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(54) **Electromagnetic detection system provided with an antenna element having one winding.**

(57) An electromagnetic detection system comprising a transmitter and receiver device, a transformer having a primary side which is connected with the transmitter and receiver device, at least one antenna element which is connected with a secondary side of the transformer for generating an electromagnetic interrogation field in a detection zone and at least one responder adapted to radiate a detection signal under the influence of the interrogation field, the antenna element consisting of a current loop having only one winding. The system further comprises a tuning element which is connected with the secondary side of the transformer and with the antenna element, so that on the secondary side of the transformer a resonance circuit is formed having a resonance frequency which corresponds with the operating frequency of the transmitter and receiver device.

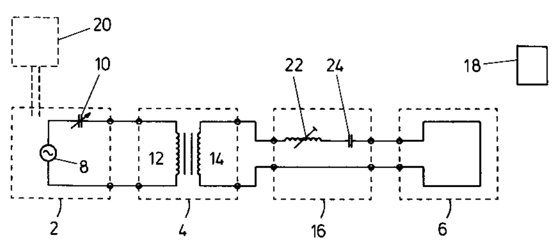

FIG. 2

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This invention relates to an electromagnetic detection system comprising a transmitter and receiver device, a transformer with a primary side which is connected with the transmitter and receiver device, at least one antenna element which is connected with a secondary side of the transformer for generating an electromagnetic interrogation field in a detection zone and at least one responder adapted to radiate a detection signal under the influence of the interrogation field, the antenna element consisting of a current loop having only one winding.

Such an electromagnetic detection system is disclosed in European patent application 0331269. Generally, these and similar detection systems are adapted for detecting and recognizing particular persons, articles, vehicles, animals and the like, or the class or group to which these persons, articles, vehicles, animals and the like belong. These systems comprise responders which generate a coded detection signal in a suitable interrogation field. Such a responder is disclosed, for instance, in Dutch patent 176404. This responder is employed on a large scale, for instance in automatic cattlefeed systems. A cow or a pig carries the responder, for instance on a collar. If this responder is used in the proximity of a transmitting coil which radiates an electromagnetic interrogation field, the responder reacts thereto by radiating a unique code. This code is received by an antenna which may, for instance, be the same as the transmitting antenna, detected in an electronic device and applied to a computer. The computer then determines how much feed there is in store for the animal, whereafter this amount can be deposited automatically in a feeding through in the proximity of the animal. A gate construction ensures that only the animal in question receives its share of feed and that the animal, while eating, is not disturbed by other animals. In practice, for the purpose of detecting the responder of an animal, the animal is typically made to walk through windings of the antenna. In that case, the antenna coil has appropriate dimensions for that purpose, for instance of 2 x 1 metres. It is an advantage that the antenna coil resonates at the operating frequency. In fact, as a result of the resonant rise, the current in the circuit then becomes much greater than the control current, so that a particular field strength can be achieved even at a small control current. Moreover, for the received signals, the resonating coil constitutes a filter which filters out interference of low frequencies in particular. Traditionally, the antenna coil consists of a plurality of windings. In addition, the coil must be robust (resistant to attack by animals and to the cattle house environment) and will have to be accommodated in a casing for protection. This casing, for instance a plastic tube, must in turn be treated and sealed, for instance against penetration of moisture. In practice, these requirements often result in complex and objectionable constructions of the antenna coil, which moreover require much time to install.

These drawbacks can be partly obviated by using an antenna coil having only one winding. The antenna can then be constructed from a strong metal conductor, for instance stainless steel. Thus, a robust antenna is obtained and moisture proofing and mechanical protection are no longer necessary. It is also possible, as described in European patent application 0331269, to use a part of the physically present construction as an antenna coil with one winding. The self-induction of the coil is proportional to the square of the number of windings. This means that in the case of an antenna having only one winding, the self-induction, and hence the impedance, is low. The system according to European patent application 0331269 meets this drawback and to that end comprises a transformer by which the impedance is transformed upwards. Together with an appropriate capacitor, this transformed impedance constitutes a resonance circuit. The transformer is then a part of the resonance circuit. In that case, the resonance circuit comprises both the primary and the secondary side of the transformer. In the case of not unduly high resonant rise factors, this method is also practically useful. However, with increasing resonant rise, the losses and particularly incomplete coupling of the primary and secondary windings of the transformer, begin to constitute a limitation. The detection system is adjusted to the proper tuning frequency by means of a regulable capacitor which is arranged on the primary side of the transformer. The drawback of this manner of tuning is that the tuning capacitance is highly dependent on the transformation ratio of the transformer. Because the transformer is part of the resonance circuit, the losses in the transformer will also affect the quality factor Q of the tuned antenna.

