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Measuring device with cylindrical monopole antenna

15 Reference to related applications

The present application claims the priority of German patent application No. 10 2023 206 601.7, filed on July 12, 2023, which is incorporated in its entirety by reference into the present document.

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Field of the invention

The present invention relates to measuring device technology in industrial and private environments. In particular, the present invention relates to a measuring device with a
25 cylindrical monopole antenna, a cylindrical monopole antenna, and the use of a cylindrical monopole antenna in a measuring device.

Technical background

30 In measuring devices for process automation in industrial or private environments, and in particular in self-sufficient sensors, the arrangement of the antenna in the interior of the housing often leads to a reduction in transmission and reception characteristics, resulting in a higher energy requirement for radio communication. In particular, energy storage devices and their cabling or additional circuit boards often prove to be disruptive due to
35 their relatively large dimensions in close proximity to the antenna, thus impairing its radiation behavior. Furthermore, SMT chip antennas cannot achieve particularly high efficiencies at lower mobile radio frequencies with circuit boards that are too small or circular.

Summary

Against this background, it is an object of the present disclosure to provide a measuring device which has good transmission characteristics when transmitting the measurement data to an external receiver.

This object is solved by the features of the independent patent claims. Further details of the invention are provided in the subclaims and the following description of embodiments.

10 A first aspect of the present disclosure relates to a measuring device that is configured as a level measuring device for process automation in industrial or private environments. It has a sensor device that is configured to detect level measurement data, as well as a cylindrical monopole antenna that serves to transmit the level measurement data to an external receiver. One or more batteries or charge storage devices and/or a printed circuit
15 board and/or a radar antenna horn are arranged in the interior of, i.e., the inside of the cylindrical monopole antenna.

The measuring device can be configured as a field device for automation technology. It can have a plastic housing or a metal housing with a housing opening and an electronic
20 unit arranged in the interior of the housing with at least one printed circuit board. The antenna is configured to transmit and receive electromagnetic waves with at least one specified wavelength, whereby the antenna is aligned in such a way that it is configured to transmit electromagnetic waves through the housing or the housing opening and to receive electromagnetic waves to be received from the direction of the housing or the
25 housing opening, whereby a wireless communication connection can be established between the electronic unit and a transmitting/receiving unit located outside the housing of the field device by means of the antenna.

The term "process automation in an industrial environment" can be understood as a subfield of technology that involves measures for operating machines and systems
30 without human intervention. One goal of process automation is to automate the interaction of individual components of a plant in the chemical, food, pharmaceutical, petroleum, paper, cement, shipping, or mining industries. A variety of sensors can be used for this purpose, which are specially adapted to the specific requirements of the process industry,

such as mechanical stability, insensitivity to contamination, extreme temperatures, and extreme pressures. The measured values from these sensors are usually transmitted to a control room, where process parameters such as fill level, limit level, flow, pressure, or density can be monitored and settings for the entire plant can be changed manually or
5 automatically.

One area of process automation in industrial environments concerns the logistics automation of facilities and supply chains. Distance and angle sensors are used in logistics automation to automate processes inside or outside a building or within a single
10 logistics facility. Typical applications include logistics automation systems for baggage and cargo handling at airports, traffic monitoring (toll systems), retail, parcel distribution, and building security (access control). What the examples listed above have in common is that presence detection in combination with accurate measurement of the size and position of an object is required by the respective application. For this purpose, sensors
15 based on optical measurement methods using lasers, LEDs, 2D cameras, or 3D cameras that measure distances using the time-of-flight (ToF) principle can be used.

Another subfield of process automation in the industrial environment concerns factory/production automation. Applications for this can be found in a wide variety of
20 industries, such as automotive manufacturing, food production, the pharmaceutical industry, or in the packaging sector in general. The aim of factory automation is to automate the manufacture of goods using machines, production lines, and/or robots, i.e., to run without human intervention. The sensors used here and the specific requirements with regard to measurement accuracy when detecting the position and size of an object
25 are comparable to those in the previous example of logistics automation.

The terms used in the claims should be interpreted in such a way that they are given the broadest reasonable interpretation in accordance with the above description. For example, the use of the article "a" or "the" when introducing an element should not be
30 interpreted as excluding a plurality of elements. Similarly, the mention of "or" should be interpreted as including a plurality of elements, so that the mention of "A or B" does not exclude "A and B" unless it is clear from the context or the preceding description that only one of A and B is meant. Furthermore, the phrase "at least one of A, B, and C" should be understood as one or more elements from a group of elements consisting of A, B, and C,

and should not be interpreted as requiring at least one of each of the listed elements A, B, and C, regardless of whether A, B, and C are connected as categories or in any other way. In addition, the mention of "A, B, and/or C" or "at least one of A, B, or C" should be interpreted as including each individual unit of the listed elements, e.g., A, each subset of
5 the listed elements, e.g., A and B, or the entire list of elements A, B, and C.

