow in both directions are flowing through the primary pickup-coil (24, 25). Hence, the effective magnetic flux is zero for the primary pickup-coil (24, 25) and no eddy-current is generated.

A preferred example uses elliptic or circular primary pickup-coils (24, 25). The respective centres (c1, c2) of the primary pickup-coils (24, 25) are preferably located on the axis (29). The primary pickup-coils (24, 25) are displaced by, preferably equal, displacement (32) to the sensor centre (28) along the axis (29). The displacement (32) is chosen to achieve the above described overlap of the primary pickup-coils (24, 25) and the pair of excitation-coils (22, 23). The displacement (32) equals the radius (R1) of the first excitation-coil (22) or is approximately 90 % to 100 % of the radius (R1). The centre (c1) of the first primary pickup-coil (24) is on or near the circumference of the first excitation-coil (22). The centre (c1) of the first primary pickup-coil (24) is preferably inside the first excitation-coil (22). Symmetrically, the second primary pickup-coil (25) is on or near the second excitation-coil (23).

The radii (r1, r2) of the primary pickup-coils (24, 25) are smaller than the radii (R1, R2) of the excitation-coils (22, 23), e.g. are less than 75 % of the radii (R1, R2). The pickup-coils (24, 25) do not overlap with each other.

The first primary pickup-coil (24) has a first sense of winding; the second primary pickup-coil (25) has a second sense of winding. The first sense of winding and the second sense of winding are equal, i.e. eddy-currents in the primary pickup-coils (24, 25) are of equal sign and phase for the same magnetic field.

The excitation-coils (22, 23) are powered by the same current source (31). The excitation-current (33) flows in the windings of the excitation-coils (22, 23) such that the excitation-current (33) flows in both excitation-coils (22, 23) in the same rotational direction around the centre (28). The magnetic fields of the two excitation-coils (22, 23) are parallel and are adding up. The current source (31) provides a periodically alternating excitation-current (33), preferably a sinusoidal current with at a pre-set frequency. The frequency is preferably in the range of 8 kHz to 30 kHz.

The induced voltage-signal (34) of the first primary pickup-coil (24) and the induced voltage-signal (35) of the second primary pickup-coil (25) are subtracted to generate a difference-signal (36). The first primary pickup-coil (24) and the second primary pickup-coil (25) may be interconnected in series by wire to obtain the difference-signal (36) with no circuitry. The induced voltage-signals (34, 35) may be forwarded to a differential amplifier (37) or a similar unit for determining the difference-signal (36). The induced voltage-signals (34, 35) may be individually pre-amplified or even phase-locked to two separate phase-locked loops for a higher signal-noise ratio. The difference-signal (36) can be generated based on the pre-amplified induced voltage-signals (34, 35).

The difference-signal (36) has the same modulation as the induced voltage-signals (34, 35) and the excitation-current (33). For the given example, the difference-signal (36) is sinusoidal with the pre-set frequency. A phase-difference (ϕ) of the difference-signal (36) and the excitation-current (33) is determined by a phase-analyser (38). The phase-difference (ϕ) short phase) is basically a measure for the delay of the difference-signal (36) with respect to the excitation-current (33). The phase-analyser (38) may be incorporated in a logic circuitry, e.g. a microprocessor, or may be implemented by an analogue electric phase detector.

An interpretation unit (17) receives the relative phase (ϕ) via a signal (39) from the phase-analyser (38). The interpretation unit (17) receives further a position signal (x) from the movement sensor (13). The interpretation unit (17) compares the relative phase (ϕ) versus the position (x) of the scanning detector (1).

Fig. 4, Fig. 5 and Fig. 6 illustrate the phase (ϕ) over the position (x) characteristic while scanning over rods along the measuring-direction (9). The rod may extend perpendicular to the measuring-direction (9) as illustrated for the structure (5) in Fig. 1. The centre (28) of the electromagnetic field-sensor (21) corresponds to a position (x) equal 0. The exemplary position and dimensions of the first excitation-coil (22) are indicated by its centre (C1) and radius (R1); the position and dimensions of the second excitation-coil (23) are indicated by its centre (C2) and radius (R2). The position and dimensions of the first primary pickup-coil (24) are indicated by its centre (c1) and radius (r1); the position and dimensions of the second primary pickup-coil (25) are indicated by its centre (c2) and radius (r2). The measurements starts roughly once the rod is close to the circumference of the excitation-coils (22, 23). The y-axis indicates the relative phase (ϕ) in arbitrary units, both for the zero level and scaling. For instance, the zero level depends on whether the phase (ϕ) is measured with respect to a minimum, maximum or zero-crossing of the excitation-current (33). The scaling depends

on the strength of the magnetic field and the excitation-current (33), for instance. Fig. 5 and Fig. 6 are to scale with Fig. 4; the zero levels of the phase (ϕ) are chosen independently. The frequency of the excitation-current (33) is 20 kHz for the illustrated example.

