

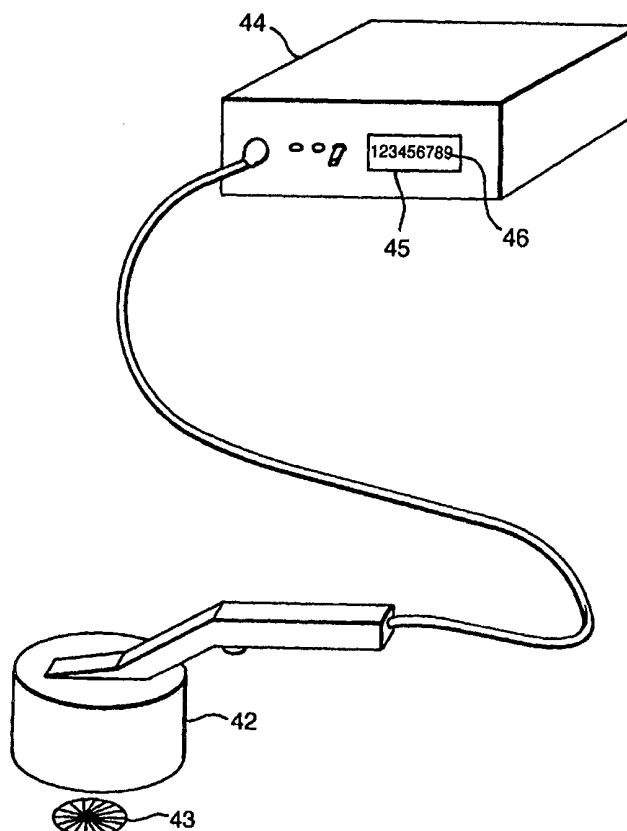


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/GB99/02546 <b>(22) International Filing Date:</b> 3 August 1999 (03.08.99) <b>(30) Priority Data:</b> 9816969.1      4 August 1998 (04.08.98)      GB <b>(71) Applicant (for all designated States except US):</b> FLYING NULL LIMITED [GB/GB]; Harston Mill, Harston, Cambridgeshire CB2 5NH (GB). <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> MATTHEWSON, Peter [GB/GB]; 28 Johnson Road, Great Baddow, Chelmsford, Essex CM2 7SL (GB). <b>(74) Agent:</b> ABRAMS, Michael, John; Haseltine Lake & Co., Imperial House, 15-19 Kingsway, London WC2B 6UD (GB).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>

**(54) Title:** MAGNETIC TAGS AND READERS THEREFOR**(57) Abstract**

The present application describes methods for storing information within a magnetic medium, which involves depositing a plurality of magnetically detectable strips onto the surface of a generally planar substrate, such that the mutual angular arrangement of the longitudinal axes of the strips represents a coded sequence. An interrogation system for use in decoding such a tag is also described, involving the use of a single frequency rotating magnetic field, which comprises regions of zero magnetic field contiguous with a high saturating field. A decoding algorithm incorporated within the interrogation system allows corrections to be made for systematic errors including the effects of the earth's magnetic field.



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MAGNETIC TAGS AND READERS THEREFOR

In previous patent applications, in particular  
PCT/GB96/00823 (WO96/31790), PCT/GB96/00367  
5 (WO97/04338) and PCT/GB97/03389 (WO98/26312), we have  
described and claimed novel techniques for spatial  
magnetic interrogation and novel magnetic tags. The  
technology described in WO96/31790 is based on  
exploiting the behaviour of magnetic materials as they  
10 pass through a region of space containing a magnetic  
null. The disclosures of each of these published  
applications is incorporated herein by reference  
thereto. In particular, these earlier applications  
describe, inter alia, how passive tags containing one  
15 or more magnetic elements can perform as  
remotely-readable data carriers, the number and spatial  
arrangement of the elements representing information.

In the above applications we described a number of  
20 possible system embodiments employing either permanent  
magnets or electromagnets to create the magnetic null.  
We also described several system implementations some  
of which are particularly appropriate for tags  
employing very low coercivity, high permeability  
25 magnetic elements. These implementations work by  
detecting harmonics of a superimposed low-amplitude  
alternating interrogation field.

In a later application PCT/GB97/01662  
30 (WO97/48990), the disclosure of which is incorporated  
herein by reference thereto, we described arrangements  
which work by detecting the baseband signals generated  
by the passage of the tag through the magnetic null,  
without the need for any superimposed alternating  
35 interrogation field. A specific design for a reader in  
the form of a narrow slot is also described. In

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PCT/GB98/02479, the disclosure of which is incorporated herein by reference thereto, we described a system employing a rotating null plane to determine the angular position of a remote anisotropic magnetic element.

The present application relates to certain types of magnetic tag and tag readers which are expected to find use in detection/interrogation systems of the type described in the earlier patent applications mentioned above, but also in other systems.

