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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 April 2013 (04.04.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/045430 A1

(51) International Patent Classification:
G01D 5/14 (2006.01) *G01D 5/244* (2006.01)

(21) International Application Number:
PCT/EP2012/068842

(22) International Filing Date:
25 September 2012 (25.09.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
102011115302.4 29 September 2011 (29.09.2011) DE

(71) Applicant: TYCO ELECTRONICS AMP GMBH [DE/DE]; Amperestrasse 12-14, 64625 Bensheim (DE).

(72) Inventor: SCHAAF, Oliver; Obere Hauptstrasse 128, Lustadt (DE).

(74) Agent: HEINZ-SCHAEFER, Marion; Tyco Electronics UK LTD, European Patent Department, Faraday Road, Dorcan, Swindon Wiltshire SN3 5HH (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: METHOD FOR CONTACTLESS MEASUREMENT OF A RELATIVE POSITION BY MEANS OF A HALL SENSOR

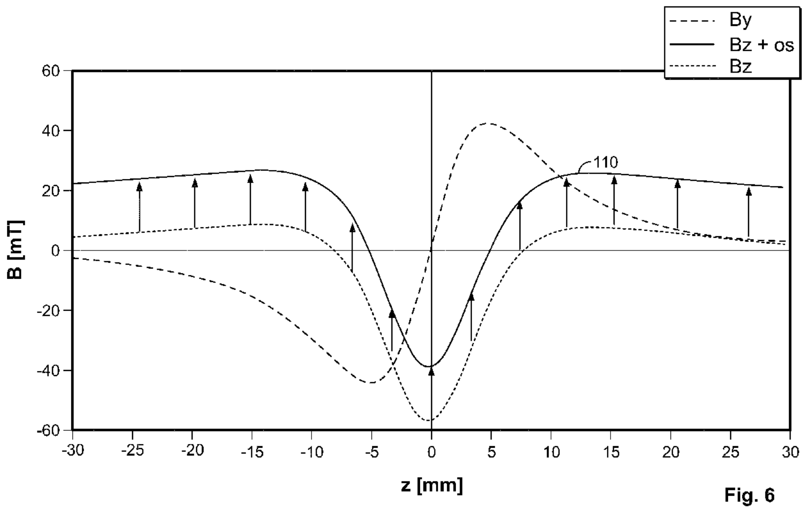


Fig. 6

(57) Abstract: The present invention relates to a method for contactless measurement of a relative position of a magnetic field source (102) which produces a magnetic field and a magnetic field sensor (100) in relation to each other. The present invention also further relates to a corresponding displacement sensor. According to the present invention, the magnetic field sensor (100) detects at least two spatial components (Bz, By) of the magnetic field and a position signal is produced from the measured components. The method comprises the following steps: calculating the position signal based on a quotient of the two magnetic field components; correcting, before the quotient is calculated, the magnetic field component which extends in a movement direction between the magnetic field source (102) and the magnetic field sensor (100).

WO 2013/045430 A1

METHOD FOR CONTACTLESS MEASUREMENT OF A RELATIVE POSITION BY MEANS OF A HALL SENSOR

The present invention relates to a method for contactless measurement of a relative position of a magnetic field source which produces a magnetic field and a magnetic field sensor in relation to each other. Furthermore, the present invention also relates to a corresponding displacement sensor.

In particular, linear movements are intended to be detected and evaluated by means of the method according to the invention in a contactless manner by means of magnetic interaction between one or more permanent magnets and a magnetic sensor based on the Hall effect.

The measurement of linear movements is used, for example, for controlling machine tools, in pneumatics, in automation technology and robotics as well as in the automotive sector. Contactless detection of movements affords inter alia the advantage of freedom from wear. Among the contactless measuring methods, optical and magnetic methods are most widespread. Whereas the optical methods ensure a very high level of precision owing to the short wavelength of the light, magnetic methods are far less sensitive with respect to contamination and damage, in particular in that magnets and sensor components can be completely enclosed in a non-magnetic hermetic casing.

Displacement sensor systems in which the position of a displaceable permanent magnet is established by means of a two-dimensional or three-dimensional Hall sensor are marketed by various manufacturers.

In order to detect the relative linear movements at a location, two magnetic field components which are perpendicular to each other are measured and their quotient is evaluated in order to determine the position. This method has the advantage that, in regions in which a field component takes up an extreme value and therefore does not detect small displacements, the other field component reacts all the more strongly to displacements so that an approximately identically high level of measurement precision is provided over the entire measurement range.

Furthermore, this principle has the advantage that it is comparatively not very sensitive with respect to a change in the absolute magnetic field strength because proportional numbers between the field components are used to detect the position.

European patent specification EP0979988 B1 discloses measurement methods for contactless magnetic detection of relative linear movements between permanent magnets and electronic sensors. In order to detect the relative linear movements by means of the electronic sensors, two mutually perpendicular field components whose quotient is evaluated to establish the position are detected.

In a second method variant, the known measurement method can also be carried out so that two mutually perpendicular field components whose quotient is evaluated to establish the position are detected at two locations in order to detect the relative linear movements by means of the electronic sensors.

The published European patent application EP2159546 A2 discloses a measurement method for contactless detection of relative linear movements between a sensor arrangement for detecting two mutually perpendicular magnetic field components (R, A) and a permanent magnet. A two-dimensional or three-dimensional Hall sensor is used in place of individual sensors in order to detect different field components. The quasi-linear position measurement line is formed by the function U = y-e+g, where y is the functional relationship of the field components and e and g are predeterminable voltage values. In particular, a quasi-linear position measurement line U = f(y) is formed from the output signals of the Hall sensor according to the relationship $y = a + b \cdot R / f(c \cdot R^n + d \cdot A^n)$, where R is the radial field component, A is the axial field component, U is the measurement voltage and a, b, c, d and n are constant factors.

The published European patent application EP1243897 A1 relates to a magnetic displacement sensor which comprises a magnetic field source and a magnetic field sensor which can be displaced relative to each other along a predetermined path. The magnetic field sensor measures two components of the magnetic field produced by the magnetic field source. A position signal which represents the relative position of the magnetic field sensor and the magnetic field source is then derived from the measured components. The configurations of the displacement sensor shown in this specification are distinguished in that the determination of the position signal contains a division of the two measured components of the magnetic field.

However, those known methods have the disadvantage that the spacing between the permanent magnet and the magnetic sensor constitutes a significant error source in the measurement. It is often very difficult to keep that spacing constant, particularly owing to assembly tolerances, thermally induced material expansion and vibration influences.

Figure 1 shows an arrangement in which a Hall sensor 100 is fitted so as to be fixed in position in order to contactlessly detect a linear movement and detects the magnetic field of a movable permanent magnet 102. In accordance with the north/south polarisation in the direction of movement of the permanent magnet 102, the magnetic field extending in the direction of movement is referred to below as the magnetic field component Bz and the component extending transversely thereto is referred to as the component By. The angle α, which can be calculated in accordance with the following equation (1) is generally used as the measurement signal.

$$\alpha = \arctan\left(\frac{Bz}{By}\right) \qquad (1)$$

As illustrated in Figure 2, the angle α is dependent in a comparatively linear manner on the position of the permanent magnet 102 in relation to the Hall sensor 100 up to a given threshold value. Usually, the characteristic line currently being measured is further linearised, as illustrated in Figure 2 by means of the line 104. That linearised line α_lin 104 then forms the characteristic output line of the sensor.