The present invention meets these drawbacks and is characterized in that the system further comprises a tuning element which is connected with the secondary side of the transformer and with the antenna element, so that on the secondary side of the transformer a resonance circuit is formed having a resonance frequency which corresponds with the operating frequency of the transmitter and receiver device. In accordance with the invention, resonance arises exclusively on the secondary side of the transformer. The antenna element with one winding resonates in cooperation with the tuning element at the working frequency of the system. This configuration is not obvious, because the self-induction of a single-winding antenna is very small. This implies that a very high value will have to be chosen for the capacitance of the tuning element.

The invention provides a solution here by making only a secondary winding of the transformer, rather than the entire transformer, a part of the resonance circuit. In accordance with the invention, the energy is transported from the antenna element to the tuning element and vice versa. This is entirely in contrast with the situation in known systems. Here the energy is transported from the antenna element via the transformer to a capacitor located on the primary side of the transformer, and vice versa. In accordance with the invention, the greater part of the energy accordingly remains on the secondary side of the transformer. Because of the low impedances which arise in the resonance circuit, the capacitance of the tuning element much acquire an extremely high value. Such a high value is entirely non-obvious. Moreover, making such a tuning unit regulable is difficult to realize from a practical point of view.

Swiss patent application 667955 discloses a frame antenna which, in cooperation with a tuning element, is connected with the secondary side of a transformer. However, the antenna involved here comprises a large number of windings. This means that the system described in the Swiss patent application is not comparable with the system according to the invention. Moreover, the system does not provide a solution to the problems described hereinabove. Accordingly, this system is not suitable to be used in, for instance, a cattle house. According to a particular embodiment of the detection system according to the invention, the tuning element comprises a coil with a regulable self-induction for tuning the resonance frequency to the operating frequency, i.e. to the frequency of the transmitted signal generated by the transmitter and receiver device. When realizing an antenna circuit with a high quality factor, the bandwidth is small and therefore it must be possible for the tuning to be carried out accurately. Technically, however, it is very difficult to realize a large capacitor which moreover is adjustable. The invention meets this problem in that, according to a particular embodiment, the tuning element comprises a coil with a regulable self-induction for tuning the resonance frequency. In particular, this coil and the antenna element are connected in series. Further, in accordance with the invention, the tuning element may further comprise a capacitance. This capacitance and the antenna element can also be switched in series.

Because the tuning referred to should be carried out very accurately, it is desirable that such tuning be controlled and adjusted continuously. To make this possible, the regulable coil comprises, in accordance with a highly advanced embodiment, a magnetizable core material, the system further comprising a regulable DC voltage source which generates a direct current for magnetizing the core material and thus controlling the self-induction of the coil. In this manner the resonance frequency can be controlled in a highly accurate and effective manner.

In particular, the DC voltage source is part of a control loop in which the DC voltage source is controlled in such a manner that a current and an associated voltage in the resonance circuit have the same phase. Thus a situation is realized where the resonance frequency is controlled in such a manner that it corresponds with the operating frequency of the system, i.e. with the frequency of the transmitted signal applied to the primary side of the transformer by the transmitter and receiver device.

According to a particular embodiment of the detection system, the DC voltage source is controlled in such a manner that the current and the voltage of a transmitted signal applied to a primary side of the transformer by the transmitter and receiver unit have the same phase.

According to an alternative embodiment of the detection system, the DC voltage source is part of a control loop in which the DC voltage source is controlled in such a manner that a current and an associated voltage in the resonance circuit are at a maximum. If this condition is satisfied, the resonance frequency is also equal to the operating frequency of the system, i.e. to the frequency of the transmitted signal applied to the primary side of the transformer by the transmitter and receiver device.

According to a particular embodiment of the detection system, the DC voltage source is controlled in such a manner that the current and the voltage of a transmitted signal applied to a primary side of the transformer by the transmitter and receiver unit are at a maximum.

In particular, the regulable coil and the transformer are part of one and the same component. Accordingly, the regulable coil can, for instance, be wound around a core material which is also part of the core material of the transformer.

According to a highly advanced embodiment of the electromagnetic detection system according to the invention, the system further comprises a second transmitter and receiver device, a second antenna element coupled thereto, which comprises a current loop having one winding and a regulable coupling transformer having a first and a second side, windings of the first side being connected in parallel to the current loop of the first-mentioned antenna element and windings of the second side being connected in parallel to the current loop of the second antenna element. Thus, the coupling between the windings of the coupling transformer can be adjusted in such a manner that a magnetic coupling between the two antenna elements is compensated at least substantially completely. If these two antennas are in mutual proximity, there arises no cross talk of signals from one antenna to the other and vice versa. This also makes it impossible for beats to arise in the system when the second transmitter and receiver device generates a transmitted signal of a frequency differing slightly from that of the transmitted signal generated by the first-mentioned transmitter and receiver device. It also prevents a situation where a responder which reacts to an interrogation field generated by the second antenna element also generates a current variation in the first-mentioned antenna element.