Before describing the present invention, it will be helpful to explain some of the fundamental aspects upon which such a detection/interrogation system will rely.

An essential aspect of the detection/interrogation system utilised in the present invention, is the interaction between one, or a plurality, of magnetically active elements, and the magnetic field which they are subjected to. As is well defined in the afore mentioned earlier applications, particular use can be made of magnetic fields which contain a "magnetic null". This term is used herein to mean a point, line, plane or volume in space at or within which the component of the magnetic field in a given linear direction is zero.

In particular, the invention exploits the difference between the magnetic behaviour of a magnetically active element when subjected to (i) the magnetic null and (ii) a high, saturating magnetic field. The change in the magnetic behaviour alters the local magnetic field pattern and therefore allows a relationship to exist between the changing magnetic

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field and the geometric arrangement of the magnetic elements on or within the tag.

5 The present invention provides a method of storing information on a magnetic tag. Said magnetic tag utilises a plurality of magnetically detectable strips attached thereto the geometrical arrangement of which provides a code relating to the information being stored.

10

In order to read data from such a magnetic tag, a single-frequency, rotating magnetic field, may be used to scan the tag. The magnetic field is generated such that it comprises a region of zero magnetic field (a magnetic null) contiguous with regions where the magnetic field is sufficient to saturate the magnetic strips of the tag. As the magnetic field rotates, the regions of zero magnetic field may be instantaneously aligned with the axis of a given strip element. When the magnetic strips are subjected firstly to a zero field and then to a high, saturating field, the direction of magnetic saturation in the strip element switches direction, thereby altering the local magnetic field.

25

The use of a single frequency excitation signal to generate an interrogation field is preferable since the magnetic response of the element to such a single frequency signal is easy to process. A multiple frequency excitation signal may also be used, however this would generate complex harmonic and intermodulation products, which would generally require more sophisticated receive processing. Furthermore, a single frequency excitation signal is easier to produce since tuned circuit passive resonant filters effectively reduce the out-of-band components of the

35

signal.

According to one aspect of the present invention there is provided a system for use in coding,  
5 identifying or locating articles, comprising:

(i) a magnetically coded tag having a plurality of strips of magnetically detectable material, the strips being positioned on the tag such that there exists a predetermined angular arrangement between the  
10 longitudinal axes of said strips;

(ii) means for interrogating said magnetically coded tag including a magnetic field generating means and a magnetic field detecting means,

(iii) signal processing means for converting the  
15 output of said magnetic field detecting means to one or more parameters which correspond(s) to the information stored on said tag.

According to a second aspect of the present  
20 invention, there is provided apparatus for interrogating a magnetically coded tag comprising: (i) means for generating a single frequency rotating magnetic field; (ii) means for detecting a magnetic field and (iii) signal processing means for converting  
25 the output of said magnetic field detecting means to one or more parameters which correspond(s) to the information stored on said tag.

Preferably, the means for generating a single-  
30 frequency rotating magnetic field, comprises a pair of mutually orthogonal transmit solenoids, formed from a plurality of wire turns, said wire turns arranged so as to form a plurality of layers. An AC input signal is fed to each of the transmit solenoids, preferably via  
35 an amplification means and an antenna matching network which allows the signals to be driven at plus and minus

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45 degree offsets, so that the load fed to the amplifier is predominantly resistive.

5 Preferably, the signal processing means is arranged to decode the information stored in the label and to display and/or store the decoded information for immediate or for future use.

10 The electronics of the currently preferred interrogation system is battery powered and uses a digital signal processor, together with an electronics module containing amplification and high-speed analog to digital conversion for the receive channels. Software incorporated into the electronics module  
15 advantageously provides means of synthesising a calibration pattern, which relates to the transmitted field, in order to allow signals received directly from the transmitter coils to be calibrated out.

20 Furthermore, the final decoded label signature may then be conveniently displayed on a LCD screen, preferably together with audible and visual confirmation of a valid readout.

25 According to another aspect of the present invention, there is provided a method of storing information in a magnetic medium, which comprises depositing onto a generally planar substrate a plurality of strips of a magnetically detectable  
30 material, the strips being positioned on the surface of the substrate such that there exists a predetermined angular arrangement between the longitudinal axes of said strips.

35 Preferably, the number of strips employed and the series of angular gaps between adjacent strips

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represents the information which is to be stored.

5 The magnetic material is a soft magnetic material having anisotropic magnetic properties such that each strip has an easy axis of magnetisation along its length.

10 The magnetic strips may advantageously be affixed (e.g. adhesively) onto a generally planar substrate (which may, for example, conveniently be square or rectangular) such that their longitudinal axes are coincident at a given location on the surface of the substrate, and so as to be positioned in a predetermined mutual angular arrangement (rather in the manner of irregularly placed spokes of a wheel).