With reference to Figures 3 and 4, the dependence of the output signal on the spacing d between the permanent magnet 102 and the sensor 100 is explained in greater detail (see Figure 1).

In Figure 3, the groups of lines for the magnetic field components By and Bz are indicated with different spacings b as parameters. The line having the smallest magnetic field in terms of value is the one having the greatest spacing (in this instance, 7 mm), respectively. If the angle is calculated from those field components by means of its dependence on the position of the permanent magnet, the path illustrated in Figure 4 is obtained. In order to illustrate how great the gradient error is, the characteristic lines are subtracted one from the other and the percentage error is set out. The dependence illustrated in Figure 5 is produced as a result.

The line 106 represents the error between the lines for a spacing of 7 mm and the line for a spacing of 6.5 mm, whilst the line 108 represents the difference between the angle α for a spacing of 6.5 mm and the angle for a spacing of 5.5 mm. That is to say, a spacing variation of 1 mm results in a deviation of 1.6% and a spacing variation of 1.5 mm results in a deviation of 2.3%.

However, this is not acceptable for very sensitive systems such as, for example, an assisted steering system or a pedal travel measurement in a motor vehicle, so that there is a need for an improved signal processing operation which is less sensitive with respect to an undesirable variation of the spacing between the permanent magnet and the Hall sensor element.

An object of the present invention is to improve a measurement method and a displacement sensor of the type mentioned so that as linear a measurement signal as possible is produced over as wide a measurement range as possible and is influenced as little as possible by variations in spacing between the magnetic field source and the magnetic field sensor.

This object is achieved by the subject-matter of the independent patent claims. The dependent claims relate to advantageous developments of the method and displacement sensor according to the invention.

The present invention is based on the notion of not using the value for the field component in the movement direction directly in the arc tangent calculation, but instead to expand this term by a correction value. That offset value results in gradient adaptation of lines for the angle α at different spacings d.

Since this is a comparatively simple calculation operation, it is possible to improve the precision of a displacement sensor in accordance with the generic type in an extremely simple manner.

For a better understanding of the present invention, it is explained in greater detail with reference to the embodiments illustrated in the following Figures. Identical components are indicated with identical reference numerals and identical component designations.

Furthermore, individual features or combinations of features from the embodiments shown and described may also constitute independent inventive solutions or solutions according to the invention separately.

In the drawings:
Figure 1 shows a displacement sensor whose signal can be evaluated according to the present invention;
Figure 2 shows the path of the magnetic field components produced in accordance with the position of the permanent magnet and the non-corrected angle α calculated therefrom;

Figure 3 shows the field components produced by the permanent magnet in the y direction and z direction in accordance with the spacing between the permanent magnet and the magnetic field sensor;
Figure 4 shows the angle α as a function of the position of the permanent magnet for different spacings d;
Figure 5 shows the relative error in accordance with the spacing between the permanent magnet and the magnetic field sensor;
Figure 6 shows the explanation of the calculation provisions for the correction according to the invention;
Figure 7 shows the path of the corrected angle α in accordance with the spacing between the permanent magnet and the magnetic field sensor;
Figure 8 shows the relative error in accordance with the position for different spacings;
Figure 9 shows the two lines from Figure 8 to an enlarged scale;
Figure 10 shows the path of the measured and corrected magnetic field components in accordance with the position;
Figure 11 shows the path of the magnetic field component which extends parallel with the change in position and the first derivative thereof;
Figure 12 shows a displacement sensor arrangement according to a second embodiment;
Figure 13 shows a displacement sensor arrangement according to a third embodiment;
Figure 14 shows a displacement sensor arrangement according to a fourth embodiment;
Figure 15 is an illustration of the characteristic lines for a variation in spacing between the magnet and the sensor for the conventional calculation provisions;
Figure 16 shows the path of the characteristic lines for the arrangement according to Figure 1 when the correction according to the invention is used.

The invention is intended to be explained in greater detail below initially with reference to Figure 6 and Figure 1.

A displacement sensor arrangement according to a first embodiment is shown in Figure 1. A Hall sensor 100 is mounted so as to be fixed in position and a permanent magnet 102 is supported so as to be linearly movable in relation to the Hall sensor 100. The permanent magnet 102 has such a pole configuration that its north/south axis is orientated parallel with the movement direction. In principle, however, it is also possible to use the principles of the present invention for arrangements in which the permanent magnet 102 has such a pole configuration that its north/south axis extends transversely relative to the movement direction. The permanent magnet 102 can be displaced out of the zero position shown in Figure 1 in two directions by, for example, approximately 25 mm. The Hall sensor 100 detects at least two orthogonal magnetic field components – one which extends along the movement line and one which extends transversely relative thereto. Vector addition of the two components provides the value of the magnetic field $|B|$. The angle α is defined as the angle which is enclosed by the total magnetic field vector $|B|$ with the line perpendicular to the direction of movement.

As already mentioned, the angle α is calculated from the magnetic field components in or transversely to the movement direction according to equation (1):

$$\alpha = \arctan\left(\frac{Bz}{By}\right) \qquad (1)$$

Naturally, it is also possible to transfer the principles according to the invention to other magnetic field sources, for example, electromagnets, and to other magnetic field sensors, such as magnetoresistive sensors or inductive sensors.

Figure 6 shows the measurement signals which are measured in accordance with the position of the permanent magnet 102 of the magnetic field sensor, in this instance a Hall sensor 100. These are, on the one hand, the values of the magnetic field in the movement direction Bz and, on the other hand, the values of the magnetic field transverse relative to the movement direction By. Naturally, it is also possible to use the values Bx which extend orthogonally to By for the calculation.

According to the invention, the arc tangent of the quotient Bz to By according to equation (1) is not used as the measurement signal but instead the magnetic field component Bz which extends in the movement direction is corrected by means of an offset value. That offset results in a gradient adaptation. The following equation (2) is produced for the calculation of the angle α:

$$\alpha\_OS = \arctan\left(\frac{Bz + OS}{By}\right) \qquad (2)$$

The corrected Bz + OS line is designated 110 in Figure 6.

If the line progression of the corrected angle α_OS is now considered in Figure 7 for different spacings d, it is evident that the progression of the line is substantially less dependent on a variation of the spacing d which is indicated here as a parameter for the group of lines.

This means that, on the one hand, assembly tolerances can be taken up with the solution according to the invention but, on the other hand, influences owing to vibrations can also be prevented.

The lines of Figures 8 and 9 show the corresponding relative errors of the angle α_OS for d = 7 mm in comparison with d = 6.5 mm (the line 118 indicates the relative error of α_OS_7.0 mm - α_OS_6.5 mm) and for d = 6.5 mm and d = 5.5 mm (the line 120 indicates the relative error of α_OS_6.5 mm - α_OS_5.5 mm) in relation to the higher value in each case.

In comparison with the lines of Figure 5, the influence of the spacing d on the measurement signal is substantially smaller in this instance. It can be seen that a variation in spacing of 1 mm results in a deviation of less than 0.3% and a variation in spacing of 1.5 mm also results in a deviation of less than 0.3%.

Owing to the correction according to the invention, the spacing dependence of the output signal is reduced to approximately 1/8 with respect to the uncorrected evaluation.

The correction value used in Figure 6 is OS=14.7 mT. The computational establishment of that value is intended to be explained in greater detail below with reference to Figures 10 and 11.

