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INDUCTIVE SENSOR DEVICE

Abstract

An inductive sensor device has a scale body having a multiplicity of conductor strip loops arranged in a measurement direction in at least one scale line. A sensor unit is moveable along the scale body and has one coil group for each scale line, the coil group comprising a transmitter coil for producing a transmitter signal and at least one receiver coil. Each coil group provides at least one receiver signal for an evaluation unit for determination of an absolute relative position of the sensor unit relative to the scale body. At least one of the scale lines has at least one modulating section, within which the impedances and/or the apparent resistances of conductor strip loops change from one end of the modulating section to the other, whereby the at least one receiver signal is modulated with regard to its phase position relative to the transmitter signal.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of German Patent Application No. 10 2024 103 963.9, filed Feb. 13, 2024, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The invention refers to an inductive sensor device comprising a sensor unit that can be moved along a scale body in order to determine the position between the sensor unit and the scale body. Thereby particularly the absolute position between the sensor unit and the scale body is determined.

BACKGROUND

[0003] Such inductive sensor devices are, for example used for measurement devices, such as calipers.

[0004] For example, DE 10 2004 026 311 A1 describes an inductive sensor device. Two transmitter coils are provided in a sensor unit that can be moved along a scale body, wherein the transmitter coils are enclosed by a receiver coil. The scale body comprises scale elements that can effect a magnetic coupling with the transmitter coils and the receiver coil so that a movement of the sensor unit along the scale body can be detected.

[0005] Another inductive sensor device is known from DE 102 02 275 B4. The scale elements for inductive coupling with the sensor unit comprise two loops connected with one another via connection lines. For forming a vernier the loops are arranged in two lines with different divisions (distances). In doing so, the length of the connection lines between two loops of a common scale element changes. In order to compensate a longer length of the connection lines, the width of the conductors of the loops and the connection lines can be modified so that the signal strength (amplitude) is not degraded.

[0006] In addition, an inductive sensor device is known from EP 3 594 629 A1. The scale body comprises two lines of scale elements, wherein the scale elements of one line have first distance between adjacent scale elements and the scale elements of the other line have a second distance between adjacent scale elements in order to form a vernier. Thereby the measurement range for the absolute position measurement between the sensor unit and the scale body can be extended. In addition, the scale elements of one line are varied in their height, whereby an amplitude-modulated signal is produced in the sensor unit during inductive coupling with the scale elements. This shall allow an additional extension of the absolute measurement range.

[0007] An inductive sensor device according to the vernier principle (nonius) is also described in U.S. Pat. No. 6,335,618 B1.

[0008] In these methods using the amplitude modulation of the signals in the sensor unit is disadvantageous. The amplitude of the signals generated in the sensor unit for position determination highly depends on the relative orientation of the sensor unit relative to the scale body. Varying distances and inclinations or tilts result in changes of the amplitude, which impedes the determination of the position and increases the measurement uncertainty. In addition, the amplitude also remarkably depends on the excitation field of a transmitter coil of the sensor unit and thus from the excitation current through the transmitter coil. Fluctuations in the excitation current thus affect the position determination based on an amplitude modulation in a negative manner as well. Also temperature deviations influence the amplitude, because the resistance in the conductors varies depending on the temperature.

[0009] The amplitude modulation is disadvantageous also because the modulation depth or the modulation range is limited. This is because a sufficient signal to noise ratio has to always be guaranteed.

[0010] Additional inductive sensor devices are described in EP 0 743 508 A2, EP 3 299 770 A1 and US 2016/0146636 A1, for example.

SUMMARY

[0011] Starting from the prior art it can be considered as one object of the present invention to provide an inductive sensor device that can be realized economically that comprises a sufficiently large measurement range for the absolute position determination and that allows high tolerances for assembly.

[0012] This object is solved by means of an inductive sensor device as described herein.

[0013] The inductive sensor device comprises a scale body, a sensor unit and an evaluation unit. The evaluation unit can be part of the sensor unit. The sensor unit is movably supported on the scale body in a measurement direction. The scale body can in one embodiment extend along a straight line in measurement direction. Depending on the application (e.g. depending on the configuration of a measurement device, in which the inductive sensor device is used), the measurement direction can also have a curved extension, particularly along a circular arc.

[0014] The scale body has a multiplicity of electrically conductive conductor strip loops. The conductor strip loops are arranged in at least one scale line, preferably in multiple and particularly in exactly two scale lines. The at least one scale line extends in measurement direction. If multiple scale lines are present, they are arranged offset in a transverse direction relative to one another. The transverse direction is orientated orthogonal to the measurement direction. It is advantageous, if the conductor strip loops are arranged in a common plane, wherein this plane is orientated parallel to the measurement direction and parallel to the transverse direction.

[0015] If multiple scale lines are present, the conductor strip loops in the scale lines are arranged with at least two different divisions, particularly with a first division in a first scale line and with a second division in a second scale line. The first division and the second division distinguish from each other and preferably form a vernier. The division in each scale line is preferably constant.

[0016] The division is defined by the distance of two reference points in measurement direction between directly adjacent conductor strip loops in the respective individual scale line. For example, the reference points can be located on a center line of the conductor strip loops respectively, wherein the center line extends in the center between the outer edges of each conductor strip of a conductor strip loop.

[0017] If more than two scale lines are present in an embodiment, these additional scale lines can comprise a division that distinguishes from the first division and the second division, wherein particularly each present scale line comprises a different division.

[0018] The sensor unit has a coil group for each provided scale line, wherein the coil group comprises at least one and preferably exactly one transmitter coil and at least one and preferably two and particularly exactly two receiver coils. A transmitter signal can be provided to the transmitter coil, e.g. by means of a transmitter unit of the inductive sensor device. Each receiver coil provides a receiver signal for the evaluation unit respectively. The transmitter unit and the evaluation unit can be realized as separate component groups or in a common control. The transmitter unit can be part of the sensor unit analog to the evaluation unit.

[0019] The evaluation unit is configured to evaluate the receiver signals and to determine therefrom an absolute relative position between the sensor unit and the scale body. Based on this absolute relative position, a measurement value can be determined and output, for example, if the inductive sensor device is part of a measurement device.