The invention also relates to an electromagnetic detection system comprising a first and a second transmitter and receiver device which are respectively connected via a first and a second transformer with a first and a second antenna element for generating an electromagnetic interrogation field in at least one detection zone and at least one responder capable of radiating a detection signal under the influence of an interrogation field, the antenna elements each consisting of a current loop having only one winding. In accordance with the invention, this detection system further comprises a regulable coupling transformer having a first and a second side, windings of the first side being connected in parallel to the current loop of the first antenna element and windings of the second side being connected in parallel to the current loop of the second antenna element.

The invention will be further explained with reference to the drawing. In the drawing:

Fig. 1 diagrammatically shows a known configuration of an electromagnetic detection system comprising an antenna element having one winding;

Fig. 2 diagrammatically shows a first embodiment of an electrical configuration of a detection system according to the invention;

Fig. 3 diagrammatically shows a second embodiment of an electrical configuration of a detection system according to the invention;

Fig. 4 diagrammatically shows a third embodiment of an electrical configuration of a detection system according to the invention;

Fig. 5 diagrammatically shows a part of a fourth embodiment of a detection system according to the invention; and

Fig. 6 shows an exemplary embodiment of a transformer of the system according to Fig. 5.

In Fig. 1 reference character 1 designates an identification system, which is known per se, by means of which an interrogation field is generated in a detection zone. The system comprises a transmitter and receiver device 2 which is connected to an antenna element 6 by means of an impedance transformer 4. The antenna element 6 comprises a current loop having only one winding. Accordingly, the antenna element 6 can be constructed from a strong metal conductor, for instance of stainless steel, which is suitable to be used in a cattle house. The antenna element 6 has a self-induction which is very small. By virtue of the impedance transformer 4, however, the self-induction of the antenna element 6, viewed from the transmitter and receiver device 2, i.e. the self-induction which is measured on the primary side of the transformer 4, has a higher, more conventional value. In view of the relatively high currents which can flow through the antenna element 6 and the low permissible impedance of the antenna element, the impedance transformer 4 is preferably arranged as closely as possible to the antenna element 6. The detection system is adjusted to the proper resonance frequency by means of a regulable capacitor 10 which is arranged on the primary side of the transformer 4. The drawback of this manner of tuning is that the tuning capacitance is highly dependent on the transformation ratio of the transformer 4. The antenna element 6 and the capacitor 10, together with the coupling transformer 4, constitute a resonance circuit. Because the transformer 4 is part of the resonance circuit, the losses in the transformer will also affect the quality factor Q of the tuned antenna element 6.

Fig. 2 diagrammatically shows an electrical configuration of a detection system according to the invention, which meets the above-mentioned objections. In Figs. 1 and 2, corresponding parts have been provided with the same reference characters. The detection system shown in Fig. 2 comprises a transmitter and receiver device 2 which is coupled to the primary side 12 of an impedance transformer 4. The secondary side 14 of the impedance transformer 4 is coupled with an antenna element 6 via a tuning element 16. The antenna element 6 comprises a current loop consisting of a single winding, as described with reference to Fig. 1. The detection system shown in Fig. 2 generates an interrogation field in a detection zone. If a label 18, also referred to as responder, is located in the interrogation field, it will generate a detection signal. The detection signal radiated by the label 18 can be received by a receiving antenna 20, whereafter the received signal is further processed by the transmitter and receiver device 2. In that case, the detection system according to Fig. 2 is a so-called transmission system. However, it is also possible to design the detection system according to Fig. 2 as an absorption system. In that case, the receiving antenna 20, represented in dots in Fig. 2, can be omitted. In an absorption system, the antenna element 6 functions as transmitting as well as receiving antenna. A label which is introduced into the interrogation field will absorb energy from the interrogation field for radiating a detection signal. The power produced by the oscillator 8 will thus vary as well. By measuring this energy variation, a detection signal radiated by the label can be detected and decoded with means known per se. All this will not be explained in detail here. By means of the tuning element 16, the antenna element 6 is tuned to the proper resonance frequency. The advantage of tuning on the secondary side 14 of the transformer 4 by means of the tuning element 16 is that the tuning is not dependent on the transformation ratio of the transformer 4. Tuning is dependent only on the impedance of the antenna element 6. Also, the losses in the transformer 4 are much lower because it is no longer part of the resonance circuit. In this case, the resonance circuit consists of the antenna element 6 and the tuning element 16. If the resonance circuit is in resonance, energy which is stored in the antenna element 6 is transported to the tuning element 16 and vice versa. The tuning element 16 comprises a capacitor 24 and a regulable self-induction 22 which are connected in series with the antenna element 6. In the system according to Fig. 2, the coil 22 with regulable self-induction is tuned in such a manner that the resonance frequency of the resonance circuit made up of the tuning element 16 and the antenna element 6 corresponds with the operating frequency of the system. The operating frequency of the system is equal to the frequency of the transmitted signal generated by the oscillator 8.