In Figure 10, the paths for the orthogonal magnetic field components By and Bz are indicated, Figure 11 shows the line Bz in accordance with the position of the permanent magnet 102 and the derivative of the field component along the movement to the position x. It can be seen that the optimum for the term OS is achieved when the point of inflection of Bz is equal to zero, that is to say, when the second derivative is zero or the gradient of the line 112 shown is horizontal.

The difference between the maximum value for Bz and the value at the location $d^2Bz/dz^2 = 0$ results in an offset value of OS = 14.7 mT for the embodiment shown in Figure 1.

However, that offset value does not necessarily have to be added to the field component in a computational manner but instead may also be produced physically by another auxiliary magnet 114 because a constant factor is always added in the method according to the invention.

The auxiliary magnet 114 may be arranged in a plane which has the same spacing d from the movable permanent magnet as the Hall sensor 100 (see Figures 12 and 13). Owing to the auxiliary magnet 114, a magnetic field component which ensures the necessary correction according to equation (2) is produced in the movement direction Bz_OS.

Alternatively, however, the auxiliary magnet 114 may also be mounted on the rear side of a circuit carrier, for example, a printed circuit board, PCB, 116, on the other side of which the Hall sensor 100 is constructed. This embodiment is schematically indicated in Figure 14.

The hardware solution using an auxiliary magnet 114 has the advantage that the calculation provision may be carried out in an unchanged state according to equation (1) but nevertheless the improved level of precision is achieved.

The advantageous effect of the solution according to the invention can be shown directly by a comparison of Figures 15 and 16.

Figure 15 shows the output signal of the sensor in accordance with the displacement of the permanent magnet for different distances d between the magnet and the sensor as a parameter. The different gradient values in accordance with the variation in spacing can clearly be seen. If, however, the value of the difference between the maximum of the corresponding magnetic field component and the value at the point of inflection is calculated as above with reference to Figure 11, an offset of 14.7 mT is obtained. If the value corrected by the value 14.7 mT is used in place of the uncorrected magnetic field component for the arc tangent calculation, the group of lines of Figure 16 is produced in comparison with the group of characteristic lines of Figure 15 which are greatly dependent on spacing.

In the case of a variation in the spacing d, no deviation of the characteristic line in accordance with the spacing d between the permanent magnet and the Hall sensor as a parameter can be established at all any longer in Figure 16 and the gradient error can no longer be detected with respect to the measurement noise.

REFERENCE NUMERALS

100	Hall sensor
102	Permanent magnet
104	Line progression α_lin
106	Line progression α_7.0 mm - α_6.5 mm
108	Line progression α_6.5 mm - α_5.5 mm
110	Line progression Bz + OS
112	Line progression α_OS
114	Auxiliary magnet
116	Circuit carrier (PCB)
118	Line progression α_OS_7.0 mm - α_OS_6.5 mm
120	Line progression α_OS_6.5 mm - α_OS_5.5 mm

Claims

1. Method for contactless measurement of a relative position of a magnetic field source which produces a magnetic field and a magnetic field sensor in relation to each other,
the magnetic field source and the magnetic field sensor being movable relative to each other,
the magnetic field sensor detecting at least two spatial components of the magnetic field and a position signal being produced from the measured components, and the method comprising the following steps:
calculating the position signal based on a quotient of the two magnetic field components,
correcting, before the quotient is calculated, the magnetic field component which extends in a movement direction between the magnetic field source and the magnetic field sensor.

2. Method according to claim 1, a relative linear movement being provided between the magnetic field source and the magnetic field sensor and the method comprising:
establishing at least a first measurement value for a magnetic field component which extends in the relative movement direction;
establishing at least a second measurement value for a magnetic field component which extends transversely to the relative movement direction;
calculating the position signal from the quotient of the first measurement value corrected by a correction term and the second measurement value.

3. Method according to claim 1 or 2, the magnetic field sensor comprising a two-dimensional or three-dimensional Hall sensor.

4. Method according to any one of the preceding claims, the magnetic field source comprising at least one permanent magnet.

5. Method according to any one of the preceding claims, the corrected magnetic field component being calculated by adding a constant offset value to the measured magnetic field component.

6. Method according to any one of the preceding claims, the corrected magnetic field component being formed by superimposing an auxiliary magnetic field produced by an auxiliary magnet over the magnetic field produced by the permanent magnet.

7. Method according to any one of the preceding claims, the value of the necessary correction being established by the following steps:
establishing a line of the magnetic field component in the movement direction in accordance with the position value; calculating a second derivative of the line according to the position value and establishing a zero position of the second derivative;
subtracting the function value of the line at the zero position from the function value at the position of minimum spacing in order to calculate an offset value for correction.

8. Displacement sensor for contactless measurement of a relative position of a magnetic field source (102) which produces a magnetic field and a magnetic field sensor (100) in relation to each other,
the magnetic field source (102) and the magnetic field sensor (100) being movable relative to each other,
the magnetic field sensor (100) being constructed in such a manner that it detects at least two spatial components (Bz, By) of the magnetic field and produces a position signal based on a quotient of the two magnetic field components from the measured components,
the displacement sensor further having a correction unit which corrects, before the quotient is calculated, the value of the magnetic field component which extends in a movement direction (z) between the magnetic field source (102) and the magnetic field sensor (100).

9. Displacement sensor according to claim 8, the correction unit comprising a calculation unit for computationally adding a constant correction factor (OS).

10. Displacement sensor according to claim 8 or 9, the correction unit comprising at least one auxiliary magnet (114) whose magnetic field is superimposed on the magnetic field of the magnetic field source (102) in such a manner that the value of the magnetic field component which extends in a movement direction between the magnetic field source and the magnetic field sensor is corrected by a constant correction factor.

11. Displacement sensor according to claim 10, the at least one auxiliary magnet (114) being arranged so as to be fixed in position relative to the magnetic field sensor (100).

12. Displacement sensor according to claim 11, the at least one auxiliary magnet being mounted on a common circuit carrier (116) with the magnetic field sensor (100).

13. Displacement sensor according to any one of claims 8 to 12, the magnetic field sensor (100) comprising a two-dimensional or three-dimensional Hall sensor.

14. Displacement sensor according to any one of claims 8 to 13, the magnetic field source (102) comprising at least one permanent magnet.

15. Displacement sensor according to any one of claims 8 to 13, the magnetic field source (102) producing a magnetic field which is rotationally symmetrical with respect to an axis which is defined by relative linear movement between the magnetic field source and the magnetic field sensor.