[0020] With view in measurement direction the scale line or at least one of the scale lines and preferably each scale line has a modulation section. The modulation section is preferably shorter in measurement direction than the total length of the scale line. Alternatively in an embodiment one single modulation section can extend along the entire scale line in measurement direction. In each modulation section the conductor strip loops, which are provided there, have impedances and/or apparent resistances, which distinguish from one another. Within the modulation section the

impedances and/or apparent resistances either increase or decrease from one end of the modulation section to the opposite end of the modulation section with view in measurement direction. Preferably the impedance and/or the apparent resistance changes within the modulation section from each conductor strip loop to the next conductor strip loop. The conductor strip loop arranged at the one end of the modulation section has the lowest impedance and/or the lowest apparent resistance within the modulation section, whereas the conductor strip loop arranged at the opposite end of the modulation section comprises the largest impedance and/or the largest apparent resistance in the modulation section.
[0021] Here, the apparent resistance is the magnitude of the impedance. The impedance has a reactance (e.g. an inductive reactance) and an ohmic resistance.
[0022] In the at least one modulation section the impedance and/or the apparent resistance is preferably varied so that the ratio of the reactance to the ohmic resistance changes.
[0023] Due to the impedances and/or apparent resistances changing in the modulation section, the receiver signal respectively provided by the at least one assigned receiver coil is influenced and so-to-speak modulated. In doing so, an additional parameter is provided that is considered during determination of the absolute relative position.
[0024] Due to the modulation of the receiver signal based on the changing impedances and/or apparent resistances, a robust determination of the absolute relative position can be carried out that is particularly insensitive for deviations in the relative orientation of the components of the sensor device, particularly the relative orientation between the sensor unit and the scale body. This allows larger assembly and installation tolerances and thus an economic assembly. In addition, the inductive sensor device is insensitive with regard to environmental influences, such as changing environment humidity. The environment temperature can particularly influence the ohmic resistance of the conductor strip loops and/or effect a phase drift of the transmitter signal, if the transmitter signal is not an impressed transmitter current, but an impressed transmitter voltage. However, the design can be made insensitive to temperature influences as will be apparent from the detailed description below.
[0025] These advantages result particularly from that the impedances and/or apparent resistances changing within the modulation section allow a modulation along the at least one scale line with regard to the phase position of the receiver signals relative to the transmitter signal. As phase position here the phase difference between the phase of at least one receiver signal relative to the phase of the transmitter signal is meant. The evaluation of the phase position is much more robust against deviations in the relative orientation between sensor unit and scale body and remarkably less sensitive against temperature changes or other environmental influences different to the evaluation of an amplitude in the context of an amplitude modulation.
[0026] In addition, the modulation of the receiver signals according to the invention can be realized with standard components. Particularly no application-specific integrated circuit (ASIC) is required in the evaluation unit, but the evaluation unit can be realized by means microcontrollers available on the market.
[0027] All in all, an economic sensor device can be provided that is robust against assembly errors or assembly deviations (large tolerance range) that is robust against environmental influences and yet allows a long measurement range in measurement direction for determination of the absolute relative position.
[0028] It is advantageous, if all of the conductor strip loops have impedances and/or apparent resistances that are different from one another within the at least one modulation section. The impedance and/or apparent resistance therefore increases or decreases from each conductor strip loop to the directly adjacent conductor strip loop. Basically, it would also be possible to form multiple groups of conductor strip loops within the modulation section, wherein the conductor strip loops of a common group comprise equal impedances and/or apparent resistances.
[0029] The impedance and/or apparent resistance can change in measurement direction within the

at least one modulation section in a non-linear manner. This means a change within the modulation section in which the individual impedances and/or apparent resistances of the conductor strip loops in a diagram, depending on a linearly indicated measurement direction, are not points on a common straight line, but are, for example, points on a curve (non-linear function).
[0030] The impedance and/or the apparent resistance can be predefined in measurement direction in the at least one modulation section, so that in a desired operating point the magnitude of the reactance is equal to the magnitude of the ohmic resistance. When the magnitudes of the reactance and ohmic resistance are equal, a fractional change in impedance gives the biggest change in the phase of the receiver signals. Preferably this operating point is at least substantially an average value of the varying impedance and/or apparent resistance around which the impedance and/or apparent resistance changes approximately by equal amount upward and downward.
[0031] It is preferred, if the impedance and/or apparent resistance is changed within the at least one modulation section between conductor strip loops by means of a change of the ratio between the reactance and the ohmic resistance. Preferably this change of the impedance and/or apparent resistance is exclusively realized by a change of the ohmic resistance, whereas the reactance of the conductor strip loops is substantially constant.
[0032] In a preferred embodiment the change of the impedance and/or apparent resistance between the conductor strip loops within the at least one modulation section can be realized by conductor strip cross-sections, particularly conductor strip widths, which are different from one another. Thereby the conductor strip width of the conductor strip loops increases or decreases from one end of the modulation section to the opposite end of the modulation section. The conductor strip width is measured orthogonal to its extension direction and particularly orthogonal to the outer edges of the conductor strip. The change of the conductor strip width for the conductor strip loops within the modulation section can be realized in a very simple manner.
[0033] The change of the conductor strip width from one conductor strip loop to another conductor strip loop within the modulation section is carried out preferably originating from the conductor strip center in a uniform manner outward and inward. Originating from a center line of the conductor strip, the width therefore increases uniformly on both sides. The larger the conductor strip width, the longer the outer circumference of the conductor strip loop and the shorter the inner circumference of the conductor strip loop. Thereby the division remains constant.
[0034] In a preferred embodiment the conductor strip loop with larger conductor strip width has a higher loop height in transverse direction and/or a larger loop width in measurement direction.
[0035] For changing the impedance and/or apparent resistance between the conductor strip loops within the at least one modulation section, additionally or alternatively to the change of the conductor strip width or the conductor strip cross-section one parameter or multiple of the following parameters can be changed in arbitrary combination: conductor strip thickness, cross-section shape of the conductor strip, material of the conductor strip. All changes can be provided on the conductor strip as a whole or only locally at least at one location of the conductor strip.
[0036] The shape of the conductor strip loops can vary. Each conductor strip loop can have at least one straight line conductor strip section and/or at least one curved conductor strip section. It is preferred, if each conductor strip loop comprises two transverse legs extending in a straight line in transverse direction. The two transverse legs are connected with one another by means of two longitudinal legs arranged with distance opposite one another in transverse direction. The longitudinal legs can be straight or curved and can extend parallel or inclined relative to the measurement direction. Particularly the transverse legs and the longitudinal legs have equal widths and define the conductor strip width of the conductor strip loop.
[0037] It is preferred, if the conductor strip width within the conductor strip loop does not vary, but is constant on the contrary.
[0038] It is advantageous, if all of the conductor strip loops comprise the same conductor strip thickness. The conductor strip thickness is measured orthogonal to the measurement direction and

orthogonal to the transverse direction. If the conductor strip thickness of all of the conductor strip loops is equal—apart from manufacturing tolerances—it contributes to easy and economic manufacturing of the conductor strip loops on the scale body.

[0039] It is advantageous, if at least one of the provided scale lines comprises a non-modulating section or area extending in measurement direction. Inside this non-modulating section all of the conductor strip loops have substantially equal impedance and/or apparent resistance. For example, a non-modulating section can be arranged between two modulation sections of a scale line. If one of the scale lines comprises a non-modulating section, the at least one other scale line has a modulation section in this area. If multiple modulation sections are present, they can have equal or different lengths in measurement direction.

[0040] In a non-modulating section of a scale line all of the conductor strip loops preferably have equal conductor strip width and preferably equal loop height and/or equal loop width.

[0041] It is preferred, if the first scale line and the second scale line have at least one non-modulating section in each case. The non-modulating sections of the first scale line and the second scale line are arranged offset in a non-overlapping manner in measurement direction.

[0042] Due to the at least one non-modulating section in one or multiple scale lines, the measurement range for determination of the absolute relative position can be extended.