5 Fig. 4 shows the characteristic for a subsurface construction (2) with a single iron rod (7). The phase (ϕ) changes while the scanning detector (1) is moved. The characteristic shows a rising slope of the phase (ϕ) and reaches a maximum at the position (x) equals 0 (midpoint). The midpoint can be identified with the scanning detector (1) right above and closest to the rod. When the scanning detector (1) is moved away from the rod, the phase
10 (ϕ) shows a falling slope. The rising slope and the falling slope are approximately symmetric with respect to the midpoint. The amplitude of the slope is significant. For the illustrated example, the phase (ϕ) changes by more than 30 degrees.

Fig. 5 shows the result for a structure (5) with a single copper rod (8). The relative phase
15 (ϕ) is unaffected by the distance of the centre (28) to the copper rod. The relative phase (ϕ) stays almost constant. A single copper rod has no or no measureable impact on the phase (ϕ).

Fig. 6 illustrates the phase (ϕ) over position (x) for a structure (6) with an iron rod (7) and a
20 joint copper rod (8). The subsurface structure (6) contains both kinds of rods and the rods are in close proximity. The scanning detector (1) cannot spatially separate the two rods as two separate entities. The distance of the different rods is smaller than the dimensions of the scanning detector (1). The phase (ϕ) changes while the scanning detector (1) is moved. The characteristic shows a falling slope of the phase (ϕ) and reaches a minimum at the
25 midpoint. The phase (ϕ) increases once the scanning detector (1) is moved away from the midpoint. The amplitude of the slope is significant. The illustrated example shows an amplitude of almost 60 degrees.

The characteristic shown in Fig. 6 is surprising because of two aspects. First, it seems a fair
30 assumption that a copper rod would have no influence on the phase (ϕ) based on the characteristic of Fig. 5. Second, the copper rod does not simply shift, add or scale the characteristic of Fig. 4 but reverses the characteristic around the midpoint. The iron rod has a raising slope towards the midpoint, i.e. a positive slope; the additional copper rod leads to a falling slope towards the midpoint, i.e. a negative slope. The slopes have opposite signs.

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The different results of Fig. 4, Fig. 5 may be well understood. Steel is paramagnetic or ferromagnetic with high relative magnetic permeability in the range of 100 to 15'000. Copper

is diamagnetic with a relative magnetic permeability of about 0.999'994; air and vacuum have a magnetic permeability of 1. Thus, it is not surprising copper has causes no considerable phase shift if compared to steel. The invention shall not be bound to the understanding of the effect of Fig. 6 outlined herein after, even if the understanding fails scientific standards, but only to the scanning detector making use of the effect. Copper is a very good electric conductor with a pronounced skin effect. The copper rod acts like a transceiver antenna and distorts the magnetic field for the steel rod. The steel rod interacts with the magnetic field of excitation-coils and cross-talks with the copper rod. This additional cross-talk leads to the non-linear behaviour. The effect shows to be most pronounced in a frequency range between 8 kHz and 30 kHz. It is assumed that the impedance (resistivity) of the steel rod dampens the cross-talk at frequencies above 30 kHz (kilohertz). And, the signal transmission of copper is not yet pronounced or short-ranged at frequencies below 8 kHz.

The interpretation unit (17) discriminates among a subsurface structure (2) only made of iron-based objects and a subsurface structure (2) composed of iron-based objects (7) and copper-based objects (8) in close proximity. The objects are preferably massive or hollow rods. The interpretation unit (17) can additionally identify subsurface structures (2) only made of copper-based objects.

The interpretation unit (17) tracks the position (x) of the scanning detector (1) and the slope of the phase (ϕ). The below description is given based on the simplifying assumption the user continuously moves the scanning detector (1) in the same measuring-direction (9). A back-and-forth movement and a vertical movement require some more elaborate data processing but without departing from the basic concept.