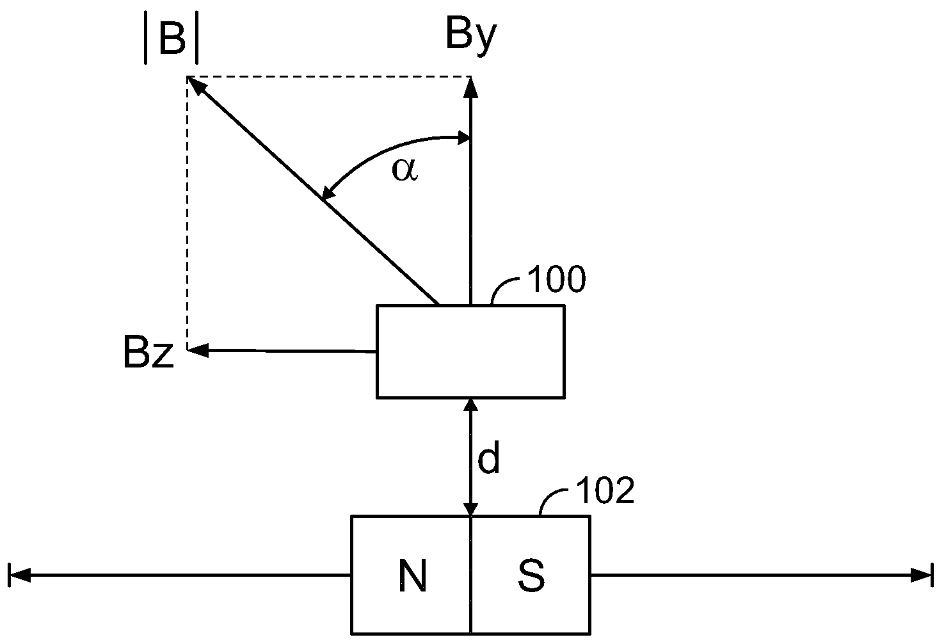
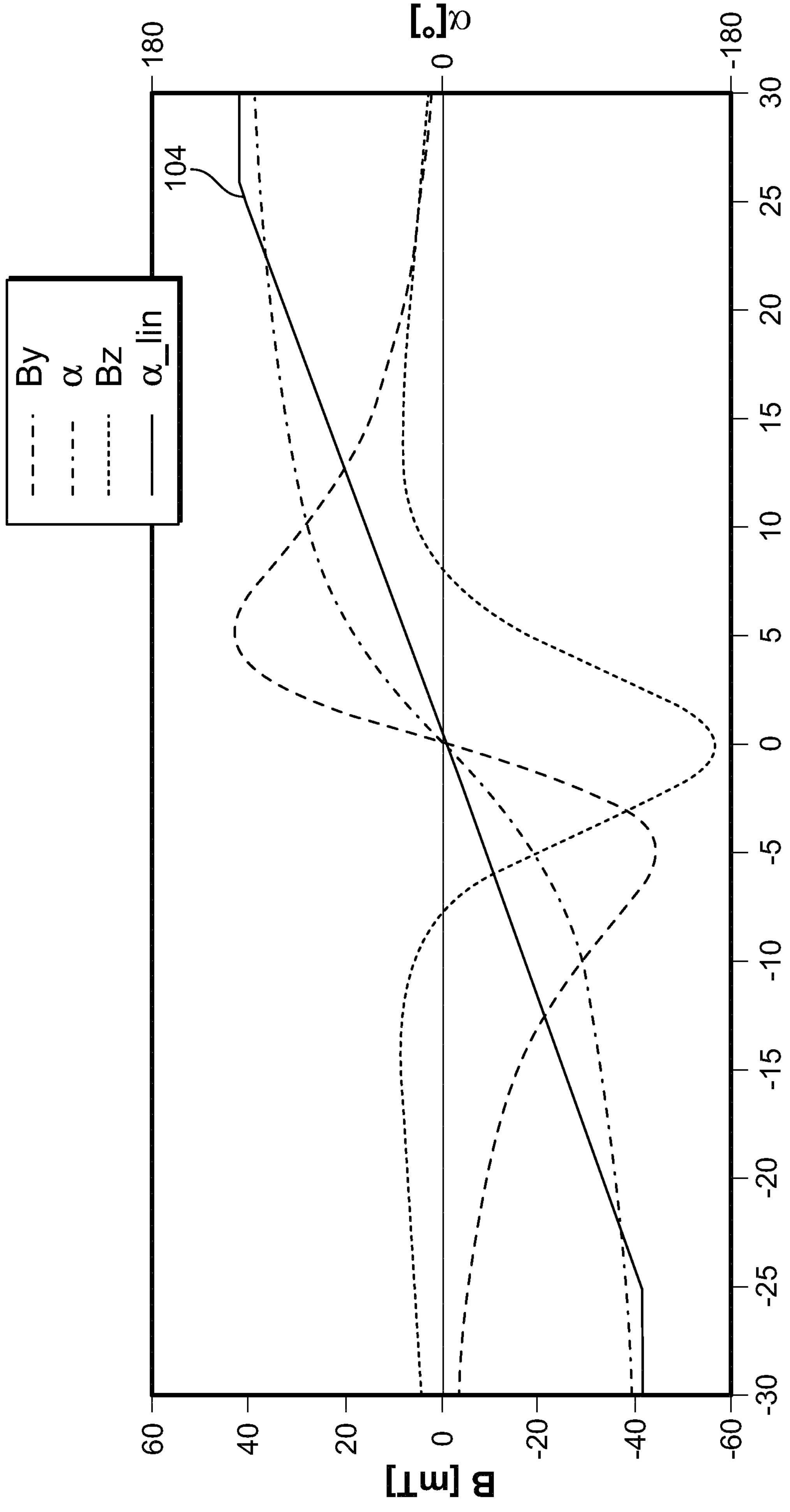


Fig. 1



By
α
Bz
α_lin
104
B [mT]
α[°]
z [mm]
60
40
20
0
-20
-40
-60
180
0
-180
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30