[0043] The evaluation unit is preferably configured to determine a phase signal from at least one of the receiver signals, wherein the phase signal is an electrical signal, for example. The phase signal describes particularly the phase shift between the transmitter signal, e.g. an excitation or transmitter coil current through the at least one transmitter coil, and a conductor strip loop current. The conductor strip loop current is induced in one and particularly multiple conductor strip loops arranged adjacent in measurement direction, due to the transmitter signal applied to the transmitter coil.

[0044] In a preferred embodiment the evaluation unit is configured to sample at least one of the receiver signals, multiple receiver signals or all of the receiver signals one time or multiple times in order to determine the phase of the respective receiver signal. Multiple sampling can be carried out in one single period and/or over multiple periods for determining a respective sample value for the assigned receiver signal respectively. The sampling points in time are offset in phase relative to the periodic receiver signal, e.g. by 90°. It is particularly advantageous, if sampling is carried out in four sampling points in time of the respective receiver signal, which are offset in phase relative to one another, so that four sampling values are provided. Preferably, the sampling is carried out in regular phase or time intervals. If for example the first sampling point in time t**1** is offset from a zero crossing of the periodic receiver signal by a phase difference q, the additional sampling points in time t(1+i) with i=1, 2, 3, 4, . . . , i.sub.max can be offset relative to this zero crossing by q+i*d+n*360° with n=0, 1, 2, 3, . . . and wherein d is a defined phase offset, e.g. 90°, whereby it particularly applies:

[00001] $d = 360° / (1 + i_{max})$.

[0045] In an embodiment the sampling can be based on the IQ-method.

[0046] From the sampling values of a receiver signal respectively one phase value can be determined by means of the evaluation unit, wherein the phase value characterizes the phase of the receiver signal. From these phase values in turn the phase signal can be formed that is considered when determining the absolute relative position.

[0047] If four sampling values E.sub.1, E.sub.2, E.sub.3 and E.sub.4 are determined for one assigned receiver signal, the phase value y for the phase signal can be determined as follows:

[00002] $E_{13} = E_1 - E_3$ (1) $E_{24} = E_2 - E_4$ (2) $= \arctan2(E_{13}, E_{24})$ (3)

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0048] Advantageous embodiments of the invention are derived from the dependent claims, the description and the drawing. In the following preferred embodiments of the invention are explained in detail based on the attached drawing. The drawing shows:

[0049] FIG. **1** a schematic basic illustration of an exemplary measurement device that is equipped with a sensor device according to the present invention,

[0050] FIG. **2** a basic circuit diagram of an embodiment of a sensor device,

[0051] FIGS. **3** and **4** exemplary time-dependent progresses of a transmitter signal, a conductor strip loop current induced due to the transmitter signal in a conductor strip loop of the sensor device and a receiver signal in each case,

[0052] FIG. **5** an exemplary schematic illustration of scale elements in two scale lines having respectively two modulation sections,

[0053] FIG. **6** exemplary basic illustration of phase signals over the entire absolute measurement range, as determined in an evaluation unit of the sensor device for determination of the absolute relative position,

[0054] FIG. **7** a basic illustration of a phase difference of phase signals,

[0055] FIG. **8** a basic illustration of conductor strip loops of the sensor device in a modulation section,

[0056] FIG. **9** a basic illustration of a measurement coil for determination of a phase of a transmitter signal,

[0057] FIG. **10** a basic illustration of the arrangement of components of an evaluation unit on a circuit board of the sensor device, and

[0058] FIG. **11** an exemplary phase trajectory showing the correlation of two phase signals from one another.

DETAILED DESCRIPTION

[0059] FIG. **1** shows an exemplary embodiment of a measurement device or measurement instrument **10** in form a caliper. The measurement instrument **10** is configured as digital measurement instrument. In the embodiment the measurement instrument **10** is configured to measure a distance or a length measurement value. For this measurement the measurement instrument **10** comprises an inductive sensor device **11** according to the present invention.

[0060] The inductive sensor device **11** comprises a scale body **12** extending in a measurement direction M and a sensor unit **13** that is movably supported in measurement direction M on the scale body **12**. In the embodiment of measurement instrument **10** in form of a caliper the measurement direction M is a linear direction. In other measurement instruments or applications the measurement direction M of the inductive sensor device **11** could also extend in a curved manner, e.g. along a circular arc. The function principle of the inductive sensor device **11** according to the invention is also applicable in devices (e.g. measurement instruments) in which the measurement direction M does not extend in straight direction.

[0061] The scale body **12** comprises a multiplicity of scale elements that are configured as conductor strip loops **17**. The conductor strip loops **17** are arranged in multiple lines according to the example, in the present case in a first scale line **18** and a second scale line **19**. Alternatively to this, also one single scale line or more than two scale lines could be present. The scale lines **18**, **19** extend parallel to one another in measurement direction M. In a transverse direction Q that is orientated orthogonal to the measurement direction M, first scale line **18** and second scale line **19** are offset to each other and particularly arranged with distance to one another.

[0062] The conductor strip loops **17** are arranged in the first scale line **18** with a first division d**1**. The conductor strip loops **17** are arranged in the second scale line **19** with a second division d**2**. The division d**1** and the division d**2** have different magnitudes. They form a vernier.

[0063] The conductor strip loops **17** consist of electrically conductive material, e.g. copper, or contain at least electrically conductive material. The individual conductor strip loops **17** are electrically insulated from each other. The conductor strip loops **17** are configured in a ring-shaped closed manner, so that a conductor strip loop current IL can flow along a conductor strip loop **17** (see for example FIG. **2**). The conductor strip loop current IL can be induced in the inductive sensor device **11** by means of temporally or spatially changing magnet field in one or multiple conductor strip loops **17**.

[0064] In the embodiment all of the conductor strip loops **17** are arranged in a common plane, which extends parallel to the measurement direction M and parallel to the transverse direction Q. The contour of the conductor strip loops **17** can be selected differently. In the embodiment illustrated here each conductor strip loop **17** is formed by one conductor strip that has two straight transverse legs **20** arranged with distance to one another in measurement direction M and extending in transverse direction Q (FIGS. **1**, **5** and **8**). The two transverse legs **20** are connected to form a closed ring by means of two longitudinal legs **21** of the conductor strip loops **17**. The two longitudinal legs **21** are arranged with distance to one another in transverse direction Q. In the embodiment the longitudinal legs **21** are straight and extend in measurement direction M. In modification to this the longitudinal legs **21** could also have a curved extension and could be semi-circular-shaped, for example.

[0065] The shape of the conductor strip loops **17** is particularly apparent from FIG. **8**. There it is also apparent that each conductor strip loop **17** comprises a center line C that extends in the center along the conductor strip of each conductor strip loop. The sections of the center line C extending along the transverse legs **20** serve as reference for definition of the first division d**1** and the second division d**2**, as illustrated in FIG. **8**.

[0066] The sensor unit **13** of the inductive sensor device **11** comprises one transmitter coil **25** and at least one receiver coil, e.g. a first receiver coil **26** as well as a second receiver coil **27** for each present scale line respectively, thus, according to the example, for the first scale line **18** and the second scale line **19** in each case. The first receiver coil **26** and the second receiver coil **27** assigned to a common scale line **18** or **19** are offset relative to each other in measurement direction M. For example, the receiver coils **26**, **27** can be realized by loops. The coil loop can be formed by means of two conductor strip portions extending in a sinusoidal-shaped manner, which are offset by half of the wavelength of the division d**1**, d**2** of the respective scale line **18** or **19** relative to one another. Due to the offset of the first receiver coil **26** relative to the second receiver coil **27**, the receiver signals thereof are out of phase to one another, for example by 90°.