Another aspect of the present disclosure relates to a measuring device that is configured as a pressure measuring device for process automation in industrial or private environments. This also has the elements described above (sensor device, cylindrical
10 monopole antenna).

Another aspect of the present disclosure relates to a measuring device that is configured as a temperature measuring device for process automation in industrial or private environments and has a sensor arrangement for detecting temperature measurement
15 data and the cylindrical monopole antenna described above.

Another aspect of the present disclosure relates to a measuring device that is configured as a flow meter for process automation in industrial or private environments and has a sensor device for recording flow measurement data and the cylindrical monopole antenna
20 described above.

The cylindrical monopole antenna is more efficient than known arrangements. By incorporating the battery or other components inside the antenna, interference/reflections/shielding that could impair the antenna's radio properties is
25 reduced.

According to a further embodiment of the present disclosure, the cylindrical monopole antenna tapers conically at its end facing the process and/or at its end facing away from the process.
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According to a further embodiment of the present disclosure, the measuring device has a high-frequency printed circuit board which is arranged outside the cylindrical monopole antenna and which is designed to generate the antenna signal to be emitted.

According to a further embodiment of the present disclosure, the cylindrical monopole antenna is placed on or attached to the RF circuit board.

5 According to a further embodiment of the present disclosure, the RF circuit board represents the counterpole of the cylindrical monopole antenna.

According to a further embodiment of the present disclosure, the inner diameter of the cylindrical monopole antenna corresponds to the outer diameter of the battery or battery pack.

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According to a further embodiment of the present disclosure, the measuring device further comprises a contact pin arranged concentrically with the cylindrical monopole antenna, which connects the positive pole of the battery to the RF circuit board.

15 According to a further embodiment of the present disclosure, the measuring device has a circuit board arranged inside the cylindrical monopole antenna. It may be provided that the battery rests on this circuit board.

20 According to a further embodiment of the present disclosure, the measuring device has a plastic housing in which the cylindrical monopole antenna and the sensor device are arranged. Preferably, the plastic housing is closed and sealed.

25 Another aspect of the present disclosure relates to a cylindrical monopole antenna, as described above and below, designed to transmit measurement data from a measuring device to an external receiver, wherein a battery and/or one or more printed circuit boards are arranged inside the cylindrical monopole antenna.

30 Another aspect of the present disclosure relates to the use of a cylindrical monopole antenna described above and below in a measuring device for process automation in an industrial or private environment for transmitting measurement data from the measuring device to an external receiver.

The following describes embodiments of the present disclosure with reference to the figures. Where the same reference numerals are used in the following figure description,

they denote the same or similar elements. The representations in the figures are schematic and not to scale.

Brief description of the figures

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Fig. 1 shows several measuring devices and an external receiver according to an embodiment.

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Fig. 2 shows a cross-sectional view through a measuring device according to an embodiment.

Fig. 3 shows a cross-sectional view through a measuring device according to a further embodiment.

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Fig. 4 shows a front view and a side view of a measuring device according to an embodiment in cross-sectional representation.

Fig. 5 shows a top view of a high-frequency printed circuit board according to an embodiment.

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Fig. 6 shows the simulation of the achievable adjustment of a cylindrical monopole antenna of a measuring device according to an embodiment.

Detailed description of embodiments

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Fig. 1 shows several measuring devices 100, 400 and an external receiver 300 in the form of a display and control unit.

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The external receiver 300 can communicate with the measuring devices 100, 400 via the cloud 500, or directly, and receive measurement data from them.

The measuring devices are configured, for example, as a level measuring device 100, a flow measuring device 100, a pressure measuring device 400, or a temperature measuring device 100, and all have a cylindrical monopole antenna 200 and a sensor

device 101. In the case of a pressure measuring device, the sensor device 101 is a pressure measuring cell; in the case of a level measuring device, it is, for example, a radar chip with an antenna; in the case of a temperature measuring device, it is a temperature measuring cell; and in the case of a flow measuring device, it is a flow measuring cell.

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The level measuring device can, for example, be configured as a level radar measuring device and emit a radar signal of 80 GHz or above (or below).

Fig. 2 shows a cross-sectional view of a measuring device 100, 400 according to an embodiment. The antenna 2 used is a monopole. It is not configured as a wire antenna, but as a cylinder with a sufficient cavity in which components such as batteries or their wiring or printed circuit boards are accommodated. Because the interior is field-free (Faraday cage), the components located there cannot influence the antenna's radiated or received field. In order for the antenna to achieve maximum efficiency at the mobile radio frequencies used for NB-IoT, LTE-M, LPWAN, and LoRaWAN, for example, modifications to the classic monopole are necessary.