Fig. 2

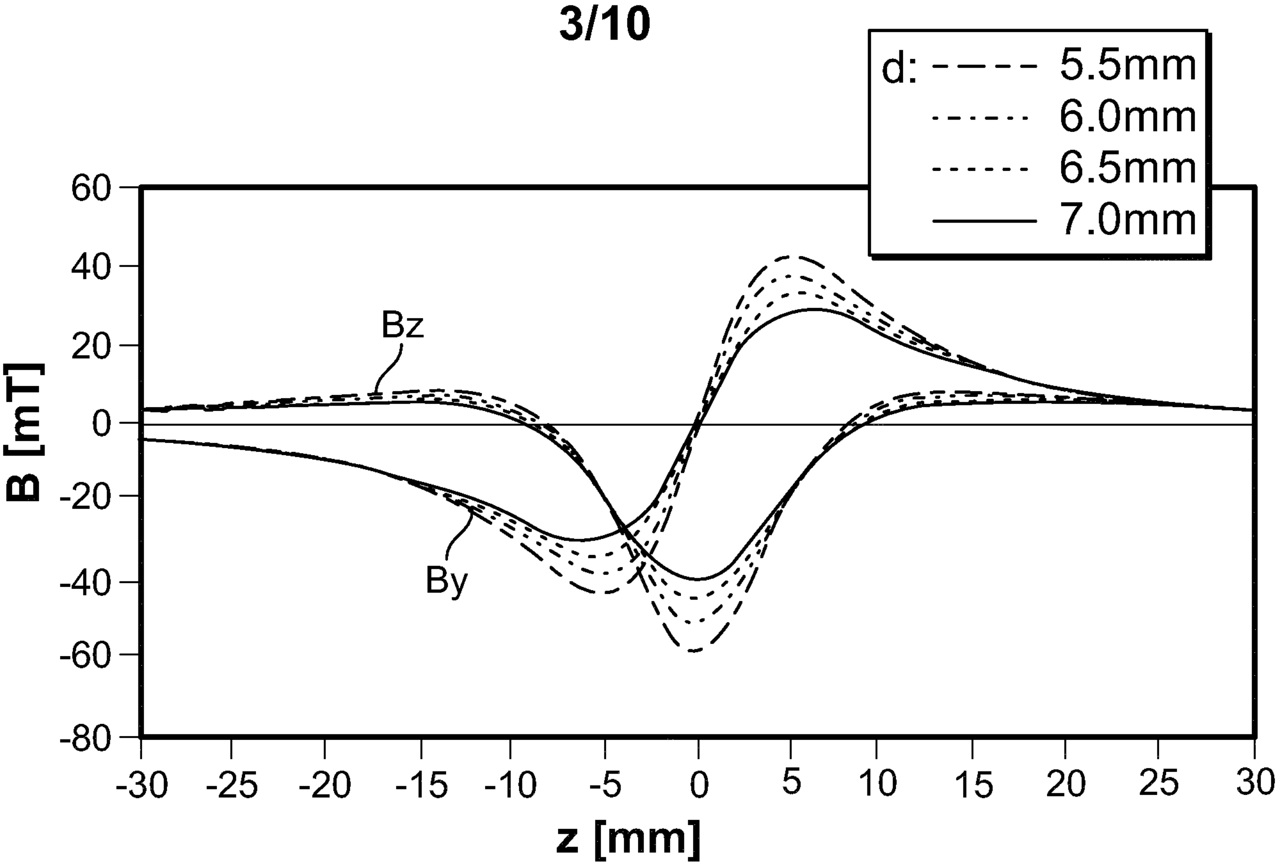

d:
5.5mm
6.0mm
6.5mm
7.0mm
60
40
20
0
-20
-40
-60
-80
B [mT]
Bz
By
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
z [mm]

Fig. 3

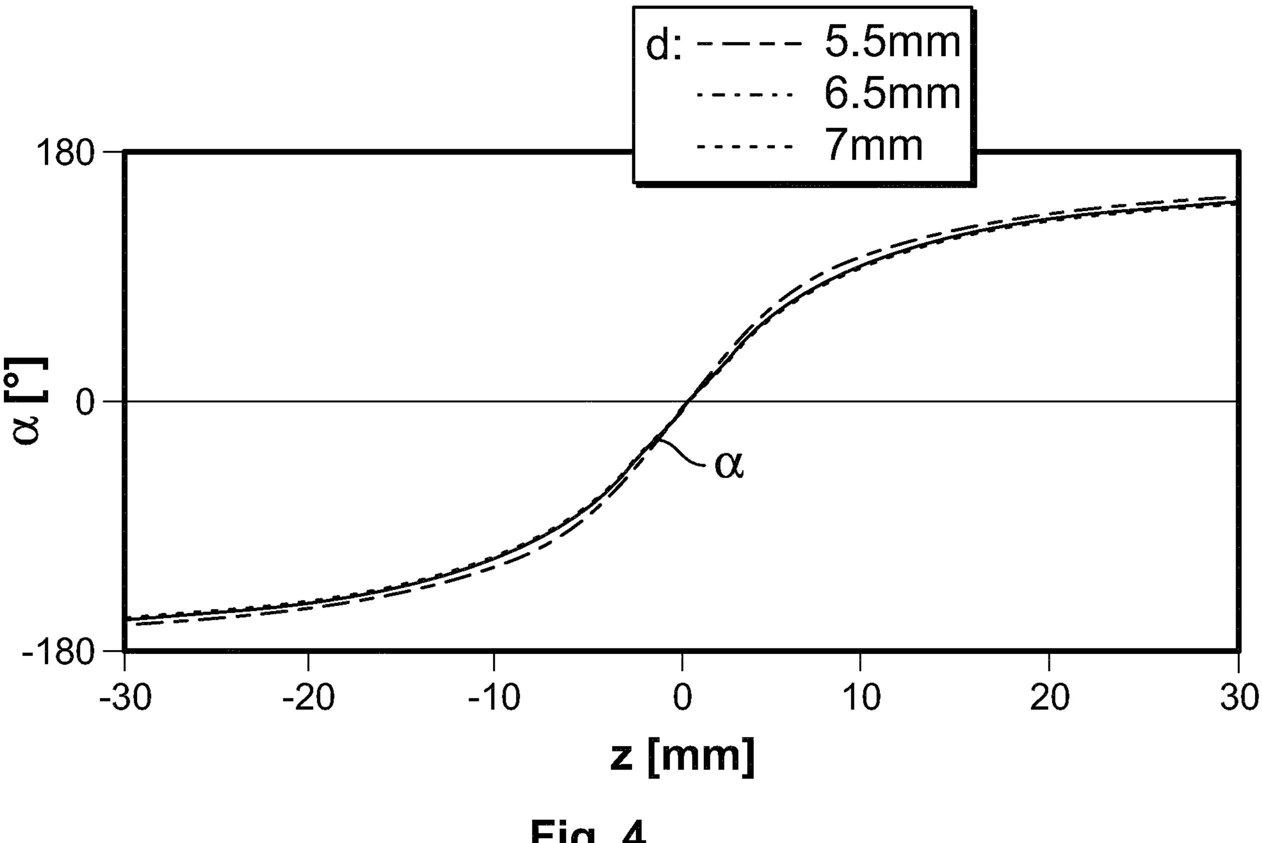

d:
5.5mm
6.5mm
7mm
180
0
-180
α [°]
α
-30
-20
-10
0
10
20
30
z [mm]