[0067] The transmitter coil **25** can surround the two receiver coils **26**, **27** that are assigned to the same scale line **18** or **19** and can preferably at least approximately form an envelope around the receiver coils **26**, **27**. The transmitter coil **25** is particularly formed by one single transmitter coil loop or by multiple transmitter coil loops that are arranged aligned in measurement direction M and in transverse direction Q.

[0068] Accordingly, exactly one transmitter coil **25**, exactly one first receiver coil **26** and exactly one second receiver coil **27** form one common coil group **28** respectively (FIG. **1**). Additional transmitter and receiver coils are not necessary. In the embodiment exactly one coil group **28** of the sensor unit **13** is assigned to each scale line **18**, **19**. The coil groups **28** are highly simplified schematically illustrated in FIG. **1**.

[0069] FIG. **2** shows an electrical circuit diagram of an embodiment of the inductive sensor device **11**. The transmitter coils **25** are connected in series to one another in a circuit branch **29**. The circuit branch **29** connects a first node **30** with a second node **31**. The circuit branch **29** is a two-terminal network according to the example. It can consist exclusively of a series connection of components.

[0070] By means of a transmitter circuit **32** a transmitter signal S can be provided for the transmitter coils **25**. Alternatively to the embodiment according to FIG. **2**, it is possible to provide one individual transmitter circuit for each transmitter coil. In the embodiment the transmitter signal S is a transmitter coil current IS. The transmitter coil current IS has a temporally non-constant progress and can be a rectangular wave signal, a triangular signal, a sawtooth signal, a sinusoidal signal or another temporally varying signal, for example. The transmitter circuit **32** comprises a parallel oscillating circuit **33**. An oscillating circuit capacitance **34** and an oscillating circuit inductance **35** are part of the parallel oscillating circuit **33**. The oscillating circuit capacitance **34** is arranged between the first node **30** and the second node **31**. The oscillating circuit inductance **35** is connected in series to the transmitter coils in the circuit branch **29**. In the embodiment the oscillating circuit inductance **35** connects the series connection of the transmitter coils **25** with the second node **31**. By means of the oscillating circuit inductance **35** and the oscillating circuit capacitance **34**, a suitable resonant frequency of the parallel oscillating circuit **33** can be set.

[0071] The oscillating circuit capacitance **34** can be realized by one or more capacitors, e.g. multiple capacitors connected in parallel. The oscillating circuit inductance **35** can be realized by one or more coils or windings.

[0072] The first node **30** is connected to a supply direct voltage UDC. The supply direct voltage UDC can be provided by means of a battery in a mobile measuring instrument **10**, as for example illustrated in FIG. **1**. The second node **31** is connected to a ground potential GND via a series resistance **36** and a controlled switch **37**. The controlled switch **37** has a control input **38**. By means of a respective switch signal SW at the control input **38** the controlled switch **37** can be switched between a conducting condition and a blocking condition. In the conducting condition an electrical connection between the second node **31** and ground potential GND is established, whereas this electrical connection is interrupted in the blocking condition of the controlled switch **37**. Particularly the controlled switch **37** can be a semi-conductor switch, e.g. a bipolar transistor or a field effect transistor. The base or gate of the respective transistor is the control input **38** in this case.

[0073] A transmitter control unit **39**, which can be part of a control device **40**, serves for control of the controlled switch **37**. The switching of controlled switch **37** is carried out by means of a clocked switch signal SW according to the example, having a clock frequency corresponding approximately to the resonant frequency of the parallel oscillating circuit **33**. If the controlled switch **37** is inductive, the oscillating circuit capacitance **34** is loaded, if the controlled switch **37** is blocked, the oscillating circuit capacitance **34** discharges via circuit branch **29** and thus the transmitter coils **25**. Thereby the transmitter signal S or the transmitter coil current IS is created, which flows through the transmitter coils **25**.

[0074] Because of the series connection in the circuit branch **29**, the transmitter coil current IS also flows through the oscillating circuit inductance **35**. A measurement coil **41** is inductively or in the type of a transformer coupled with this oscillating circuit inductance **35**. By means of the measurement coil **41**, a measurement signal can be produced, the phase of which corresponds to the phase of the transmitter coil current IS. The measurement coil **41** is electrically connected with an evaluation unit **42** that can be part of the control device **40**. The measurement coil **41** provides the measurement signal to the evaluation unit **42**. Therefore, the phase of the transmitter coil current IS is known in the evaluation unit **42**. In fact, the phase of the transmitter coil current IS results in the ideal case also from the control of the controlled switch **37** and the dimensioning of the parallel oscillating circuit **33**. However, in practice deviations can occur resulting from component tolerances and/or temperature changes and/or other external influences. By means of the optionally present measurement coil **41** and determination of the phase of the transmitter coil current IS is guaranteed independent from such influences.

[0075] The receiver coils **26**, **27** are connected to the evaluation unit **42** of the sensor device **11** and provide the receiver signal E produced by each receiver coil **26**, **27** to the evaluation unit. In the embodiment each receiver coil **26**, **27** provides a receiver coil voltage UE as receiver signal E to the evaluation unit **42**. Because according to the example, two coil groups **28** with respectively one first receiver coil **26** and one second receiver coil **27** are present, four receiver coil voltages UE are provided to the evaluation unit **42**, namely a first receiver coil voltage UE**1**, a second receiver coil voltage UE**2**, a third receiver coil voltage UE**3** as well as a fourth receiver coil voltage UE**4**.

[0076] In the embodiment the control device **40** is a customary microcontroller. Application-specific components are not necessary for realizing the sensor device **11**. Alternatively to the embodiment the evaluation unit **42** and the transmitter control unit **39** could also be realized as separate components or component units.

[0077] The transmitter circuit **32**, the receiver coils **26**, **27** and the control device **40** can be arranged on a common carrier of sensor unit **13**, e.g. a circuit board **43** (FIGS. **9** and **10**). The circuit board **43** is preferably a multi-layer circuit board. On a top side **44** of the circuit board **43** the oscillating circuit inductance **35** can be arranged, for example. The measurement coil **41** can be realized by conductor strips that form one measurement loop **45** respectively on opposite sides of the oscillating circuit inductance **35** on the top side **44**. The measurement loops **45** are not entirely closed in a ring-shaped manner, but comprise one first end point **46** and one second end point **47** respectively that are not directly electrically connected with one another, but only via the respective other measurement loop. The first end points **46** and the second end points **47** of the measurement loops **45** are electrically connected with each other respectively. In top view the conductors connecting the measurement loops **45** cross each other two times without being electrically connected at the crossing points (e.g. conductors extend in different layers of the circuit board **43**). The two measurement loops **45** thus have the shape of an “8” with a central loop **48** arranged therebetween. TAt the central loop **48** one of the measurement loops **45** is connected to the evaluation unit **42**.