25

The interpretation unit (17) may comprise a low-pass filter to implement the mathematical differential calculus of the phase (ϕ) over the position (x). The evolving phase (ϕ) is forwarded to the low-pass filter. The output of the low-pass filter is zero when the phase (ϕ) does not change with changing position (x). The filter-output of the low-pass filter has a positive value for a rising slope and a negative value for a falling slope. The rising slope or falling slope may be confirmed by a threshold comparator if the magnitude of filter-output exceeds a threshold value. Further, the rising slope or falling slope may be confirmed only if the filter-output stays above the threshold value over a significant distance of movement. For instance, the significant distance of movement is at least half the radius (R1) of the excitation-coil (22). In order to avoid a misreading, the slope can be verified to be monotonous until the centre (28). Further, it may be verified if the slope changes the sign after crossing the centre (28). The low-pass filter may be implemented by an analogue

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circuit, a digital circuit, a data processing unit, e.g. an algorithm processed in a microprocessor. The comparator can be implemented as an analogue circuit, a digital circuit, a data processing unit, e.g. an algorithm processed in a microprocessor. The low-pass filter is a simple means for determining the slope. Other means may include orthogonal regression or similar mathematical technics to calculate the average slope of several measurement points. The orthogonal regression can be implemented as an algorithm processed in a microprocessor.

The interpretation unit (17) discriminates among a rising slope and a falling slope towards the midpoint. The illustrated interpretation unit (17) identifies a rising slope with a subsurface structure (2) made only of iron objects (Fig. 4) and a falling slope with a subsurface structure (2) made of iron objects and copper objects (Fig. 6) within the visual range of the scanning detector (1). The interpretation unit (17) may further discriminate a structures made only of copper objects (Fig. 5). The interpretation unit (17) is knowledgeable which of the rising slope (positive sign) and the falling slope (negative sign) refers to an iron rod, and is knowledgeable that the slope of opposite sign refers to a mixed pair of rods. A memory unit may store the corresponding relation of the sign of the slope and material in a look-up table. The relation may be stored in the memory during manufacturing or determined by a calibration routine.

The optional pair of secondary pickup-coils (26, 27) can be arranged perpendicular to the pair of primary pickup-coils (24, 25). The secondary pickup-coils (26, 27) are arranged along a second axis (40) parallel to the surface (12) and perpendicular to the axis (29). The second axis (40) crosses the centre (28). The pair of secondary pickup-coils (26, 27) is arranged symmetrically with respect to the axis (29). Preferably, the secondary pickup-coils (26, 27) are circular or elliptic. Their respective centres may be located on the circumference of the excitation-coils (22, 23).

The magnetic field generates an eddy current in the secondary pickup-coils (26, 27). The amplitude of the eddy current corresponds to size and distance of the object, and if there is a rod. The magnitude of the eddy current rises with the scanning detector (1) moving towards the midpoint. A maximum magnitude is reached at the midpoint, i.e. when the scanning detector (1) is centred above the object. The rising slope of the magnitude is independent of the metal composition of the subsurface structure (2). A secondary-signal (41) corresponding to the magnitude of the eddy current is forwarded to the interpretation unit (17). The interpretation unit (17) can determine the size and distance of the structure (2) based on the magnitude at the midpoint and a look-up table of typical sizes of subsurface

installations. A magnitude-analyser (42) determines the eddy current. The magnitude-analyser may be based on a volt-meter or ampere-meter.

5 The interpretation unit (17) can discriminate a structure (2) made only of copper-based objects (8) among other material compositions. The interpretation unit (17) determines if the slope of the phase (ϕ) is zero or below a threshold value, i.e. a flat slope. In concurrence, the interpretation unit (17) determines if the magnitude of the secondary-signal (41) exceeds a threshold. If so, the interpretation unit (17) identifies the secondary-signal (41) with a copper object. Alternatively or in addition, the magnitude-analyser determines the magnitude
10 of the eddy currents in the primary pickup-coils (24, 25). On concurrence of a flat slope and a non-zero magnitude of eddy currents in the primary pickup-coils (24, 25) the interpretation unit (17) identifies a structure (6) in the visual range.