Fig. 4

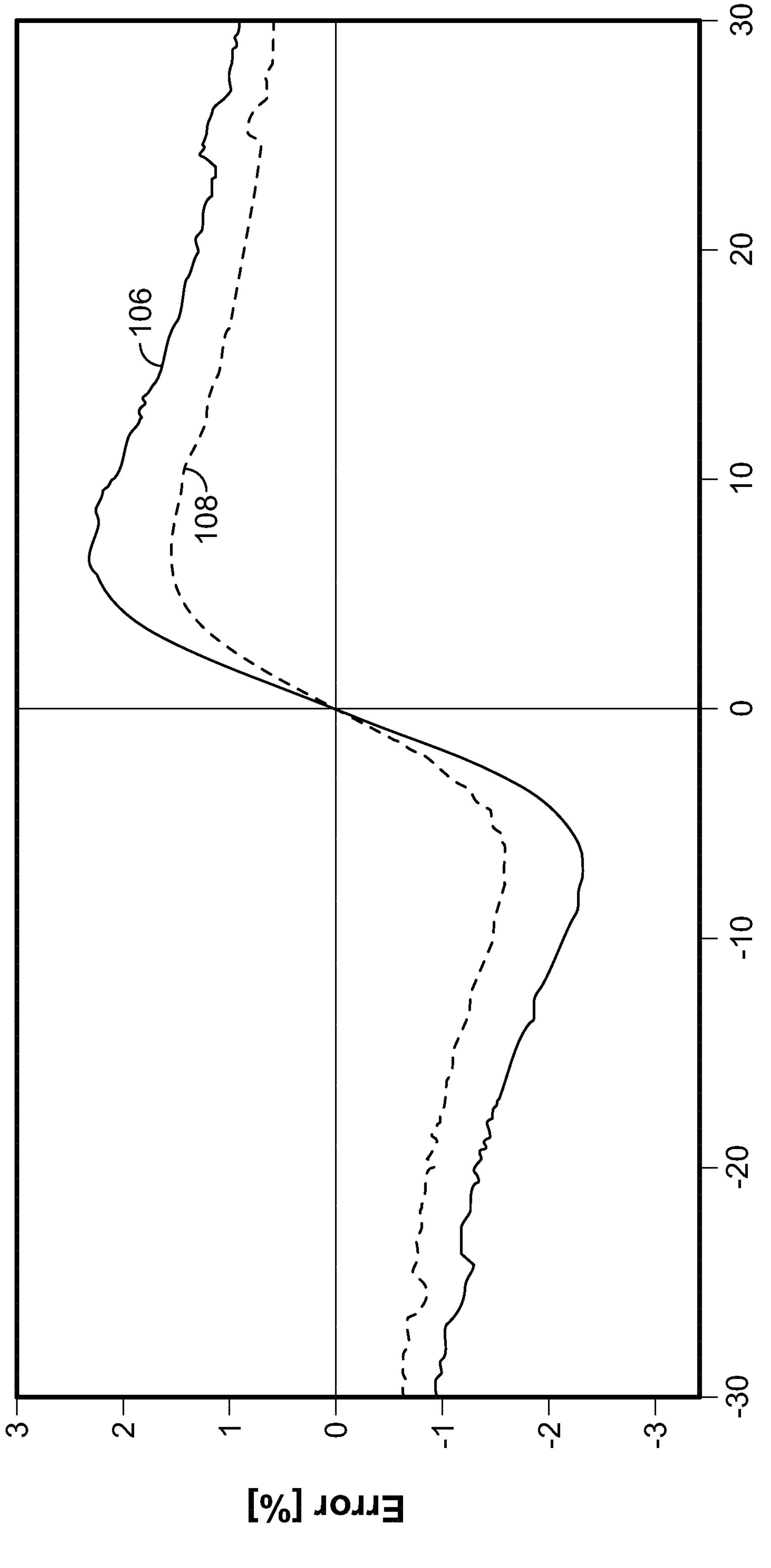


Fig. 5

5/10

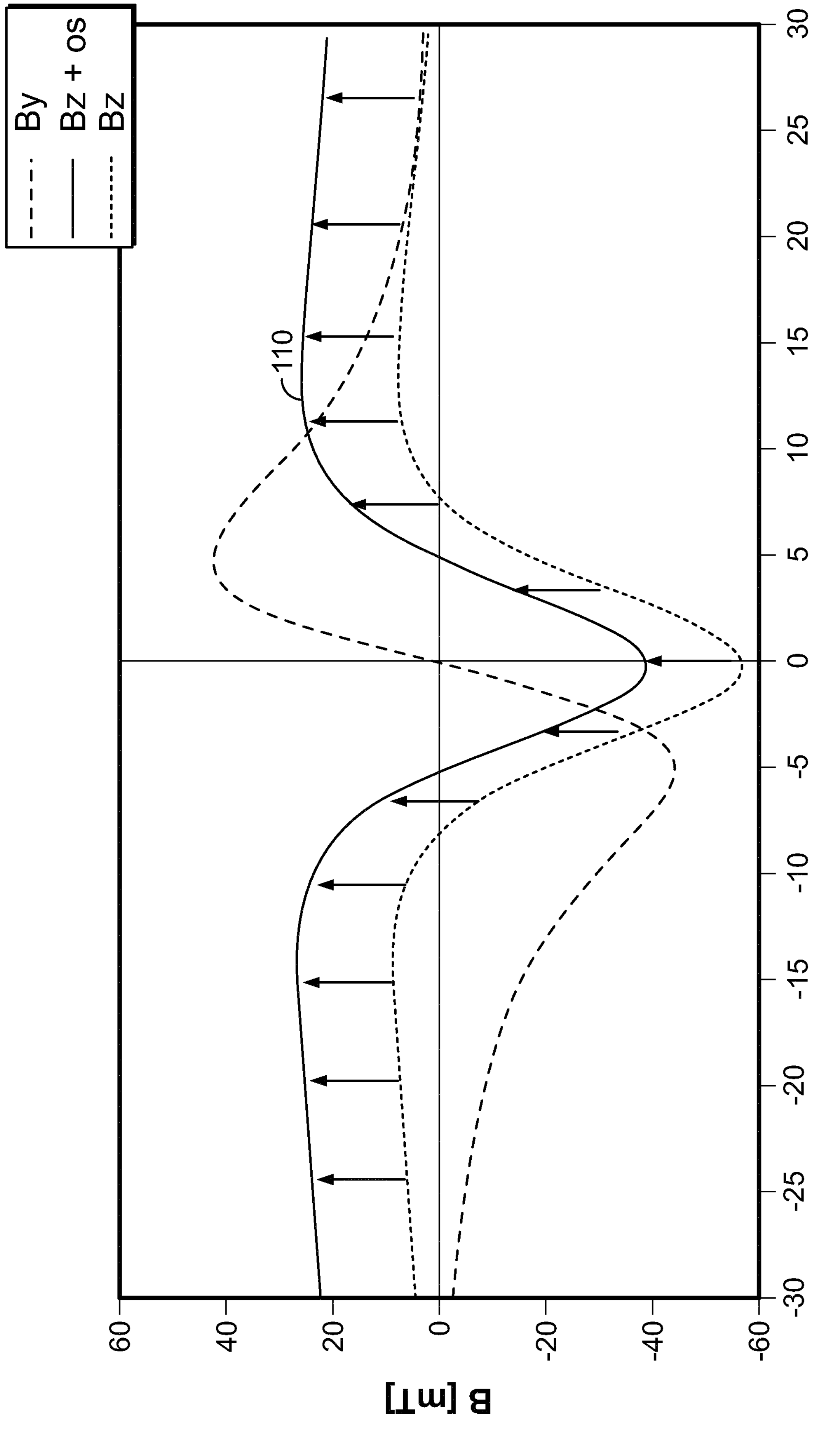

By
Bz + os
Bz
110
B [mT]
z [mm]
60
40
20
0
-20
-40
-60
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30

Fig. 6

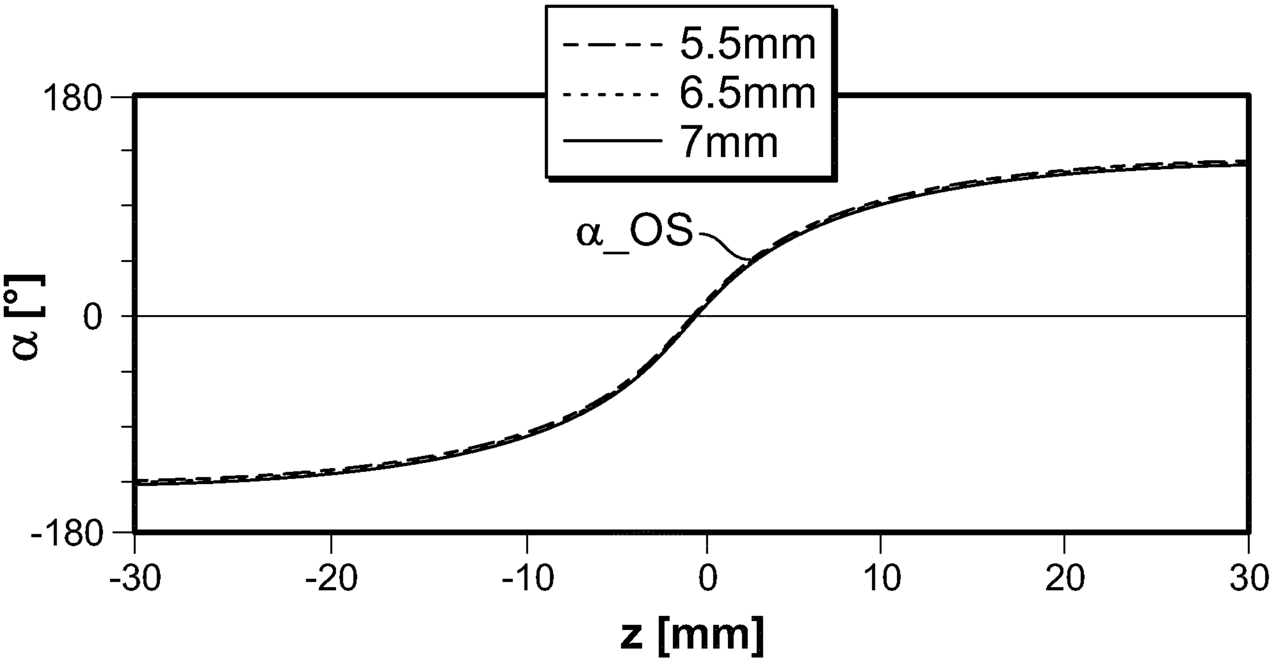

5.5mm
6.5mm
7mm
180
0
-180
α [°]
α_OS
-30
-20
-10
0
10
20
30
z [mm]