[0078] The ratio of the total area enclosed by the two measuring loops **45** is relative to the area enclosed by the central loop **48** is a defined parameter. In particular, the ratio can be equal to 1 or can be greater than 1 (i.e. the total area enclosed by both measurement loops **45** exceeds the area enclosed by central loop **48**). For example, the ratio can be weighted based on the influence of the oscillating circuit inductance **35** on the far field where the inductance with its ferrite amplifies the far field in the center loop **48**. This leads to a higher magnetic flux density compared to that within at least one of the measuring loops **45**. Due to defining this ratio as described above, a voltage induced by the magnetic field of the oscillating circuit inductance **35** is amplified and voltage induced by the far field is weakened or ideally extinguished. Due to this configuration of the measurement coil **41**, it is avoided that electromagnetic far fields affect the measurement. Please note that FIG. **9** is not drawn to scale but represents the loops **45**, **48** only schematically.

[0079] In the circuit diagram according to FIG. **2**, it is apparent that a shielding **49** can be present between the oscillating circuit inductance **35** and the transmitter coils **25**. This shielding **49** serves particularly to protect the oscillating circuit inductance **35** and the measurement coil **41** from electromagnetic influences of the transmitter coils **25**, the receiver coils **26**, **27** or the conductor strip loops **17** in order to guarantee a precise determination of the phase of the transmitter coil current IS. For example, shielding **49** can be formed by an electrically conductive layer within the circuit board **43** that is electrically connected with ground potential GND (FIG. **10**). The receiver coils **26**, **27** and as an option, additional components of the circuit can be arranged on the respective opposite side of the shielding **49** (e.g. in a layer of the circuit board), as schematically illustrated in FIG. **10**.

[0080] Based on the circuit diagram in FIG. **2**, it is also apparent that each conductor strip loop **17** can be illustrated as closed current circuit in which an inductive reactance XL and an ohmic resistance RL of the conductor strip loop **17** are connected in series. Due to the transmitter signal S or the transmitter coil current IS that flows through the transmitter coils, a conductor strip loop current IL is induced in the conductor strip loops **17**, which are inductively coupled with the transmitter coils **25**. The conductor strip loop current IL flows along the conductor strip loop **17** and thus through the inductive reactance XL and an ohmic resistance RL of the conductor strip loop **17**. The impedance {right arrow over (Z)} and/or the apparent resistance Z of the conductor strip loop **17** can be calculated as follows:

[00003] $\overset{.fwdarw.}{Z}$ == RL + jXL (4) $Z = \sqrt{RL^2 + XL^2}$ (5)

[0081] The inductive sensor device **11** described so far is configured to determine an absolute relative position xa between sensor unit **13** and scale body **12** in measurement direction M, wherein the position variable in measurement direction M is denoted by x (FIGS. **1**, **6** and **7**).

[0082] Due to the transmitter coil current IS, a conductor strip loop current IL is induced in multiple conductor strip loops **17** of first scale line **18** and second scale line **19** depending on the absolute relative position xa of sensor unit **13** relative to the scale body **12**. The conductor strip loop current IL flowing through the conductor strip loops **17** induces in turn a magnetic field that induces a receiver coil voltage UE as receiver coil signal E in the receiver coils **26**, **27**. If sensor unit **13** is moved along scale body **12** (change of the absolute relative position xa), the receiver signal in each receiver coil changes with a period corresponding to the division d**1**, d**2** of the respective scale line **18** or **19**. The exact absolute relative position xa can thus be determined within one wavelength of the position variable x corresponding to the length of the period of division d**1** or d**2**.

[0083] By evaluating the receiver signals E of both coil groups **28** based on the different scale lines **18**, **19** of different division d**1**, d**2**, a longer unambiguous range for determination of the absolute relative position xa can be achieved based on the vernier principle (nonius).

[0084] However, in practice also this measurement range is insufficiently long and additional measures are required in order to unambiguously determine the absolute relative position xa over a sufficiently long measurement path.

[0085] For this purpose, according to the invention it is provided that at least one of the scale lines —and according to the example first scale line **18** as well as second scale line **19**—respectively comprises one or multiple modulating sections xm within which the apparent resistances Z or impedances of the conductor strip loops **17** change. For example, the apparent resistance Z and/or the impedance thereby increases or decreases from one end of the modulating section xm to the other end of the modulating section xm in measurement direction M. Within one modulating section xm the apparent resistance Z and/or the impedance of all conductor strip loops **17** can have different magnitudes, so that the apparent resistance Z increases or decreases from one conductor strip loop **17** to the adjacent conductor strip loop **17** from one end of the modulating section xm to the opposite end of the modulating section xm.

[0086] The change of the impedance {right arrow over (Z)} or the apparent resistance Z in one, multiple or all present modulating sections xm is thereby preferably non-linear. In other words, the impedances {right arrow over (Z)} or apparent resistances Z within a common modulating section xm do not form points on a straight line. Rather they can be points on a non-linear curve Z(x). The impedance {right arrow over (Z)} or the apparent resistance Z increases or decreases between directly adjacent conductor strip loop **17** therefore not along the entire modulating section xm by equal difference magnitudes. Particularly the ohmic resistance varies relative to reactance. This increases the determination of the absolute relative position xa and can especially contribute to increase the insensitivity with regard to temperature deviations.

[0087] The impedance {right arrow over (Z)} and according to the example, also the apparent resistance Z of each conductor strip loop is influenced by the ohmic resistance RL, wherein in the embodiment substantially exclusively the ohmic resistance RL of the conductor strip loop **17** is varied within the modulating section xm, whereas the inductive reactance XL remains substantially constant. The ratio of the inductive reactance XL relative to the ohmic resistance RL defines a phase offset that a conductor strip loop current IL of the respective conductor strip loop **17** comprises relative to the transmitter coil current IS. Therefore, the phase offset between the transmitter coil current IS and the conductor strip loop current IL induced in the conductor strip loop **17** changes within the modulating section xm dependent on the relative position between sensor unit **13** and scale body **12** in measurement direction M.