20 The pieces of strip material are preferably positioned on a grid of angle positions, the positioning and the number of strips determining the encoded data, e.g. label number. It is not necessary to have a specific end stop element in such a coding scheme; the unique sequence of angular gaps between the longitudinal axes of adjacent elements provides sufficient and unambiguous coding.

25 For a better understanding of the invention, an example of a detection/interrogation system according to the present invention will now be described, with reference to the accompanying drawings, in which:

30 Figure 1a illustrates a magnetic tag according to one embodiment of the present invention;

35 Figure 1b illustrates a magnetic tag according to a second embodiment of the present invention;



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Figure 2a illustrates the two orthogonal transmit solenoids used to generate a rotating magnetic field;

5 Figure 2b shows the arrangement of the two orthogonal receive solenoids surrounding the transmit solenoids;

10 Figure 3 shows a block diagram of the interrogation system;

Figure 4 illustrates a simple construction of a detection/interrogation system according to the present invention.

15 Figure 1a shows a magnetic tag 15 according to one embodiment of the present invention, in which a plurality of strips 10, formed of a soft magnetic material, are deposited on a generally planar substrate 11. The pieces of strip material are positioned on a  
20 grid of angle positions; the angular arrangement of the longitudinal axes of said strips 10 around point 14, and the number of strips deposited onto the substrate, provide a unique signature for the tag.

25 A second embodiment of a tag according to the present invention is shown in figure 1b, in which a plurality of strips 17, formed of a soft magnetic material, are deposited around the outer circumference of a substantially planar substrate 18. The angular  
30 arrangement between the longitudinal axes of the strips provides a code relating to the information being stored. .

35 In a particular example of a tag comprising a total of fourteen strips, each of which is 15mm long and 0.9 mm wide, the coded sequence determined as

follows. It should be understood that the dimensions of the strips and the specific angular arrangement of the strips is not accurately illustrated by the tags shown in figures 1a and 1b. The total angular separation between the strips comprises a minimum separation of eight degrees plus an incremental separation. Each incremental separation comprises zero to thirty four two degree units. The gaps may then be described in terms of the number of units of increments of separation rather than the total angular separation between the gaps. The following table illustrates the relation between the angular position of the strip and the unique sequence of incremental units.

15

20

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Strip number	Position (degrees)	No. of Incremental units
0	0	0
1	8	0
2	16	0
3	26	1
4	40	3
5	60	6
6	90	11
7	98	0
8	120	7
9	132	2
10	140	0
11	150	1
12	160	1
13	172	2

Preferably the sequence of incremental units is represented in a normalised form by writing the number of the highest incremental separation first. In this example the normalised sequence would be written:

5

11, 0, 7, 2, 0, 1, 1, 2, 0, 0, 0, 1, 3, 6

If two or more gaps have the same largest value of incremental separation, the gap with the largest adjacent incremental separation is used to determine the normalised sequence. This normalisation process allows the starting point of the tag signature to be unambiguously identified. The unique normalised sequence represents a coded form of the information which has been stored within the label. A decoding algorithm, which will be described more fully later on, is used to enumerate a decimal label code.

A magnetic tag of this embodiment may be read unambiguously from either side of the planar tag in the following way. The normalised sequence may be "reversed" and compared to the sequence which has only been normalised such that the two sequences would be:

Sequence 1: 11, 0, 7, 2, 0, 1, 1, 2, 0, 0, 0, 1, 3, 6  
Sequence 2: 11, 6, 3, 1, 0, 0, 0, 2, 1, 1, 0, 2, 7, 0

The second sequence is identified as the "higher" sequence since the second unit of the sequence, six, is higher than the second unit of the first sequence which is zero. The "higher" or "lower" sequence may then be chosen and used to enumerate a decimal label code that is the same irrespective of the orientation of the label. The dimensions and angles chosen for this example merely represent a specific working example and it should be understood, that although this embodiment

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of the invention utilises a planar tag which is shown to be substantially circular in shape, any other shape may conveniently be used.

5 Means may be taken to ensure that the highest angular gap is not repeated elsewhere. One such means involves incorporating a "checksum" strip 13 positioned between the fixed strips 12. Another method of identifying the starting point of the tag signature  
10 involves including one strip which is made from a different magnetic material, or is of different width or length, or exhibits any other feature which will allow that particular strip to be uniquely identified.

15 In order to de-code the magnetic tag 15, an interrogator is provided in which a pair of mutually orthogonal transmit coils 21, carrying an alternating current, are used to induce a rotating magnetic field,  
20 in the region surrounding said transmit coils.

Each transmit coil 21, comprises a solenoid wound on a rectangular former, having plurality of wire turns, said wire turns arranged so as to form a  
25 plurality of layers. In the specific embodiment illustrated in figure 2a, each solenoid consists of seven layers of sixty turns of enamelled copper wire. The reader will appreciate however, that the inductance of the coils is dependant upon a number of parameters  
30 including the number of turns, the diameter of the wire and the magnitude of the current flowing through the wire. Thus the values given in this description for the various parameters are given merely by way of example. The actual values of the parameters will vary according  
35 to the size of the system and its intended function.