As the diameter of the cylindrical base plate of the monopole increases, the capacitive load causes the antenna to become detuned, especially in the upper frequency bands. For this reason, the lower part of the antenna is designed as a truncated cone, which can also be used as a parameter to improve the matching. A short-circuit connection from the antenna housing to the ground of the RF circuit board 10 is also provided, which, as with the well-known PIF antennas, provides an additional option for impedance matching. This ground connection also allows the negative pole of the battery to be connected to the RF circuit board without interference. The positive pole of the battery is routed coaxially inside the RF feed and therefore has no noticeable influence.

An important aspect is the integration of components such as the battery and circuit boards inside the antenna 2 so as not to interfere with the radiation characteristics of the antenna and to achieve the highest possible efficiency of the antenna.

In principle, the measuring devices described are self-sufficient sensors, i.e., battery-powered measuring devices whose recorded values are transmitted to the control center in the desired time sequence via a radio interface. The efficiency of the antenna has a

significant influence on battery life because if the antenna efficiency is too low, significantly more power is required for radio communication.

Fig. 2 shows an initial design of a measuring device in which the necessary components are housed in a dust- and water-tight plastic enclosure 1. The batteries and their wiring are advantageously integrated into the cylindrical cavity of the antenna 2, as these are exclusively conductive parts with a corresponding influence on the electromagnetic fields of the antenna. In the embodiment shown, five batteries 4 are grouped together in a battery holder 5 and connected by cable plugs or other means to the printed circuit board 6 resting on the edge of the cone. Depending on requirements and available height, additional printed circuit boards 6' can also be installed inside the cylinder. This also applies to the measuring cells 3 and 3', which are not described in detail and can be located inside and/or outside the antenna 2. The measuring cell 3' can, for example, be located on the radar antenna horn. The batteries can also be arranged in the measuring cell 3, which is located outside the cylindrical cavity. The monopole antenna 2, which tapers to a cone shape due to the capacitive load, is placed in the center of the RF circuit board 10 and fixed to the RF circuit board by a plastic ring 7 with supports, while also being supported by the housing 1.

Fig. 3 shows a minimalist design in which a single size D battery 4 (mono cell) is installed. In this case, it is advantageous for the diameter of the antenna 2 to be designed so that the battery 4 is supported on the cylindrical wall of the monopole 2. A circuit board 8 located inside the antenna accommodates the positive pole of the battery 4 and conducts the pole to the RF circuit board 10 in a shielded manner via a contact pin 9. The circuit board 8 can also have simple circuit components such as reverse polarity protection or current limiting to reduce malfunctions.

All components for radio communication are located on the RF circuit board 10. The RF circuit board 10 also acts as the opposite pole of the monopole.

The negative pole of the battery is connected via a spring contact 11 to the conductive cover 5, which is screwed into the antenna cylinder, for example, and thus also clamps the battery in place. Other fastenings are also possible for this purpose; the important thing is the electrical contact between the battery 4 and the antenna 2.

The antenna 2 is attached to the center of the RF circuit board 10 via a plastic ring with supports, so that there is a constant distance to the housing 1. This results in a circular antenna pattern in the azimuth direction.

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On the lower side, antenna 2 tapers conically toward RF circuit board 10 in order to reduce the capacitive load to ground. Varying the lower diameter of the truncated cone can simultaneously improve the adaptation in the frequency bands used.

- 10 Fig. 4 shows two more detailed views of the connection between the antenna 2 and the RF circuit board 10. The contact pin 9 from the positive pole 4' of the battery 4 is inserted coaxially through the feed 13 directly into the RF circuit board 10. Either air is used for insulation from ground inside the cylindrical feed 13, or a plastic body 15 is inserted into the cavity of the feed 13. This provides better support for the contact pin 9 and at the same
- 15 time hermetically shields the battery 4 inside the antenna from external influences.

- The signal to be transmitted reaches the antenna via two connection pins 14. Below the cone base of the antenna 2 is a short-circuit plate 12, which, similar to the well-known PIF antennas, establishes a current path to the ground of the circuit board. The negative pole
- 20 of the battery is connected to the circuit board via contact pin 16, which also provides an additional option for improving the antenna's matching.

- In order to achieve optimum adjustment of the antenna for the lower and upper LTE frequency bands, for example, it has proven advantageous to connect the contact pin 16
- 25 of the short-circuit plate 12 via a short-circuited line.