[0088] The phase offset between the transmitter coil current IS and the conductor strip loop current IL defines the phase position of the receiver signals E in the receiver coils **26**, **27** relative to the transmitter coil current IS and according to the example, the phase position of the receiver coil voltages UE (here: UE**1**, UE**2**, UE**3**, UE**4**) relative to the transmitter coil current IS. Because the phase of the transmitter coil current IS is known in the evaluation unit **42** (based on the measurement signal of the measurement coil **41**), the phase position of one or more receiver coil voltages UE relative to the transmitter coil current IS can be determined. Based on the known correlation between the phase position and the relative position between sensor unit **13** and scale body **12** in measurement direction M, a coarse position detection of the relative position between sensor unit **13** and scale body **12** in measurement direction M (or along the axes of the position variable x) can be carried out. If the coarse position is known, the more precise relative position within the vernier or nonius length and further within the first division d**1** or the second division d**2** can be determined. Accordingly, a phase modulation of the receiver signals E is carried out in order to extend the measurement range beyond multiple vernier or nonius lengths within which measurement range an unambiguous determination of the absolute relative position xa is possible.
[0089] FIG. **5** schematically shows by way of example a section of scale lines **18**, **19**. In the embodiment each scale line **18**, **19** has at least one modulating section xmi (i=natural number) and optionally at least one non-modulating section xci (i=natural number). In each non-modulating section xci the impedance or apparent resistance Z of the conductor strip loops **17** does not change. In these non-modulating sections xci, therefore, no phase modulation of the receiver signals E (according to the example receiver coil voltages UE**1** to UE**4**) is carried out.
[0090] In FIG. **6** a first phase signal P**1** based on the modulation of the first scale line **18** and a second phase signal P**2** based on the modulation of the second scale line **19** are schematically illustrated by way of example respectively. In this embodiment each scale line **18**, **19** comprises multiple modulating sections xmi and according to the example, two modulating sections respectively: The first scale line **18** has a first modulating section xm**1** and a second modulating section xm**2** and the second scale line **19** has a third modulating section xm**3** and a fourth modulating section xm**4**.
[0091] The modulating sections xm**1**, xm**2** or xm**3**, xm**4** of one single scale line **18** or **19** do not adjoin one another directly, but are respectively separated from each other by one non-modulating section xci. According to the example, the first scale line **18** as a first non-modulating section xc**1** as well as a second non-modulating section xc**2**. Between the two non-modulating section xc**1**, xc**2** first modulating section xm**1** is arranged. The second modulating section xm**2** adjoins the second non-modulating section xc**2**. The second scale line **19** has, for example, a third non-modulating section xc**3** as well as a fourth non-modulating section xc**4**. The third non-modulating section xc**3** is arranged between the third modulating section xm**3** and the fourth modulating section xm**4** and the fourth non-modulating section xc**4** adjoins the fourth modulating section xm**4**.
[0092] In doing so, a first phase signal P**1** results for the first scale line **18** depending on the position variable x in measurement direction M and a second phase signal P**2** for the second scale line **19** accordingly. The phase signals P**1**, P**2** as well as the modulating sections xm**1** to xm**4** and the non-modulating sections xc**1** to xc**4** are also schematically indicated in FIG. **6**.
[0093] In FIG. **6** it is in addition apparent that non-modulating sections xc**1**, xc**2** of first scale line **18** do not overlap with non-modulating sections xc**3**, xc**4** of second scale line **19** in measurement direction M. In doing so, it is guaranteed that in each area of scale lines **18**, **19** in measurement direction M (i.e. in direction of the position variable x) a phase modulation is carried out at least in one scale line **18** or **19**.
[0094] In the example shown in FIG. **6** the locus of the phase signals P**1**, P**2** is a square. Alternatively P**1**, P**2** can be defined to provide other locus shapes, such as a circle or a diamond shape.
[0095] The magnitude of the phase signals P**1**, P**2** depends from the ratio of the magnitudes of the

inductive reactance XL to the ohmic resistance RL respectively. If the magnitude of the ohmic resistance RL increases relative to the magnitude of the inductive reactance XL, the magnitude of the phase offset and thus the magnitude of the respective phase signal P**1**, P**2** decreases. Thus, by means of changing this ratio, the phase signal P**1**, P**2** can be modified and can be modulated so-to-speak. In the embodiment for this purpose the ohmic resistances RL of the conductor strip loops **17** are different from one another in the respective modulating sections xm.

[0096] The change of the ohmic resistance RL of the conductor strip loops **17** is achieved in the embodiment in that the conductor strip cross-section is changed. Thereby particularly a conductor strip thickness orthogonal to the extension plane of the conductor strip loop **17** is kept constant and rather the respective conductor strip width b of a conductor strip loop **17** compared to the adjacent conductor strip loop **17** is increased or decreased. The change of the conductor strip width b is schematically illustrated in FIG. **8**.

[0097] By way of example, FIG. **8** shows 3 conductor strip loops **17** within a modulating section xm. The conductor strip width b is respectively determined orthogonal to the extension direction of a conductor strip and particularly orthogonal to the inner edge and/or outer edge of the conductor strip. The conductor strip width b of each conductor strip loop **17** is constant. This means that in the embodiment the transverse legs **20** and the longitudinal legs **21** being part of the same conductor strip loop **17** comprise equal conductor strip widths b. According to the example, the conductor strip width b of transverse leg **20** is measured in measurement direction M and the conductor strip width b of longitudinal leg **21** is measured in transverse direction Q.

[0098] Only by way of example and schematically it is illustrated in FIG. **8** that the conductor strip width b increases in the illustration from left to right from conductor strip loop **17** to conductor strip loop **17**. In the illustration the left conductor strip loop **17** has a first conductor strip width b**1**, the center conductor strip loop **17** has a second conductor strip width b**2** and the right conductor strip loop **17** has a third conductor strip width b**3**. Thereby the second conductor strip width b**2** is larger than the first conductor strip width b**1** and the third conductor strip width b**3** is larger than the second conductor strip width b**2**. It is apparent that the number of conductor strip loops **17** within a modulating section xm can be remarkably higher than 3 and that the illustration in FIG. **8** is only to be considered as schematic basic illustration.

[0099] Preferably a minimum conductor strip width b is 100 μm. The minimum distance between directly adjacent conductor strip loops **17** is preferably minimum 100 μm. The minimum distance between two transverse legs **20** and between two longitudinal legs **21** of a common conductor strip loop **17** is preferably minimum 100 μm.

[0100] In the embodiment the conductor strip width b between the conductor strip loops **17** within a common modulating section xm is modified in a manner so that the conductor strip width b is increased or decreased starting from the center line C inward and outward relative to the adjacent conductor strip loop **17**. Therefore, for all conductor strip loops **17** within a common modulating section xm center line C has the same dimension and shape in measurement direction M as well as in transverse direction Q. It results therefrom in turn that within the modulating section also a loop height H of the conductor strip loop **17** and a loop width W of the conductor strip loop **17** increases with increasing conductor strip width b. In the example of FIG. **8** this means that the conductor strip loop **17** having the first conductor strip width b**1** has a first loop height H**1** and a first loop width W**1**. Analog to this the conductor strip loop **17** having the second conductor strip width b**2** has a second loop height H**2** and a second loop width W**2** and the conductor strip loop **17** having the third conductor strip width b**3** has a third loop height H**3** and a third loop width W**3**.

[0101] By way of example, temporal progresses of a transmitter coil current IS, a conductor strip loop current IL as well as a receiver coil voltage UE are illustrated in FIGS. **3** and **4** respectively. Therefrom a phase offset between transmitter coil current IS and conductor strip loop current IL results depending on the impedance, particularly depending on the apparent resistance Z, of the respective conductor strip loop **17**. In the preferred embodiment the phase offset between the receiver coil voltage UE and the conductor strip loop current IL is substantially independent from the electrical characteristics of the receiver coils **26**, **27**, because the receiver coils **26**, **27** are connected to a relatively high impedance in the evaluation unit **42**. The phase position of the receiver coil voltages UE relative to the transmitter coil current IS is therefore characterizing for the phase position of the conductor strip loop current IL relative to the transmitter coil current IS and can therefore be used for determination of the phase signal P**1**, P**2**.

[0102] In the embodiment described here at least one of the receiver coil voltages UE of each coil group **28** is sampled for producing the respective phase signal P**1**, P**2**. For example, the first receiver coil voltage UE**1** can be used for determination of the first phase signal P**1** and the third receiver coil voltage UE**3** can be used for determination of the second phase signal P**2**.