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As shown in figure 2a, the transmit coils 21 are arranged such that the turns of one solenoid are wound over the top of the turns of the other with their winding directions at 90 degrees to each other.

5 Preferably, at the boundary between the two coils, the layers of wire turns are interleaved ensuring that the coils are as similar to each other magnetically as possible.

10 An AC input signal, having a frequency of 500Hz and an rms voltage of up to 0.707 volts, is generated by an analogue to digital converter incorporated within the DSP card 35. Said AC input signal is amplified and passed to an antenna matching network which passively  
15 splits the amplified signal into two quadrature channels. Each channel is driven slightly off resonance and at plus and minus 45-degree offsets, thereby cancelling out the reactive components. This has the effect that the net load presented to the power  
20 amplifier is predominantly resistive and therefore easy to drive.

The antenna arrangement described allows a rotating magnetic field to be induced. This rotating  
25 field, is used to scan the tag 15; the magnetic strips of which are formed of anisotropic material having an easy axis of magnetisation along their length. When the imposed magnetic field is orthogonal to a given strip element the direction of saturation of the magnetic  
30 field in the strip element changes thereby generating a change in the magnetic field pattern surrounding the tag.

Thus there exists a relationship between the  
35 change in magnetic field pattern, arising from changes in direction of the magnetic saturation in the strips,

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and the geometrical arrangement of the magnetic strips. This relationship allows the signature of the tag to be identified.

5           Figure 2b, shows a second pair of coils 25, positioned mutually orthogonally, so as to surround the transmit coils. The magnetic field generated by the transmit coils and by the change in saturation of the magnetic element induces a current to flow in the  
10           receive coils 25. Therefore a signal pattern representing the rotating transmit field plus the angular changes in saturation of the element is obtained. As will be described more fully later on, the signals induced in the receive coils may then be  
15           calibrated so that signals received directly from the transmitter coils to be calibrated out.

          As is illustrated by figure 3, the interrogator system comprises an antenna wand 31, connected to a  
20           electronics module 32, a Digital Signal Processing (DSP) card 35 and an LCD display 33 for displaying the results of the information read from the magnetic tag  
15.

25           The signals from each of the receive coils 25, are amplified and digitalised, separately and simultaneously and a wide analogue signal bandwidth is achieved. Digitalisation is preferably implemented using a high speed analogue to digital converter, which  
30           performs 192k samples per second at 16 bits precision, for each channel. The output of both channels may conveniently be multiplexed onto a single serial port and carried to the DSP processor 35.

35           A calibration pattern relating to the transmitted field may advantageously be synthesised

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from the output signals of the receiver channels.  
Software incorporated into the electronics module 32  
allows static breakthrough signals, which have come  
directly from the transmitter coils, to be calibrated  
5 out. Angular peaks in the signal may then be detected  
and various parameters, including amplitude, position  
angle, and width are readily measured. Using the  
variation in the measurement of peak width, corrections  
may be made for the effects of the earth's magnetic  
10 field and also for angular tilt and the displacement of  
the label from the centre line of the antenna assembly.

The electronics module 32 also provides a decoding  
algorithm for transforming the information represented  
15 by the measured peaks, into a unique decoded label  
signature. The decoding algorithm performs the  
following steps:

- i) A number of cycles of the rotating  
interrogation field are integrated in order to improve  
20 the signal to noise ratio;
- ii) The background pattern, which has been pre-  
recorded when there is no tag present, is subtracted  
from the receive signal;
- iii) A plot of the receive signal versus time is  
25 generated to allow an estimate of the angular position  
of the elements to be made;
- iv) A model of the errors of the actual  
interrogation field position based on harmonic  
components of the interrogation frequency is  
30 constructed from measurements of the peak widths, and  
from a prior knowledge of the estimated angular  
separations between adjacent elements. A least squares  
fit is used to estimate the parameters of the model.  
This allows the positional estimate to be corrected for  
35 the effects of the earth's magnetic field and other  
systematic errors in the measurements;

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v) The error corrected positional data is computed;

vi) The angular separation is rounded to the nearest possible angular position, for example into  
5 bins of 2 degree separation;

vii) The minimum angular separation is subtracted from the total angular separation and the remainder is then divided by the incremental unit to give a sequence of multiple incremental units;

10 viii) The sequence of incremental units is normalised; and

ix) The unique normalised sequence is converted to a linear decimal code.

15 The decoded signal is transmitted to the LCD 33, via an LCD driver interfaced to the DSP processor. The final decoded label signature is then displayed on the LCD screen, together with audible and visual confirmation of a valid readout.

20

Figure 4 shows a simple embodiment for such a system in which a hand held antenna wand 42, housing the transmit and receive coils, is held so as to subject tag 43 to the rotating magnetic field. The  
25 electronics module, DSP card and battery pack are all contained within an electronics box 44 which also features an LCD 45 for displaying the final decoded tag signature 46.