Fig. 7

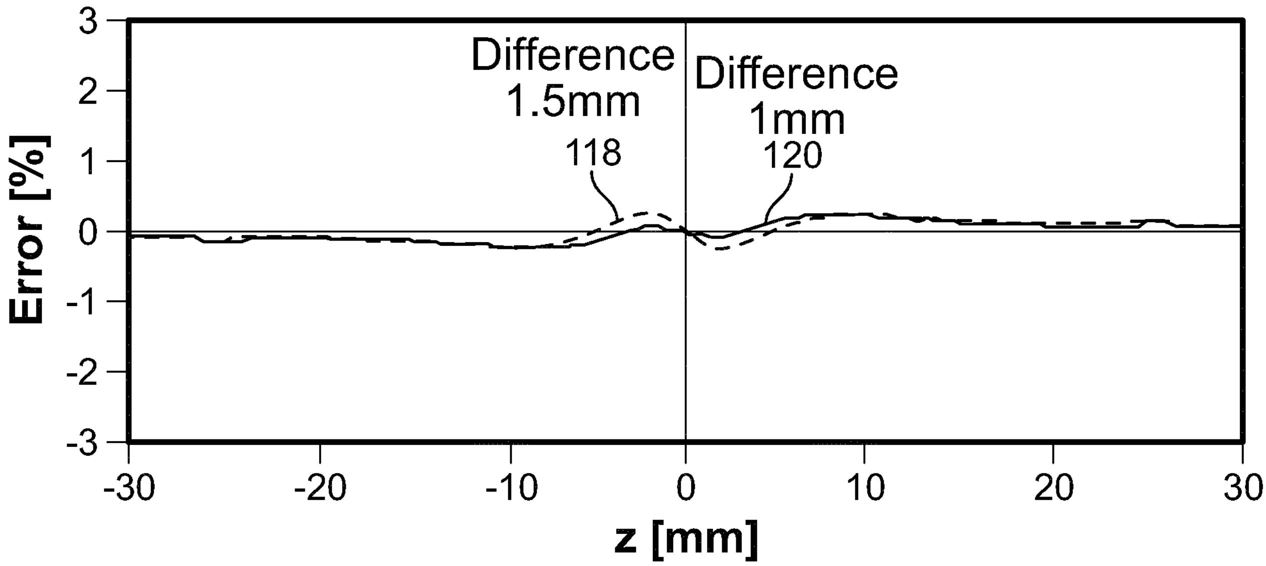
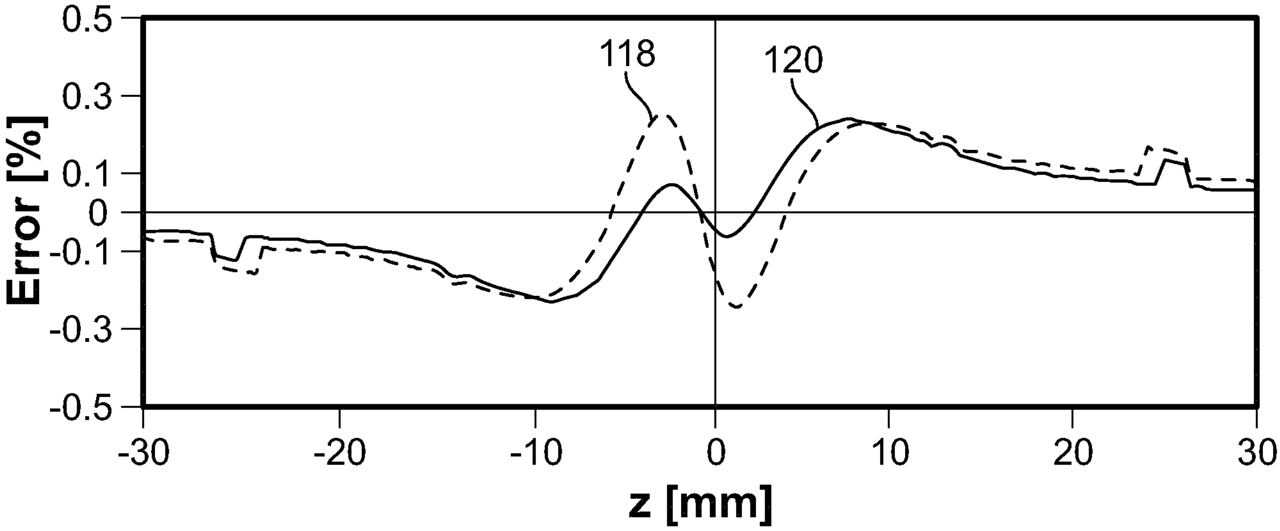
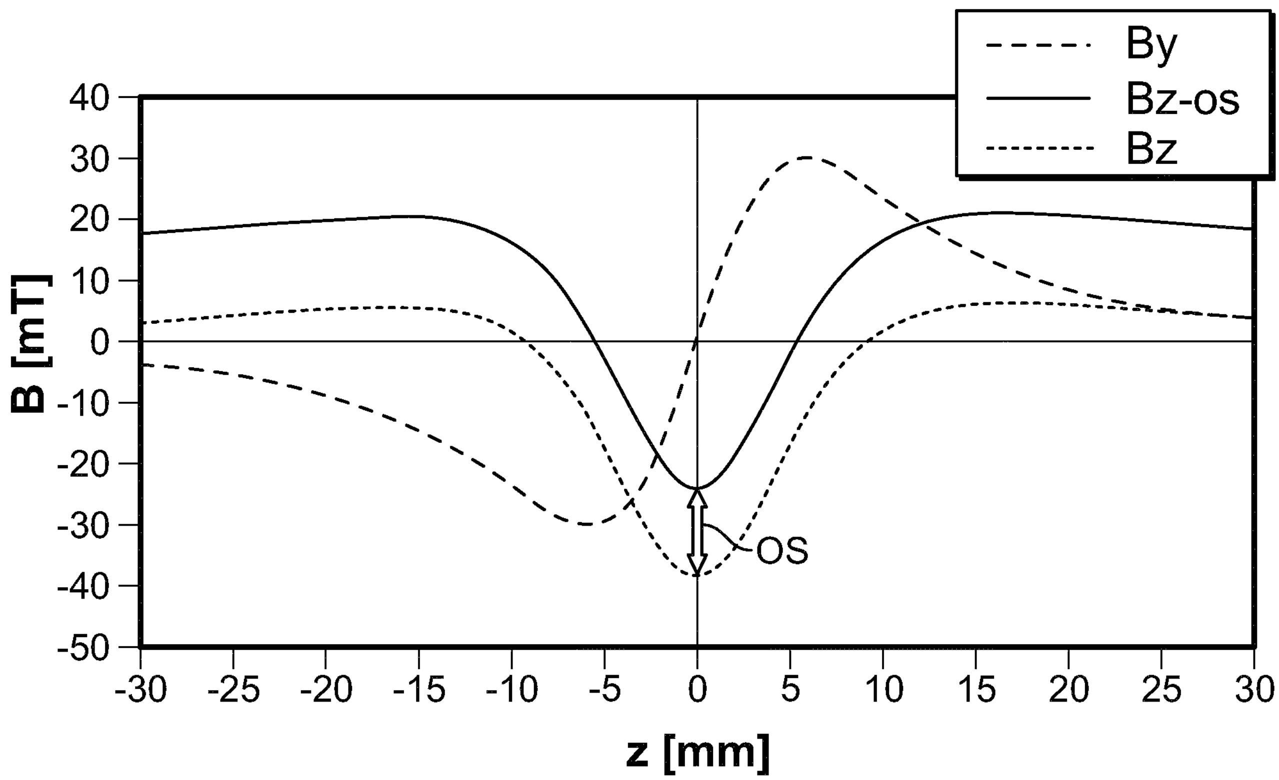