[0103] In the embodiment a sampling of the continuous receiver coil voltage UE (which can also be denoted as A/D conversion) is carried out by means of the evaluation unit **42**. Preferably the receiver coil voltage UE is detected or sampled during each complete period multiple times, in the embodiment four times in each period, i.e. in a first point in time of detection t**1**, a second point in time of detection t**2**, a third point in time of detection t**3** as well as a fourth point in time of detection t**4** within each period, as schematically illustrated in FIGS. **3** and **4**. The detection is carried out in uniform time intervals, wherein the time interval between two directly subsequent points in time of detection corresponds to a phase angle of 90° or one fourth of the period T. From the detected receiver coil voltages the following voltage differences can be calculated by means of subtraction:

[00004] $UE_{13} = UE(t1) - UE(t3) \quad (6) \quad UE_{24} = UE(t2) - UE(t4) \quad (7)$

[0104] From these differences in turn a phase value p can be calculated:

[00005] $= \arctan2(UE_{13}, UE_{24}) \quad (8)$

[0105] This phase value y thus depends on the impedance or the apparent resistance Z, which varies spatially in measurement direction M within the at least one modulating section xm (according to the example four modulating sections). Therefrom first phase signal P**1** for the first scale line **18** and second phase signal P**2** for second scale line **19** result. This in turn allows a coarse evaluation of the absolute relative position xa between sensor unit **13** and thus a relatively long measurement range.

[0106] For example, based on the first phase signal P**1** and the second phase signal P**2**, a (coarse) value of the absolute relative position xa can be assigned to the phase signals P**1**, P**2** in a table or another assignment stored in the evaluation unit **42**. The determined first and second phase signals P**1**, P**2** may vary due to external influences, e.g. due to variations of the ohmic resistance of scale loops **17** due to temperature changes. A phase trajectory PT (FIG. **11**) characterizing the correlation between first and second phase signals P**1**, P**2** (locus) can have different shapes, as already explained above. However, the points defining this phase trajectory cannot be exactly defined, but vary depending on external influences, e.g. due to temperature changes. However, average values for the first and second phase signal P**1**, P**2** can be determined and/or ranges A of expected values on the phase trajectory PT can be determined. The progress of the phase trajectory PT can have a closed shape (e.g. circle, square, diamond, etc.). One single and complete turn around the phase trajectory PT corresponds to the measurement range with unambiguous (coarse) position determination.

[0107] However, it would also be possible to limit the measurement range corresponding to a continuous section of the phase trajectory PT.

[0108] A table can be defined characterizing the correlation of the first and second phase signals P**1**, P**2**. This table particularly contains only phase values that allow unambiguously position determination. This means that coarse Vernier ranges can be distinguished from one another. With reference to FIG. **11**, ranges A of expected values have to be selected and used for the table that do not overlap with one another. In doing so, ambiguity is eliminated.

[0109] Preferably environmental influence (particularly temperature) that could result in a variation of the first and/or second phase signal P**1**, P**2** can be determined and can be used as additional parameter in the table containing the values for the first and second phase signal P**1**, P**2** (reflecting the dependency shown in FIG. **11**). In doing so, the sizes of the ranges A can be reduced and thus a more reliable coarse position determination is made possible.

[0110] A modified embodiment of the present invention for determination of the rough position of sensor unit **13** relative to scale body **12** can be explained based on FIG. **7**. FIG. **7** shows a phase difference signal PD depending on the position variable x. The phase difference signal PD is formed by calculating the difference between first phase signal P**1** determined based on first scale line **18** and second phase signal P**2** determined based on second scale line **19**. The two phase signals P**1**, P**2** can thereby have a different qualitative progress than illustrated in FIG. **6**. Preferably first phase signal P**1** continuously decreases, whereas second phase signal P**2** continuously increases or vice versa (e.g. with increasing position variable x) for determination of phase difference signal PD. This can be achieved, for example, in that the ohmic resistance RL of conductor strip loops **17** of first scale line **18** increases continuously, whereas the ohmic resistance RL of the conductor strip loops **17** of second scale line **19** decreases continuously or vice versa (e.g. with increasing position variable x).

[0111] In a preferred embodiment segments xc**1** and xm**1** are used for the first phase signal P**1** and xm**4** and xc**4** for the second phase signal P**2**. The phase trajectory PT (locus) resulting therefrom has two phase trajectory segments extending orthogonally to one another (‘L’ rotated by 180 degrees). On each of the two phase trajectory segments, one of the phase signals P**1**, P**2** is constant and the receiver signal is large, which provides good signal quality.

[0112] The invention refers to an inductive sensor device **11**, particularly for a measurement device or a measurement instrument **10**, preferably a mobile measurement instrument **10** that is operated by means of a battery. The inductive sensor device **11** has a scale body **12** having a multiplicity of electrically conductive conductor strip loops **17**. The conductor strip loops **17** are arranged in a measurement direction M in at least one scale line and preferably in a scale line **18** having a first division d**1** and in a second scale line **19** having a second division d**2**. A sensor unit **13** is movably arranged on scale body **12** in measurement direction M. The sensor unit **13** has one coil group **28** respectively for each present scale line **18**, **19**, e.g. comprising a transmitter coil **25** for producing a transmitter signal S and at least one receiver coil **26**, **27**. Each coil group **28** provides at least one receiver signal E for an evaluation unit **42** for determination of an absolute relative position xa of sensor unit **13** relative to scale body **12** in measurement direction M. At least one of the present scale lines **18**, **19** has at least one modulating section xm, within which the impedances, particularly the apparent resistances Z, of conductor strip loops **17** change from one end of the modulating section xm to the other end of the modulating section xm in measurement direction M, wherein particularly the apparent resistances Z increase or decrease, whereby the at least one receiver signal E is modulated with regard to its phase position relative to the transmitter signal S. The modulation is considered when determining the absolute relative position xa in the evaluation unit **42**. For example, in doing so the measurement range can be enlarged within which the absolute relative position xa can be determined unambiguously. This position determination is in addition robust against assembly tolerances.