30 The reader should appreciate, however, that various constructional embodiments for the system may be implemented, including one in which the electronics module is housed within the antenna wand. The structural design depends on the size of the system and  
35 also on its intended function.



## CLAIMS

1. A system for use in coding, identifying or locating articles, comprising:

5 (i) a magnetically coded tag having a plurality of strips of magnetically detectable material, the strips being positioned on the tag such that there exists a predetermined angular arrangement between the longitudinal axes of said strips;

10 (ii) means for interrogating said magnetically coded tag including a magnetic field generating means and a magnetic field detecting means,

(iii) signal processing means for converting the output of said magnetic field detecting means to one or more parameters which correspond(s) to the information stored on said tag.

2. Apparatus for interrogating a magnetically coded tag comprising: (i) means for generating a single frequency rotating magnetic field; (ii) means to receive a magnetic field and (iii) signal processing means for converting the output of said magnetic field receiving means to one or more parameters which correspond(s) to the information stored on said tag.

25

3. Apparatus as claimed in claims 1 or 2, in which said means for generating said single frequency rotating magnetic field comprises a pair of transmit solenoids.

30

4. Apparatus as claimed in claim 3, in which each of said transmit solenoids comprises a plurality of wire turns, said wire turns arranged so as to form a plurality of layers.

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5. Apparatus as claimed in the preceding claim, in which said transmit solenoids are arranged such that the turns of one solenoid are wound over the top of the turns of the other with their winding directions at 90 degrees to each other.

6. Apparatus as claimed in the preceding claim, in which said layers of wire turns, at the boundary between the two solenoids, are interleaved.

7. Apparatus as claimed in claims 1 and 3 to 6, in which said transmit solenoids are driven by an AC single-frequency input signal, which is passively split into two channels via an antenna matching network.

8. Apparatus as claimed in claim 7, in which said channels are driven at ninety degrees out of phase with each other, thereby causing the reactive components to be cancelled.

9. Apparatus as claimed in any preceding claim, in which said magnetic field detecting means comprises a pair of receive solenoids.

10. Apparatus as claimed in claims 3 and 9, in which said receive solenoids are positioned so as to surround said transmit solenoids.

11. Apparatus as claimed in claim 9 or 10, in which the outputs of said receive solenoids are multiplexed into a single serial port and carried to said signal processing means.

12. Apparatus as claimed in any preceding claim, in which said signal processing means comprises a Digital Signal Processing (DSP) card.

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13. Apparatus as claimed in claims 3, 9 and 12, in which said DSP card comprises means to process the output of said receive solenoids, such that signals received directly from the transmit solenoids, may be calibrated out.

14. Apparatus as claimed in any preceding claim, further comprising an LCD display for displaying the results of said signal processing means.

15. Apparatus as claimed in any preceding claim, further comprising means for generating an audible and/or visual confirmation of a valid readout.

16. A method of storing information in a magnetic medium, which comprises depositing onto a generally planar substrate a plurality of strips of a magnetically detectable material, the strips being positioned on the surface of the substrate such that there exists a predetermined angular arrangement between the longitudinal axes of said strips.

17. A method according to claim 16, wherein the number of strips employed and the series of angular gaps between adjacent strips is used to represent the information which is to be stored.

18. A method according to claim 16 or 17, in which said magnetic material is a soft magnetic material having anisotropic magnetic properties such that each strip has an easy axis of magnetisation along its length.

19. A method according to claims 16, 17 or 18, wherein two of the magnetic strips are arranged such that there exists a unique angular gap between them.

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20. A planar tag, having a plurality of strips of magnetically detectable material attached thereto, the geometric arrangement of which provides means of coding information.

5

21. A method according to claim 20, in which said magnetically detectable material is a soft magnetic material having anisotropic magnetic properties such that each strip has an easy axis of magnetisation along its length.

10

22. A tag according to claim 20 or 21, in which said magnetically detectable strips are positioned on the tag such that there exists a predetermined angular arrangement between the longitudinal axes of said strips.

15

23. A tag according to claim 20, 21 or 22, in which said magnetically detectable strips are positioned about a predetermined point.

20

24. A tag according to claims 22 or 23, wherein two of the magnetically detectable strips are arranged such that there exists a unique angular gap between them.

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30

35

Fig.1a.