CLAIMS

1. Scanning detector (1) for detecting and identifying a structure as a first structure (2) only
5 made of iron-based objects (7) or second structure (6) comprising iron-based objects (7)
and non-magnetic and highly conductive metallic objects (8) below a surface (12),
comprising:
a movement sensor (13) for determining a movement of the scanning detector (1) along
a measuring-direction (9),
10 a field-sensor (13) comprising a pair of primary pickup-coils (24, 25) along the
measuring-direction (9) and an excitation-coil arrangement (22, 23) arranged between
the primary pickup-coils (24, 25),
a current source (31) injecting an alternating excitation-current (33) in the excitation-coil
arrangement (22, 23),
15 a phase-analyser (38) determining a phase (ϕ) between the alternating excitation-
current (33) and a difference (36) of induced voltage-signals (34, 35bz) in the primary
pickup-coils (24, 25),
an interpretation unit (17) determining a slope of the phase (ϕ) and identifying the
structure by discriminating among the first structures (2) and the second structures (6)
based on whether the slope is increasing or decreasing, and
20 a display (18) or a transceiver (20) communicating the identified structure (2, 6).
2. Scanning detector (1) according to claim 1 wherein each of the primary pickup-coils (24,
25) is overlapping with the excitation-coil arrangement (22, 23).
- 25 3. Scanning detector (1) according to claim 2 wherein at least a third of each of the pickup-
coils (24, 26) is overlapping with the excitation-coil arrangement (22, 23) at least a half of
each of the pickup-coils (24, 26) is not overlapping with the excitation-coil arrangement
(22, 23).
- 30 4. Scanning detector (1) according to claims 1 to 3 wherein the excitation-coil (23)
arrangement comprises two circular or elliptical excitation-coils (22, 23) which are
displaced to each other along the measurement-direction (9).
- 35 5. Scanning detector (1) according to claims 1 to 4 wherein the field sensor (13) comprises
a pair of secondary pickup-coils (26, 27) arranged on an axis (40) perpendicular to the
measurement-direction (9).

6. Scanning detector (1) according to claims 1 to 5 comprising an magnitude-analyser (42) determining a magnitude of eddy currents in the primary pickup-coils (24, 25) or the secondary pickup-coils (26, 27) and wherein the identification unit (17) identifies the structure as third structure (5) only made of copper-based objects (8) based on a flat slope of the phase (ϕ) and the magnitude exceeding a threshold.
- 5
7. Scanning detector (1) according to claims 1 to 6 wherein a frequency of the alternating current is in the range of 8 kHz and 25 kHz.
- 10
8. Detection method according to claim 1 to 7 wherein the non-magnetic and highly conductive metallic comprise metals with an electric conductivity of at least 250 nS/m.
9. Detection method according to claim 1 to 7 wherein the non-magnetic and highly conductive metallic objects (8) are copper-based objects (8) or aluminium-based objects (8).
- 15
10. Detection method of identifying first structures (2) only made of iron-based objects (7) and second structures (6) comprising iron-based objects (7) and non-magnetic and highly conductive metallic objects (8) below a surface (12), the method comprising the steps:
- 20
- determining a movement of the scanning detector (1) along a measuring-direction (9) by a movement sensor (13)
- injecting an alternating excitation-current (33) in a excitation-coil arrangement (22, 23) of a field-sensor (13) comprising a pair of primary pickup-coils (24, 25) along the measuring-direction (9) and the excitation-coil arrangement (22, 23) arranged between the primary pickup-coils (24, 25),
- 25
- determining a phase (ϕ) between the alternating excitation-current (33) and a difference 36 of induced voltage-signals (34, 35) in the primary pickup-coils (24, 25) by a phase-analyser (38),
- 30
- determining a slope of the phase (ϕ) by identification unit (17),
- identifying the structure (2) by discriminating among the first structures (2) and the second structures (6) based on whether the slope is increasing or decreasing by the identification unit (17), and
- displaying or communicating the identified structure (2, 6) by a display (18) or a transceiver (20).
- 35
11. Detection method according to claim 10 comprising the steps:

determining a magnitude of eddy currents in the primary pickup-coils (24, 25) or in the secondary pickup-coils (26, 27) by a magnitude-analyser (42) and identifying the structure (6) as a third structure (5) only made of copper-based objects (8) based on a flat slope of the phase (ϕ) and the magnitude exceeding a threshold.

5

12. Detection method according to claim 10 or 11 wherein a frequency of the alternating current is in the range of 8 kHz and 25 kHz.

10

13. Detection method according to claim 10 to 12 wherein the non-magnetic and highly conductive metallic comprise metals with an electric conductivity of at least 250 nS/m.