The tuning of the resonance frequency to the operating frequency of the system can be realized by magnetizing a core (not shown) of the regulable coil 22. As a result of the magnetization, the permeability of the core changes and thereby the value of the self-induction changes accordingly. Thus, by varying the magnetization, the self-induction of the coil 22 can be controlled.

This principle can be used advantageously when it is desired to implement an automatic tuning of the coil 22.

Fig. 3 shows an embodiment of such a system. In Figs. 2 and 3, corresponding parts have been provided with the same reference characters. Compared with the system of Fig. 2, the system of Fig. 3 further comprises a phase comparator circuit 23. The phase comparator circuit 23 drives a regulable DC voltage source 25. The phase comparator circuit 23 is of a type known per se and will not be explained in detail here. The DC voltage source 25 generates a direct current I1 in an auxiliary coil 26 which thus generates a static magnetic field in the core of the coil 22, as described hereinbefore. By means of the direct current I1, a premagnetization of the core (not shown) of the coil 22 is realized, which accordingly enables variation of the permeability of the coil core and hence the self-induction of the coil 22. The system further comprises a voltage and current detector 28 by means of which the phase of the current and the phase of the voltage of the transmitted signal which is applied to the transformer 4 can be determined. The phase of the voltage of the transmitted signal can be determined by means which are known per se, such as, for instance, a voltage detector 30. Similarly, the phase of the current of the transmitted signal can be determined with means known per se, such as, for instance, a current detector 32. The phases determined by the voltage and current detectors 30, 32 are applied to the phase comparator circuit 23. The phase comparator circuit 23 compares the phase of the current and voltage referred to and controls the direct current I1 in such a manner that any phase difference between current and voltage no longer exists. In that case the resonance circuit 6, 16, 14 will resonate. Thus, a control loop is provided which is built up from the phase comparator circuit 23, the regulable DC voltage source 25, the tuning element 16, the transformer 4 and the voltage and current detector 28.

It holds for resonance not only that the current and voltage referred to are in phase, but also that the two are at a maximum.

By virtue of this property, an alternative embodiment of a detection system can be realized, as is shown in Fig. 4. Fig. 4 substantially corresponds with Fig. 3, the difference being that the phase comparator 23 of Fig. 3 has been replaced with an amplitude comparator circuit 34. The amplitude comparator circuit 34 is of a generally known type and will therefore not be explained in detail here. The amplitude comparator circuit 34 determines the difference in amplitude between the above-mentioned voltage and current of the transmitted signal applied to the primary side of the transformer 4. The amplitude comparator circuit 34 controls the DC voltage source 25 in such a manner that a current I1 is generated with the above-mentioned amplitudes being at a maximum. In this case, too, the resonance circuit will resonate, i.e. the resonance frequency is controlled in such a manner that it corresponds with the above-mentioned operating frequency of the transmitter and receiver device 2. Fig. 4 thus comprises a control loop made up of the regulable DC voltage source 25, the tuning element 16, the transformer 4, the voltage and current detector 28 and the amplitude comparator circuit 34.

Antenna systems having only one winding are often of very large design. As a consequence, the magnetic coupling between two of such antennas associated with different transmitter and receiver devices is not always negligibly small by any means, see also Fig. 5. In Fig. 5 the coupling M between a first antenna element 6 and a second antenna element 6' is symbolized by a curved arrow. The antenna element 6 can be connected with a detection system such as shown, for instance, in Figs. 1, 2, 3 and 4. The second antenna element 6' can also be connected with a detection system as shown, for instance, in any one of Figs. 1, 2, 3 or 4. Preferably, the antenna elements 6, 6' are each coupled with a detection system according to Fig. 2, 3 or 4. The so obtained combination of detection systems can in turn be regarded as one detection system.

If the first and second antenna element 6, 6' are arranged in mutual proximity, there will typically arise cross talk of signals from one antenna to the other and vice versa. If this remains limited to just the transmitted signal, this is not a major problem. Because the difference in frequency of, on the one hand, the transmitter and receiver device 2 which is coupled with the first antenna element 6 and, on the other, the transmitter and receiver device 2' which is coupled with the second antenna element 6', is typically small, there arise beats of a very low frequency which is equal to the above-mentioned frequency difference. In the transmitter and receiver devices 2, 2', these beats can be simply filtered from the received signal. Detection signals of labels are also transmitted via this undesired coupling. For instance, a label which is activated in the field of the first antenna element 6 will generate a signal in the second antenna element 6'. The signal generated by the label in the second antenna element 6' is relatively weak. However, because of the magnetic coupling M between the antennas 6 and 6', yet a signal is transmitted indirectly and the label may be detected in the wrong place, i.e. in the wrong transmitter and receiver device 2'. To prevent such coupling, in accordance with the invention a transformer 36 with a regulable inductive coupling is connected to the antenna elements 6, 6'. The transformer 36 is connected with a phase such that upon proper adjustment the coupling M which is present between the first and second antenna elements 6, 6' is precisely compensated.