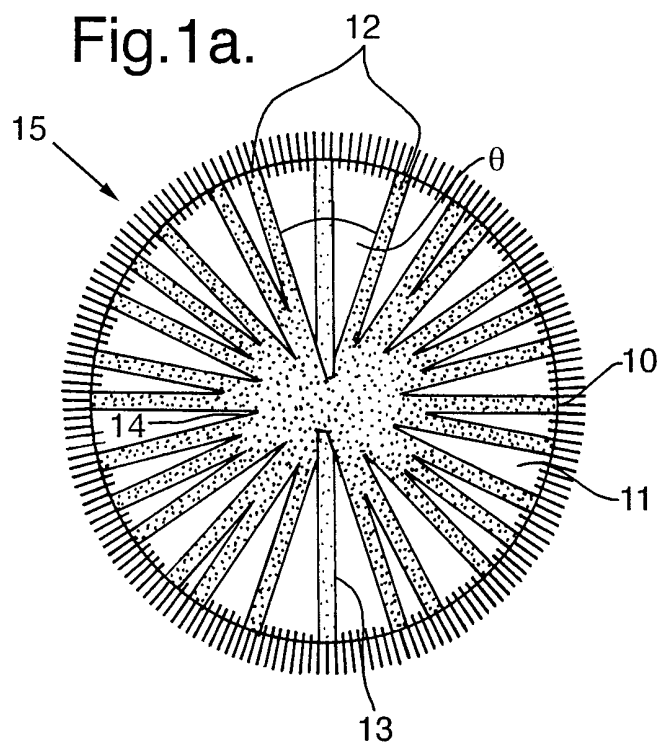
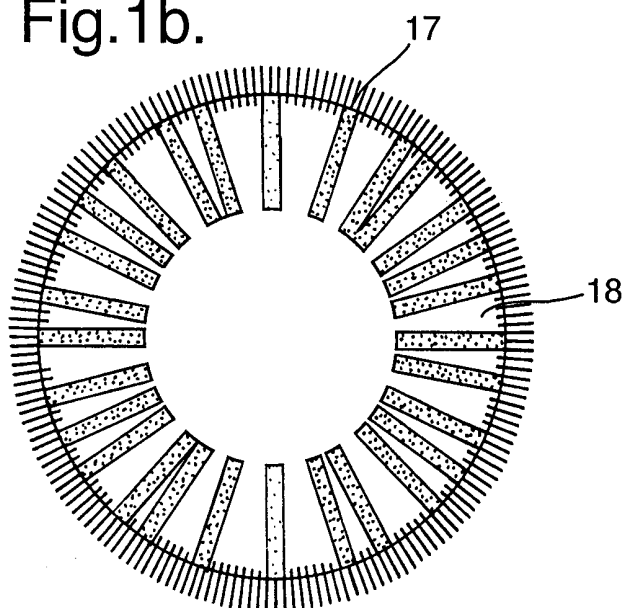
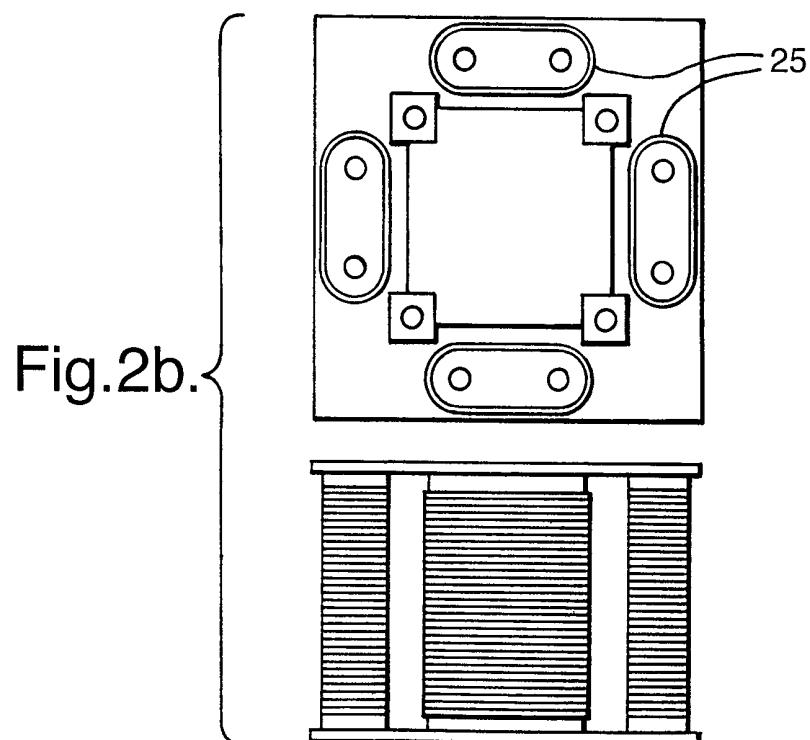
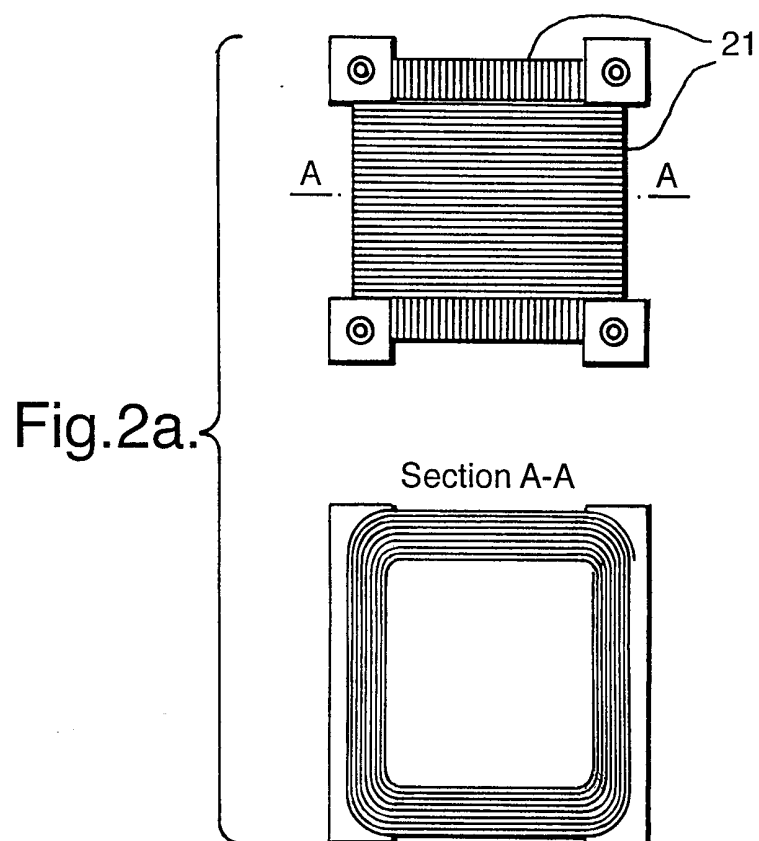