14. Detection method according to claim 10 wherein the non-magnetic and highly conductive metallic objects (8) are copper-based objects (8) or aluminium-based objects (8).

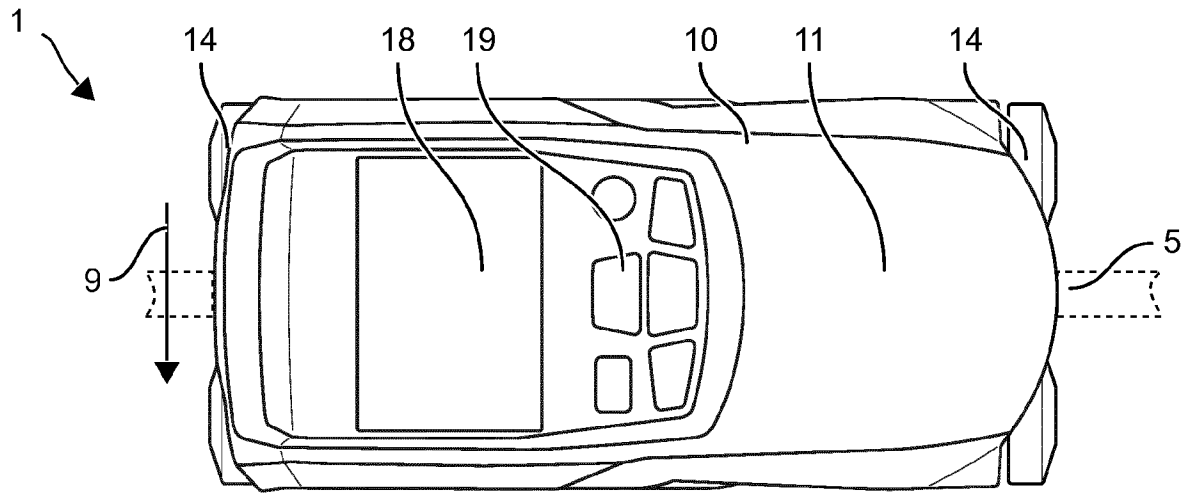


Fig. 1

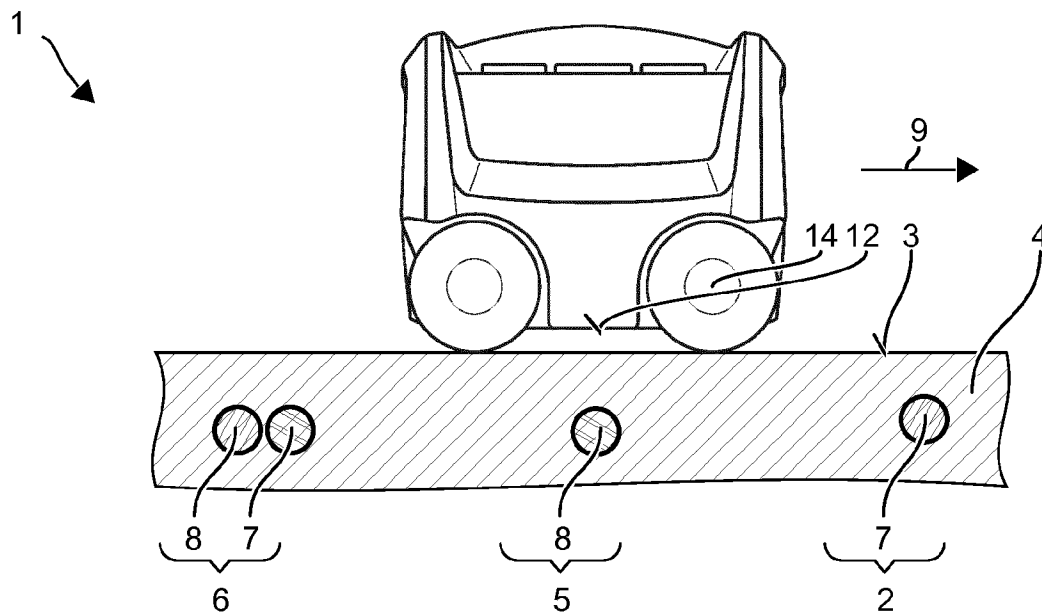


Fig. 2

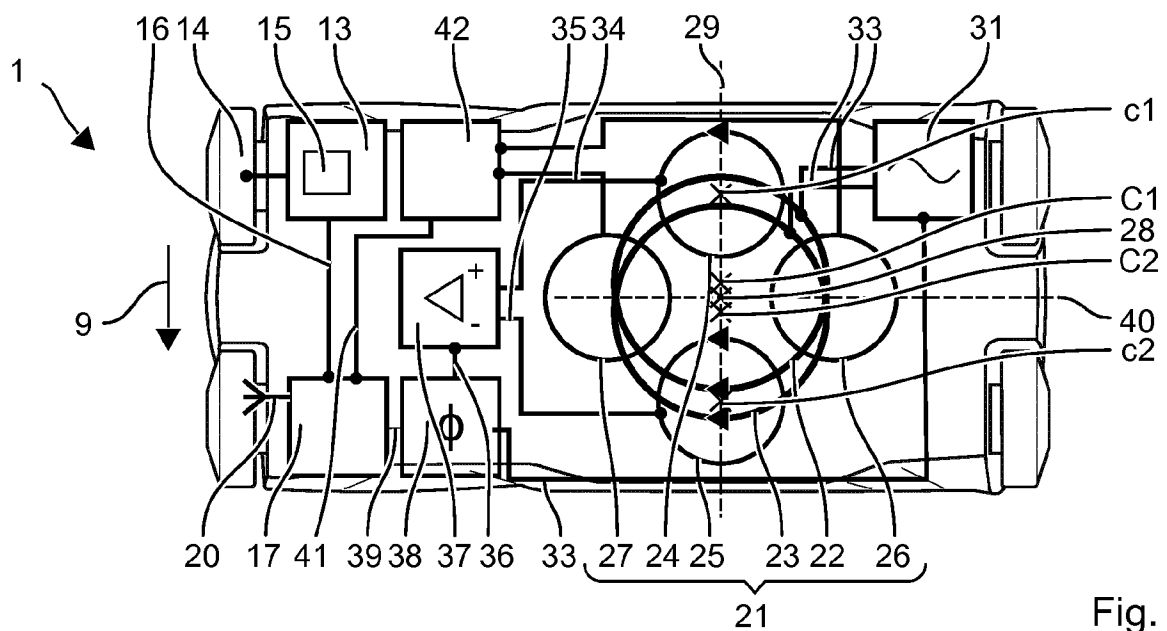


Fig. 3

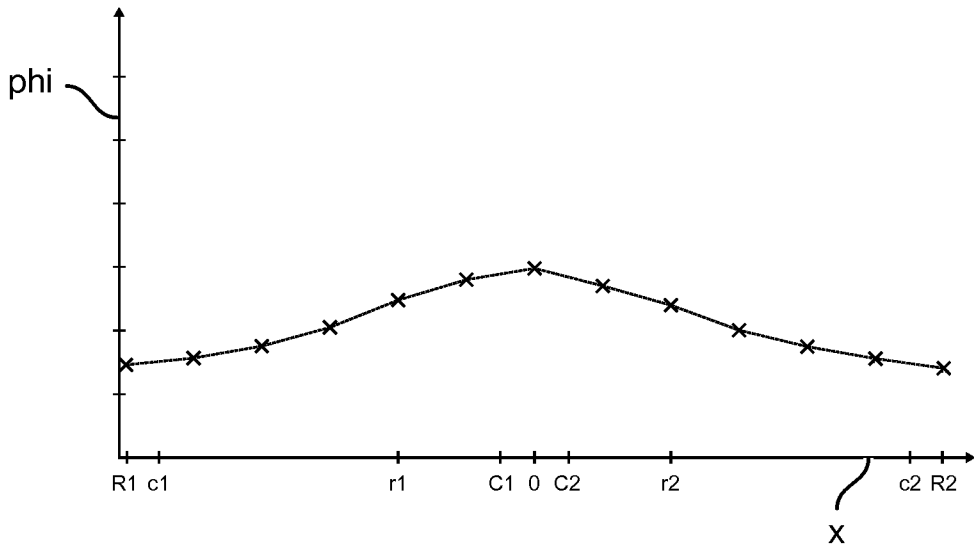


Fig. 4

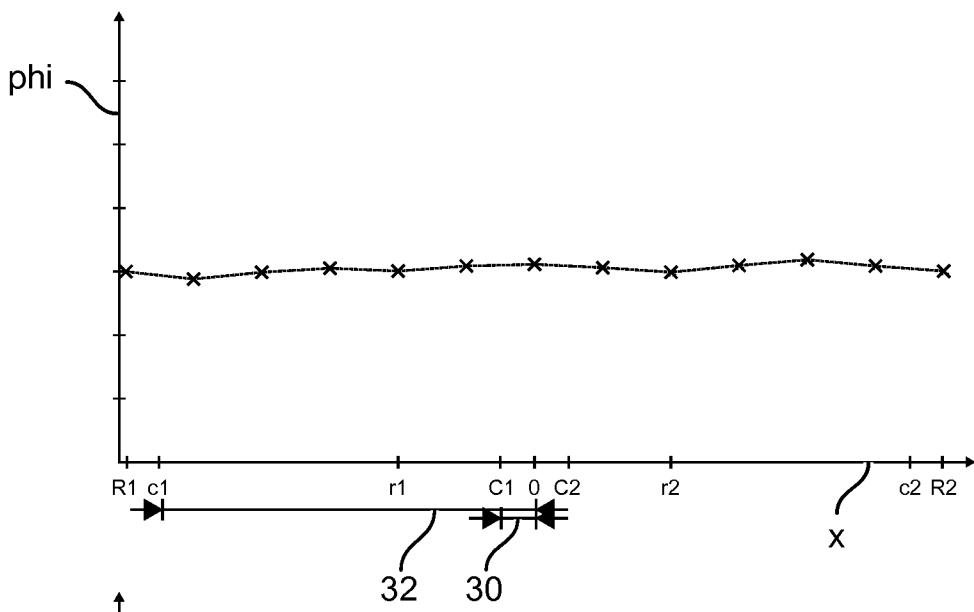


Fig. 5

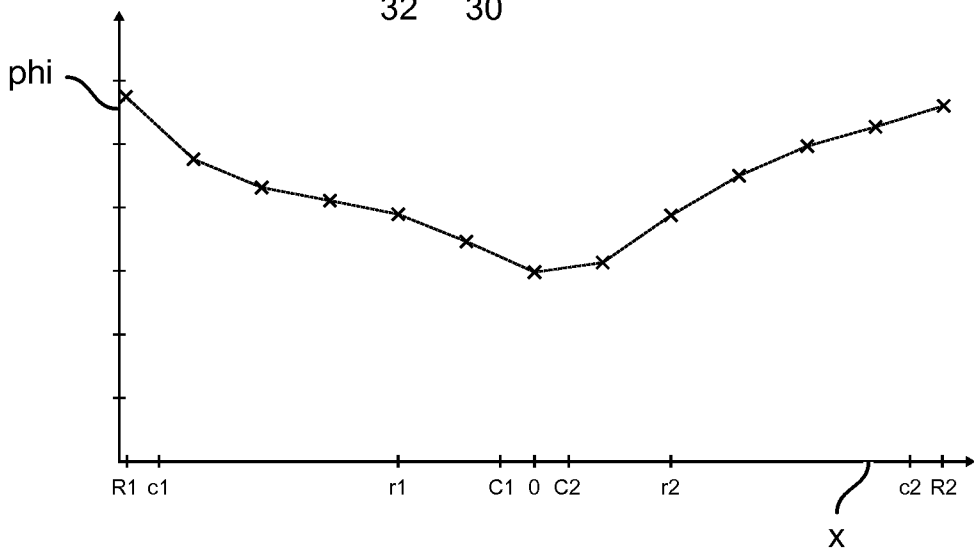


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/054698

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01V3/10
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	paragraph [0001]	2,3,7,9,
A	paragraph [0007]	12,14
	paragraph [0010]	6,8,11,
	paragraph [0016]	13
	figures 1-13	

Y	US 5 729 143 A (TAVERNETTI RUSSELL E [US] ET AL) 17 March 1998 (1998-03-17)	2,3
A	figure 1a	1,4-14

Y	US 2010/164512 A1 (KISS MICHAEL [AT] ET AL) 1 July 2010 (2010-07-01)	7,12
A	paragraph [0059]	1-6, 8-11,13, 14

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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 2 May 2017	Date of mailing of the international search report 12/05/2017
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Hippchen, Sabine
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/054698

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	paragraph [0021]	1-8, 10-13
A	----- WO 2006/037176 A1 (ROBERTS KENNETH BRIAN [AU]; SEIDEL RAYMOND LESLIE [AU]) 13 April 2006 (2006-04-13) page 4, line 11 - page 5, line 28 page 15, line 10 - line 32 -----	1-14

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International application No

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