A practical embodiment of the regulable transformer 34 is shown in Fig. 6. The transformer 34 consists of two pot core halves 38, 40 which are mounted on a shaft 42 for relative sliding movement. Sliding the pot core halves 38, 40 towards each other increases the inductive coupling between the two halves. Conversely, when the distance between the pot core halves 38 and 40 is increased by sliding these halves over the shaft away from each other, the magnetic coupling between the two halves 38, 40 is reduced.

Claims

1. An electromagnetic detection system comprising a transmitter and receiver device, a transformer having a primary side which is connected with the transmitter and receiver device, at least one antenna element which is connected with a secondary side of the transformer for generating an electromagnetic interrogation field in a detection zone and at least one responder adapted to radiate a detection signal under the influence of the interrogation field, the antenna element consisting of a current loop having only one winding, characterized in that the system further comprises a tuning element which is connected with the secondary side of the transformer and with the antenna element, so that on the secondary side of the transformer a resonance circuit is formed having a resonance frequency which corresponds with the operating frequency of the transmitter and receiver device.

2. An electromagnetic detection system according to claim 1, characterized in that the tuning element comprises a coil with a regulable self-induction for tuning the resonance frequency to the operating frequency.

3. An electromagnetic detection system according to claim 2, characterized in that the coil and the antenna element are connected in series.

4. An electromagnetic detection system according to claim 2 or 3, characterized in that the tuning element further comprises a capacitance.

5. An electromagnetic detection system according to claim 4, characterized in that the capacitance and the antenna element are connected in series.

6. An electromagnetic detection system according to claim 2, characterized in that the coil comprises a magnetizable core material, the system further comprising a regulable DC voltage source which generates a direct current for magnetizing the core material and thus controlling the self-induction of the coil.

7. An electromagnetic detection system according to claim 6, characterized in that the DC voltage source is part of a control loop in which the DC voltage source is controlled in such a manner that a current and an associated voltage in the resonance circuit have the

same phase.

8. An electromagnetic detection system according to claim 7, characterized in that the DC voltage source is controlled in such a manner that the current and the voltage of a transmitted signal applied to a primary side of the transformer by the transmitter and receiver unit have the same phase.

9. An electromagnetic detection system according to claim 6, characterized in that the DC voltage source is part of a control loop in which the DC voltage source is controlled in such a manner that a current and an associated voltage in the resonance circuit are at a maximum.

10. An electromagnetic detection system according to claim 7, characterized in that the DC voltage source is controlled in such a manner that the current and the voltage of a transmitted signal applied to a primary side of the transformer by the transmitter and receiver unit are at a maximum.

11. An electromagnetic detection system according to any one of the preceding claims, characterized in that the regulable coil and the transformer are part of one and the same component.

12. An electromagnetic detection system according to any one of the preceding claims, characterized in that the system further comprises a second transmitter and receiver device, a second antenna element coupled thereto, which comprises a current loop having one winding and a regulable coupling transformer with a first and a second side, windings of the first side being connected in parallel to the current loop of the first-mentioned antenna element and windings of the second side being connected in parallel to the current loop of the second antenna element.

13. An electromagnetic detection system according to claim 11, characterized in that the coupling between the windings of the first and second side, respectively, of the second transformer is adjusted in such a manner that the magnetic coupling between the first-mentioned antenna element and the second antenna element is compensated.

14. An electromagnetic detection system comprising a first and a second transmitter and receiver device which are respectively connected via a first and a second transformer with a first and a second antenna element for generating electromagnetic interrogation fields in at least one detection zone and at least one responder adapted to radiate a detection signal under the influence of an interrogation field, the antenna elements each consisting of a current loop having only one winding, characterized in that the system further comprises a regulable coupling transformer having a first and a second side, windings of the first side being connected in parallel with the current loop of the first antenna element and windings of the second side being connected in parallel with the current loop of the second antenna element.

15. An electromagnetic detection system according to claim 14, characterized in that the coupling between the windings of the first and second sides, respectively, of the second transformer is adjusted in such a manner that the magnetic coupling between the first antenna element and the second antenna element is compensated.