Fig.1b.



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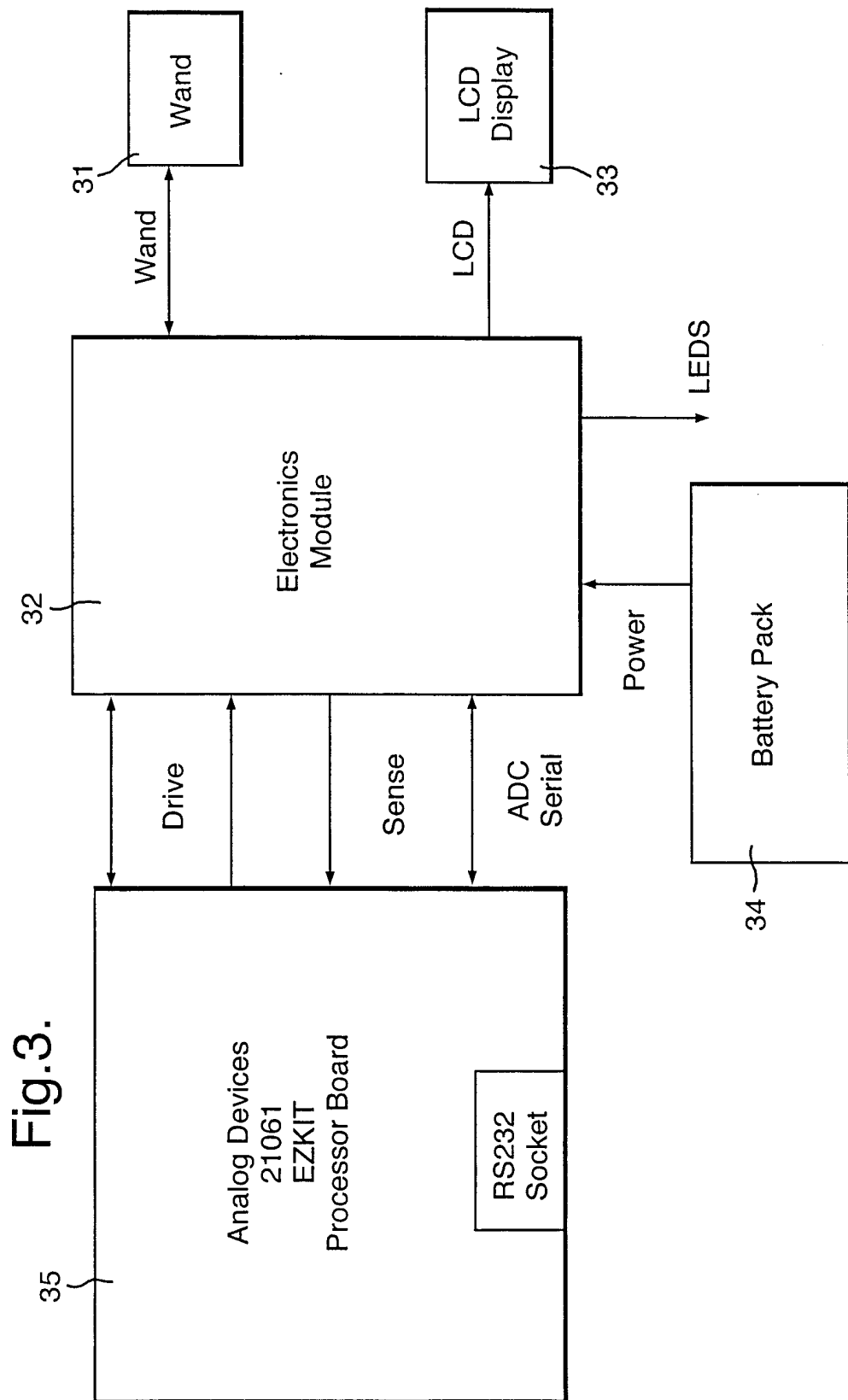
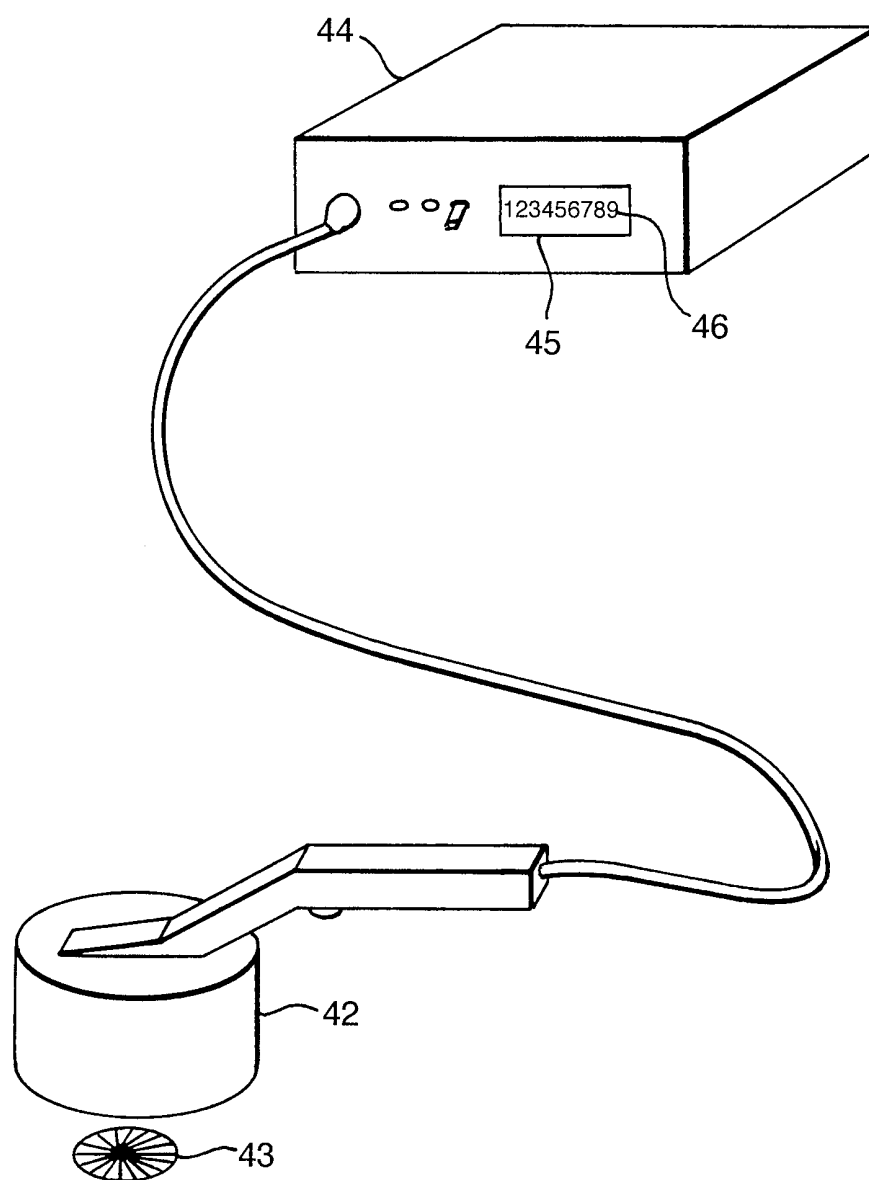


Fig.4.





## INTERNATIONAL SEARCH REPORT

International Application No

PC1/GB 99/02546

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01V3/10 G01V15/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01V G06K H01F

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 713 195 A (MINNESOTA MINING & MFG) 22 May 1996 (1996-05-22)	1-3, 14-24
Y	abstract; claims 1-7, 13-17; figures 1, 2, 4, 5	4, 5, 7, 8
A	the whole document	9-13
Y	US 3 932 827 A (BUHRER CARL F) 13 January 1976 (1976-01-13)	4, 5, 7, 8
A	abstract; figure 1 column 1, line 20 - line 40 column 3, line 56 - column 4, line 19 --- -/--	6

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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# INTERNATIONAL SEARCH REPORT

International Application No

PC1/GB 99/02546

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