- Fig. 5 shows the connection of the antenna to the printed circuit board again separately. It shows a line 17 that is short-circuited with ground holes 19. The length of this line 17 to contact pin 16 determines the effective impedance with which the antenna is matched.

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Alternatively, an inductor can be installed between contact pin 16 and ground, and tuning can be achieved by varying the inductance value.

Opposite this is a 50-ohm line 18, on which the high-frequency signals are fed to the antenna. This is done via the two contact pins 14, which are connected to the connection ring 20. Inside the connection ring 20, the hole for receiving the contact pin 9 is visible. If several signals are to be fed into the interior of the antenna, this is possible in principle.

- 5 In this case, an insulating body can be provided which receives the connection pins and is pressed into the cylinder of the feed together with them.

Fig. 6 shows a simulation for a sensor as shown in Fig. 2 in a closed PTFE housing with a total diameter of 93 mm and a total length of 150 mm, in which the achievable matching was calculated using a field simulator. The result of the simulation is the matching curve shown in Fig. 6, which has a very good value for S11 of ≤ -14 dB (VSWR ≤ 1.5) at the band limits. This allows antenna efficiencies of more than 90 percent to be achieved in both bands.

Patent claims

1. Measuring device, configured as a level measuring device for process automation in industrial or private environments, comprising:
 - 5 a sensor device (101, 3) configured to detect level measurement data;
 - a cylindrical monopole antenna (2, 200) configured to transmit the level measurement data to an external receiver (300);
 - wherein a battery (4) and/or a printed circuit board (6) and/or a radar antenna horn (3') is arranged in the interior of the cylindrical monopole antenna.
- 10 2. Measuring device, configured as a pressure measuring device (400) for process automation in industrial or private environments, comprising:
 - a sensor device (101, 3) configured to detect pressure measurement data;
 - a cylindrical monopole antenna (2, 200) configured to transmit the pressure
 - 15 measurement data to an external receiver (300);
 - wherein a battery (4) and/or a printed circuit board (6) is arranged in the interior of the cylindrical monopole antenna.
- 20 3. Measuring device, configured as a temperature measuring device (100) for process automation in industrial or private environments, comprising:
 - a sensor device (101, 3) configured to detect temperature measurement data;
 - a cylindrical monopole antenna (2, 200) configured to transmit the temperature measurement data to an external receiver (300);
 - wherein a battery (4) and/or a printed circuit board (6) is arranged in the interior of
 - 25 the cylindrical monopole antenna.
- 30 4. Measuring device, configured as a flow meter (100) for process automation in industrial or private environments, comprising:
 - a sensor device (101, 3) configured to detect flow measurement data;
 - a cylindrical monopole antenna (2, 200) configured to transmit the flow measurement data to an external receiver (300);
 - wherein a battery (4) and/or a printed circuit board (6) is arranged in the interior of the cylindrical monopole antenna.

5. Measuring device according to one of the preceding claims,
 wherein the cylindrical monopole antenna (2, 200) tapers conically at its end facing
 or facing away from the process.
- 5 6. Measuring device according to one of the preceding claims, further comprising:
 an RF printed circuit board (10) which is arranged outside the cylindrical monopole
 antenna (200) and which is configured to generate the antenna signal to be emitted.
7. Measuring device according to claim 6,
 10 wherein the cylindrical monopole antenna (2, 200) is mounted on the RF circuit
 board (10).
8. Measuring device according to claim 6 or 7,
 wherein the RF printed circuit board (10) is configured as counterpole of the
 15 cylindrical monopole antenna (200).
9. Measuring device according to one of the preceding claims,
 wherein the inner diameter of the cylindrical monopole antenna (2, 200)
 corresponds to the outer diameter of the battery (4).
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10. Measuring device according to one of claims 4 to 7, further comprising:
 a contact pin (9) arranged concentrically to the cylindrical monopole antenna (2,
 200), which connects the positive pole of the battery (4) to the RF circuit board (10).
- 25 11. Measuring device according to one of the preceding claims, further comprising:
 a printed circuit board (6) arranged in the interior of the cylindrical monopole
 antenna (2, 200) and on which the battery rests.
12. Measuring device according to one of the preceding claims, further comprising:
 30 a plastic housing (1) in which the cylindrical monopole antenna (2, 200) and the
 sensor device (101, 3) are arranged.
13. Cylindrical monopole antenna (2, 200) configured to transmit measurement data from
 a measuring device to an external receiver (300),

wherein a battery (4) and/or a printed circuit board (6) and/or a radar antenna horn (3') is arranged in the interior of the cylindrical monopole antenna.

14. Use of a cylindrical monopole antenna (2, 200) according to claim 13 in a measuring
5 device for process automation in an industrial or private environment for transmitting measurement data from the measuring device to an external receiver (300).