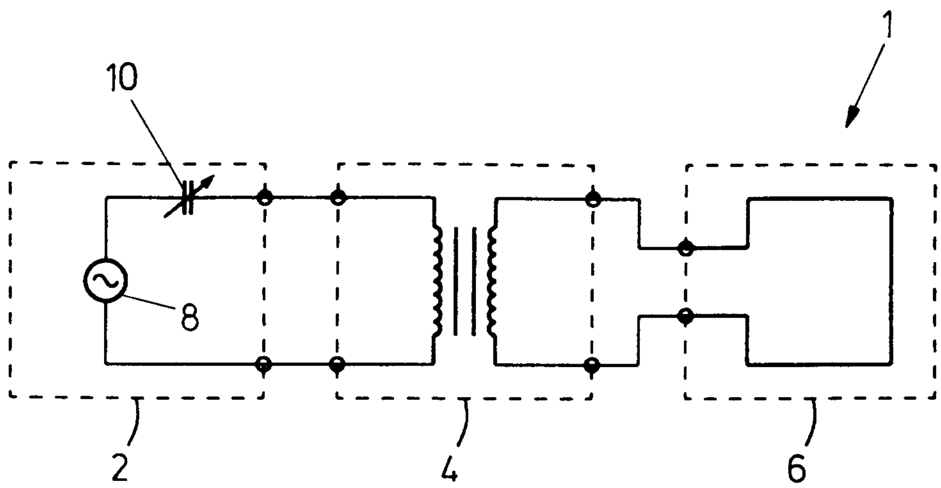

FIG. 1

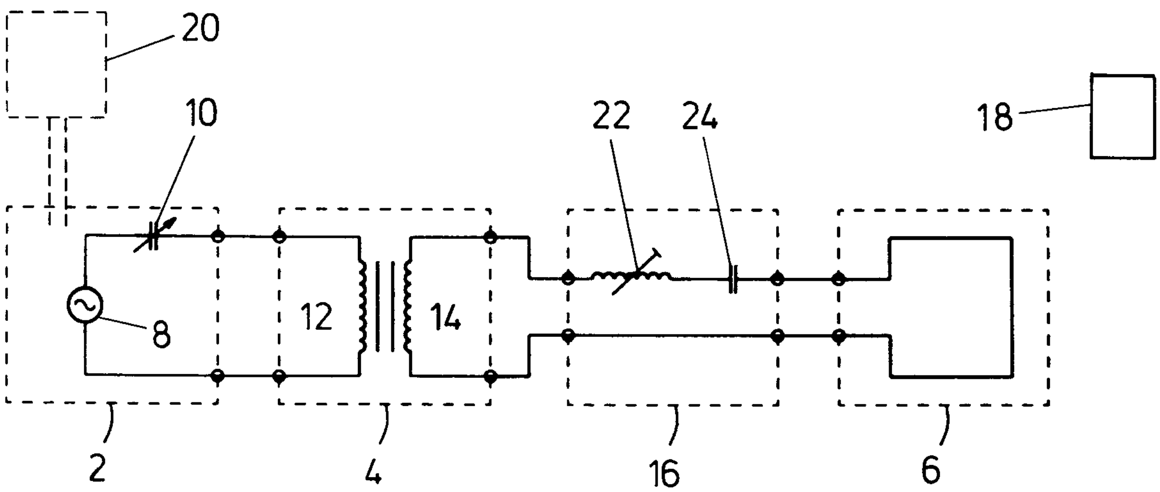

FIG. 2

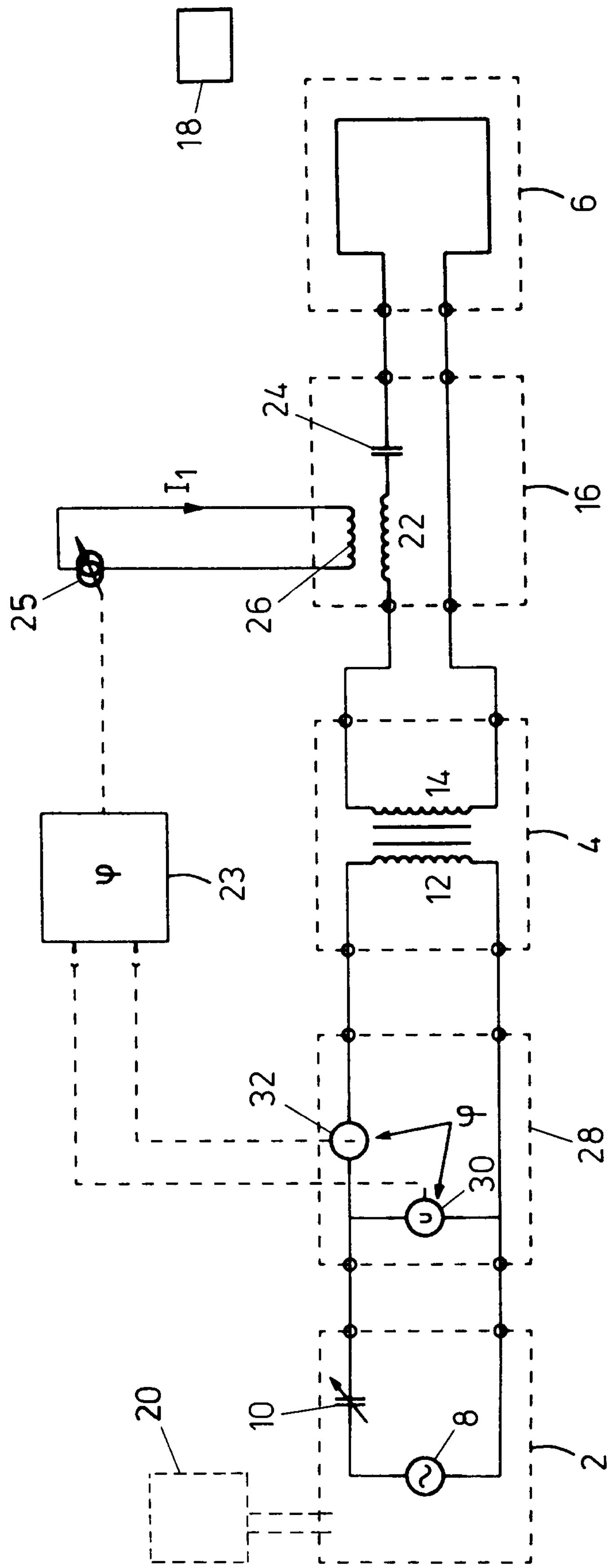

FIG. 3

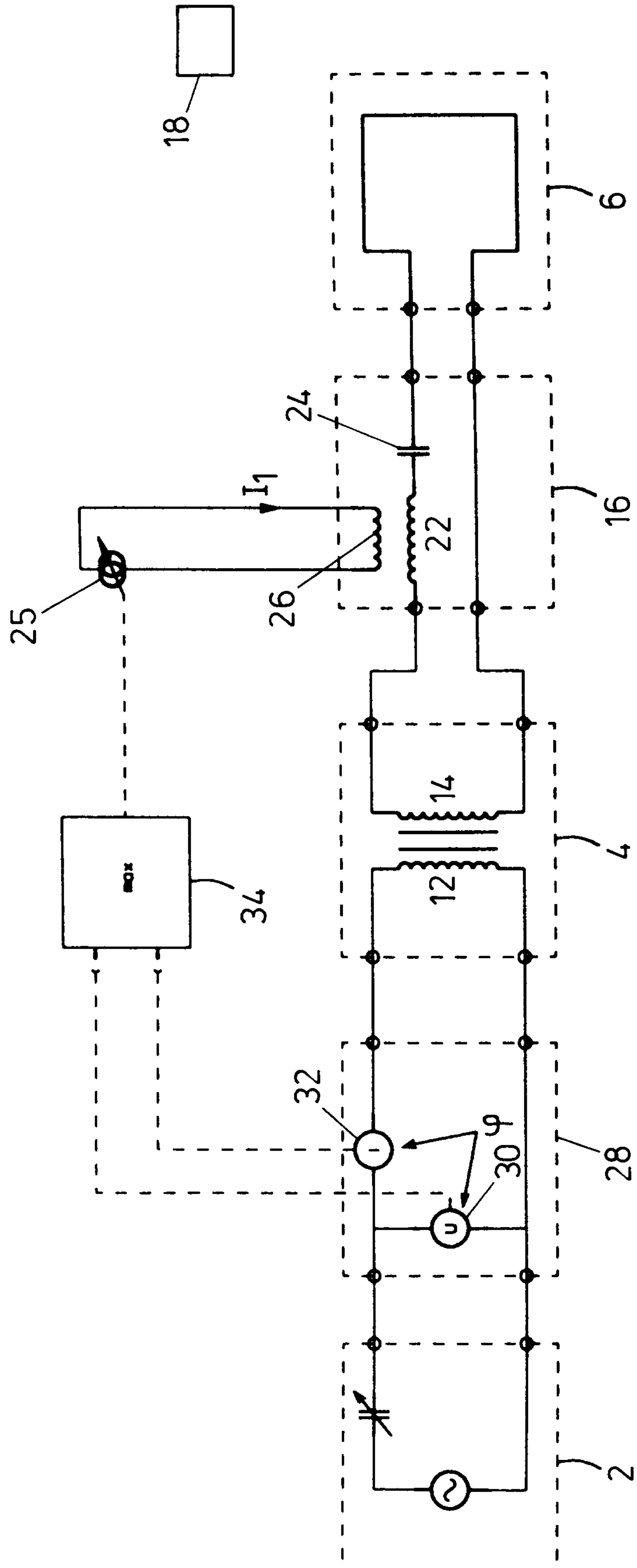

FIG. 4

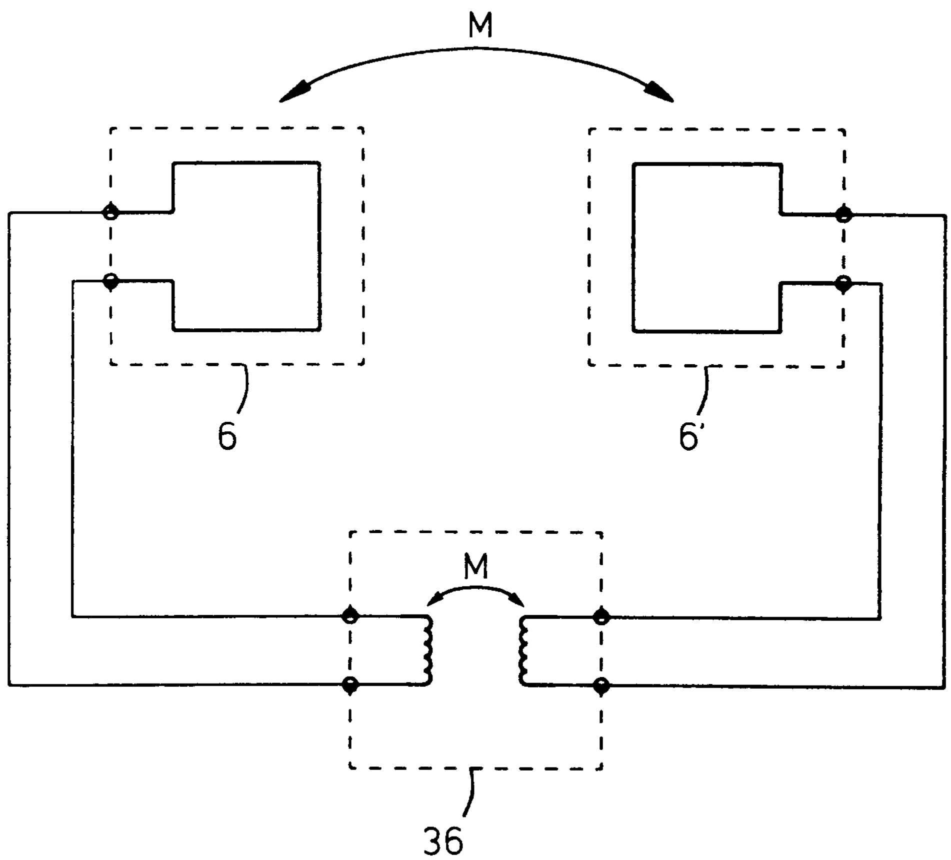

FIG. 5

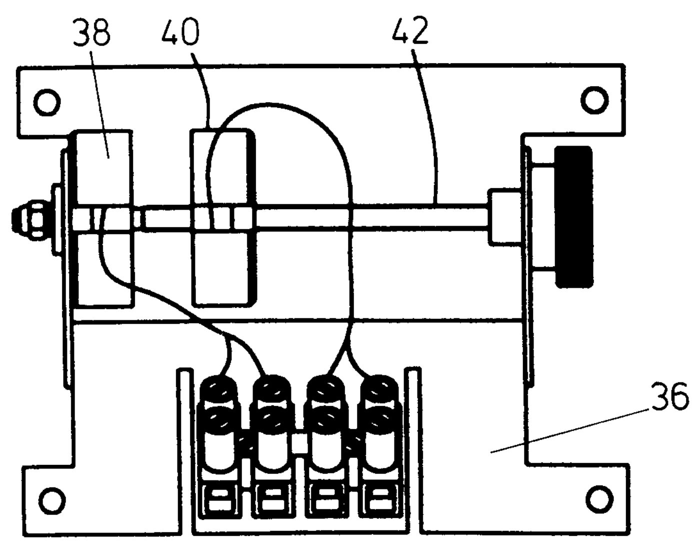

FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 20 2552

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	CH-A-667 955 (SVÄTOPLUK) * page 2; figures 1-8 * ---	1-5	H01Q7/00
D,Y	EP-A-0 331 269 (N.V.NEDERLANDSCHE APPARATENFABRIEK NEDAP) * claims 1-10; figure 1 * ---	1-5	
A	IEE PROCEEDINGS H. MICROWAVES, ANTENNAS & PROPAGATION, vol.140, no.2, April 1993, STEVENAGE GB pages 129 - 134 BARR ET AL. 'ELF,VLF and LF radiation from a very large loop antenna with a mountain core' * page 130, paragraph 3 4 - page 131; figure 3 * ---	1-5	
A	DE-A-31 12 033 (SIEMENS) * page 8, line 28 - page 10, line 6; figure 2 * ---	1-15	
A	US-A-5 225 847 (ROBERTS ET AL.) * abstract; figure 1 * -----	1-15	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01Q G01S G01V A01K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 November 1994	Angrabeit, F

CATEGORY OF CITED DOCUMENTS

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