LIST OF REFERENCE SIGNS

[0113] **10** measurement instrument [0114] **11** sensor device [0115] **12** scale body [0116] **13** sensor unit [0117] **17** conductor strip loop [0118] **18** first scale line [0119] **19** second scale line [0120] **20** transverse leg [0121] **21** longitudinal leg [0122] **25** transmitter coil [0123] **26** first receiver coil [0124] **27** second receiver coil [0125] **28** coil group [0126] **29** circuit branch [0127] **30** first node [0128] **31** second node [0129] **32** transmitter circuit [0130] **33** parallel oscillating circuit [0131] **34** oscillating circuit capacitance [0132] **35** oscillating circuit inductance [0133] **36** series resistance [0134] **37** controlled switch [0135] **38** control input [0136] **39** transmitter control unit [0137] **40** control device [0138] **41** measurement coil [0139] **42** evaluation unit [0140] **43** circuit board [0141] **44** top side of circuit board [0142] **45** measurement loop [0143] **46** first end point of measurement loop [0144] **47** second end point of measurement loop [0145] **48** central loop [0146] **49** shielding [0147] A range of expected values [0148] b conductor strip width [0149] b**1** first conductor strip width [0150] b**2** second conductor strip width [0151] b**3** third conductor strip width [0152] C central line [0153] d**1** first division [0154] d**2** second division [0155] E receiver signal [0156] GND ground potential [0157] H loop height [0158] H**1** first loop height [0159] H**2** second loop height [0160] H**3** third loop height [0161] IS transmitter coil current [0162] IL conductor strip loop current [0163] UE receiver coil voltage [0164] UE**1** first receiver coil voltage [0165] UE**2** second receiver coil voltage [0166] UE**3** third receiver coil voltage [0167] UE**4** fourth receiver coil voltage [0168] M measurement direction [0169] P**1** first phase signal [0170] P**2** second phase signal [0171] PD phase difference signal [0172] PT phase trajectory [0173] Q transverse direction [0174] RL ohmic resistance of conductor strip loop [0175] S transmitter signal [0176] SW switch signal [0177] T period of receiver coil voltage [0178] t time [0179] t**1** first point in time of detection [0180] t**2** second point in time of detection [0181] t**3** third point in time of detection [0182] t**4** fourth point in time of detection [0183] UDC supply direct voltage [0184] W loop width [0185] W**1** first loop width [0186] W**2** second loop width [0187] W**3** third loop width [0188] x position variable in measurement direction [0189] xc non-modulating section [0190] xc**1** first non-modulating section [0191] xc**2** second non-modulating section [0192] xc**3** third non-modulating section [0193] xc**4** fourth non-modulating section [0194] xa absolute relative position [0195] XL inductive reactance of conductor strip loop [0196] xm modulating section [0197] xm**1** first modulating section [0198] xm**2** second modulating section [0199] xm**3** third modulating section [0200] xm**4** fourth modulating section [0201] Z apparent resistance of conductor strip loop

Claims

1. An inductive sensor device (**11**) comprising: a scale body (**12**) having multiple electrically conductive conductor strip loops (**17**) that are arranged in at least one scale line (**18**) having a respectively defined division (d**1**, d**2**), wherein the at least one scale line (**18**, **19**) extends parallel to a measurement direction (M); a sensor unit (**13**), which is movably arranged in the measurement direction (M) on the scale body (**12**) and which comprises for each scale line (**18**, **19**) at least one transmitter coil (**25**) for application of at least one transmitter signal (S) and at least one receiver coil (**26**, **27**) for providing a receiver signal (E); and an evaluation unit (**42**), which is configured to evaluate the receiver signal or signals (E) and to determine therefrom an absolute relative position (xa) between the sensor unit (**13**) and the scale body (**12**); wherein the at least one scale line (**18**, **19**) comprises a modulating section (xm) extending in the measurement direction (M), wherein within the modulating section individual ones of the conductor strip loops (**17**) have impedances and/or apparent resistances (Z) which are different from one another, and wherein the evaluation unit (**42**) is configured to evaluate a modulation of the receiver signal or signals (E) resulting from the impedances and/or apparent resistances (Z) that change within the modulating section (xm).
2. The inductive sensor device according to claim 1, wherein the conductor strip loops (**17**) are arranged with a first division (d**1**) in a first scale line (**18**) and with a second division (d**2**) in a second scale line (**19**) and wherein the first and second scale lines (**18**, **19**) are arranged adjacent to one another in a transverse direction (Q).
3. The inductive sensor device according to claim 1, wherein two receiver coils (**26**, **27**) of the at least one receiver coil are assigned to each scale line (**18**, **19**).
4. The inductive sensor device according to claim 1, wherein each of the conductor strip loops (**17**) within the at least one modulating section (xm) have impedances and/or apparent resistances (Z) that are different from one another.
5. The inductive sensor device according to claim 1, wherein the impedances and/or apparent

resistances (Z) of the individual ones of the conductor strip loops (**17**) in the modulating section (xm) are different to each other in that the individual ones of the conductor strip loops (**17**) have different ratios of a reactance (XL) relative to an ohmic resistance (RL).
6. The inductive sensor device according to claim 1, wherein a change of the impedance and/or apparent resistance (Z) between the individual ones of the conductor strip loops (**17**) which are adjacent in the measurement direction (M) within the at least one modulating section (xm) is non-linear.
7. The inductive sensor device according to claim 1, wherein a change of the impedance and/or apparent resistance (Z) between the individual ones of the conductor strip loops (**17**) which are adjacent in the measurement direction (M) within the at least one modulating section (xm) is exclusively or at least primarily based on a change of an ohmic portion of the apparent resistance (Z).
8. The inductive sensor device according to claim 1, wherein multiple conductor strip loops (**17**) within the at least one modulating section (xm) have conductor strip widths (b) that are different from one another.
9. The inductive sensor device according to claim 8, wherein each conductor strip loop comprises a loop height (H) in a transverse direction (Q) and a loop width (W) in the measurement direction (M) and wherein two conductor strip loops (**17**) having different conductor strip widths (b**1**, b**2**, b**3**) comprise loop heights (H**1**, H**2**, H**3**) of different magnitude and loop widths (W**1**, W**2**, W**3**) of different magnitude.
10. The inductive sensor device according to claim 1, wherein each conductor strip loop (**17**) of the multiple conductor strip loops comprises two transverse legs (**20**) each extending in a straight line in a transverse direction (Q).
11. The inductive sensor device according to claim 1, wherein each conductor strip loop (**17**) of the multiple conductor strip loops comprises two longitudinal legs (**21**) each extending in a straight line in the measurement direction (M).
12. The inductive sensor device according to claim 1, wherein each individual conductor strip loop (**17**) of the multiple conductor strip loops comprises a constant conductor strip width (b).
13. The inductive sensor device according to claim 1, wherein the at least one scale line (**18**, **19**) comprises a non-modulation section (xc) extending in the measurement direction (M) in which each of the conductor strip loops (**17**) have equal impedances and/or equal apparent resistances (Z).
14. The inductive sensor device according to claim 13, wherein each of the conductor strip loops (**17**) within the non-modulating section (xc) have equal conductor strip cross-sections and equal conductor strip widths (b).
15. The inductive sensor device according to claim 2, wherein the at least one scale line (**18**, **19**) comprises a first scale line (**18**) and a second scale line (**19**) that each comprise at least one non-modulating section (xc) respectively, wherein the at least one non-modulating section of each scale line are arranged in a non-overlapping manner in the measurement direction (M).
16. The inductive sensor device according to claim 1, wherein the evaluation unit (**42**) is configured to determine a phase signal (P**1**, P**2**) from the receiver signal or signals (E), wherein the phase signal (P**1**, P**2**) describes a phase offset between the at least one transmitter signal (S) and a conductor strip loop current (IL), which is induced in at least one of the conductor strip loops (**17**) due to the at least one transmitter signal (S).
17. The inductive sensor device according to claim 16, wherein the evaluation unit (**42**) is configured to sample the receiver signal or signals (E) multiple times and to determine one sample value respectively.
18. The inductive sensor device according to claim 17, wherein the evaluation unit (**42**) is configured to determine a phase value (φ) for the phase signal (P**1**, P**2**) from the sample values of the receiver signal (E).