3
2
1
0
-1
-2
-3
Error [%]
Difference
1.5mm
118
Difference
1mm
120
-30
-20
-10
0
10
20
30
z [mm]

Fig. 8



118
120
Error [%]
0.5
0.3
0.1
0
-0.1
-0.3
-0.5
-30
-20
-10
0
10
20
30
z [mm]

Fig. 9



By
Bz-os
Bz
B [mT]
40
30
20
10
0
-10
-20
-30
-40
-50
OS
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
z [mm]

Fig. 10

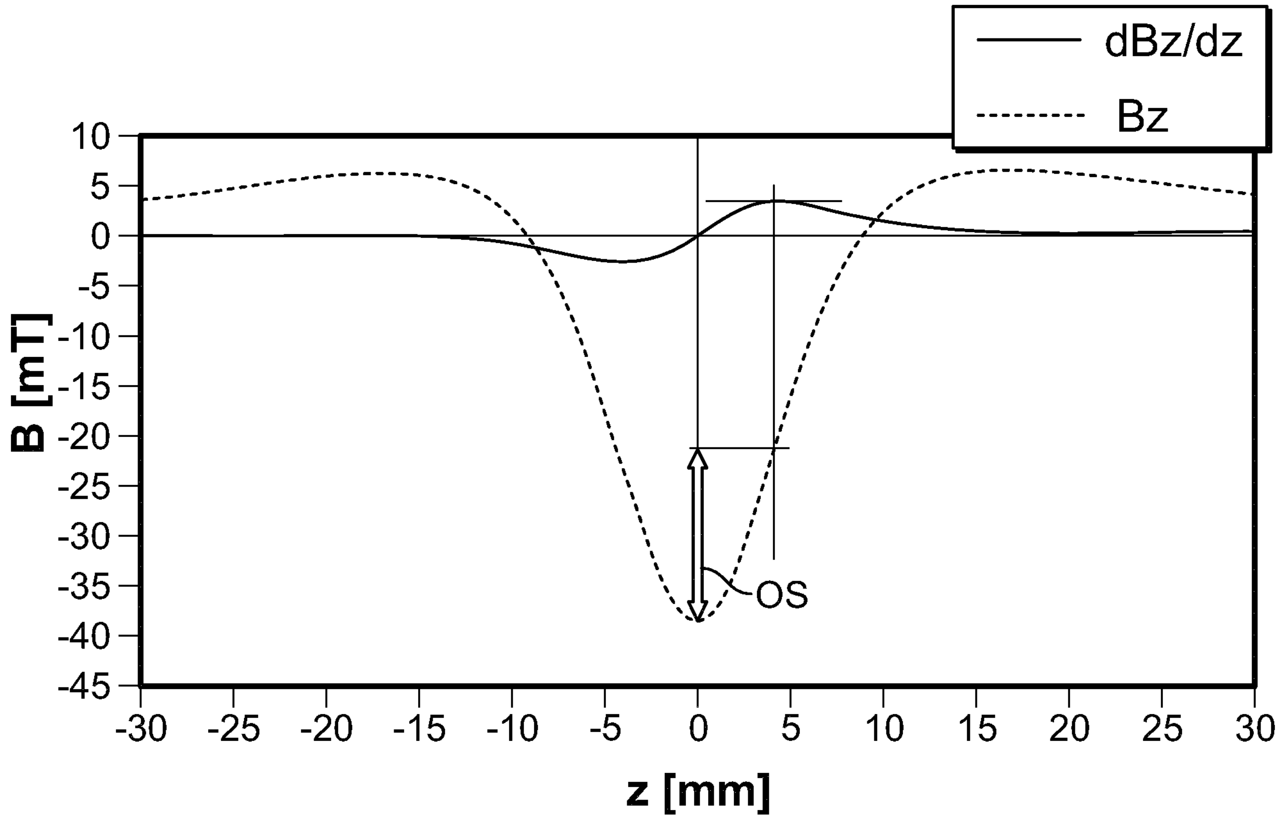

dBz/dz
Bz
B [mT]
z [mm]
OS
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30

Fig. 11

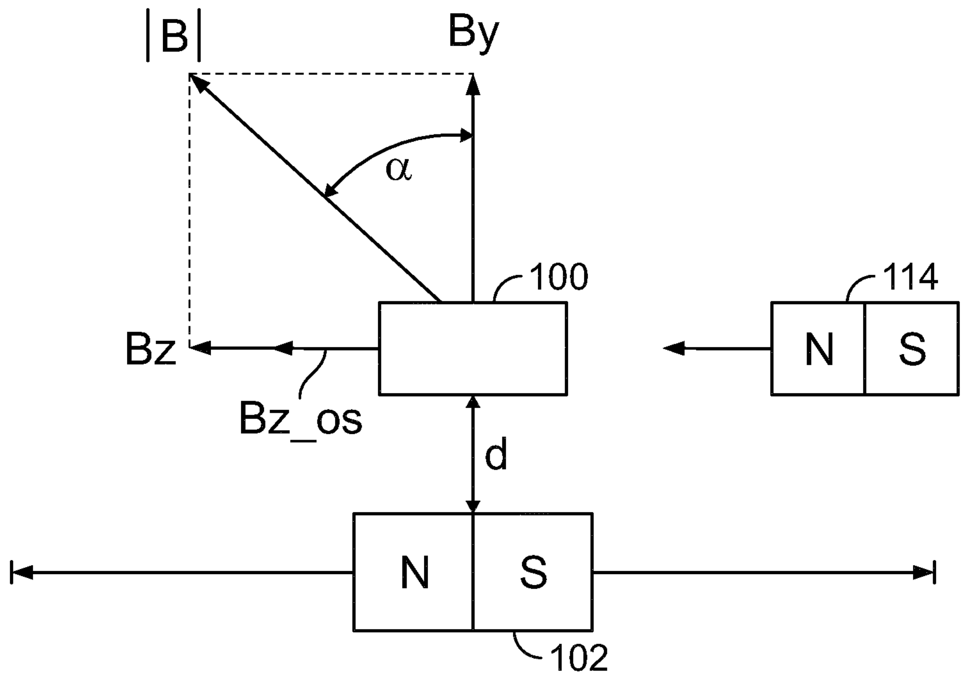

|B|
By
α
100
114
Bz
Bz_os
N
S
d
N
S
102

Fig. 12

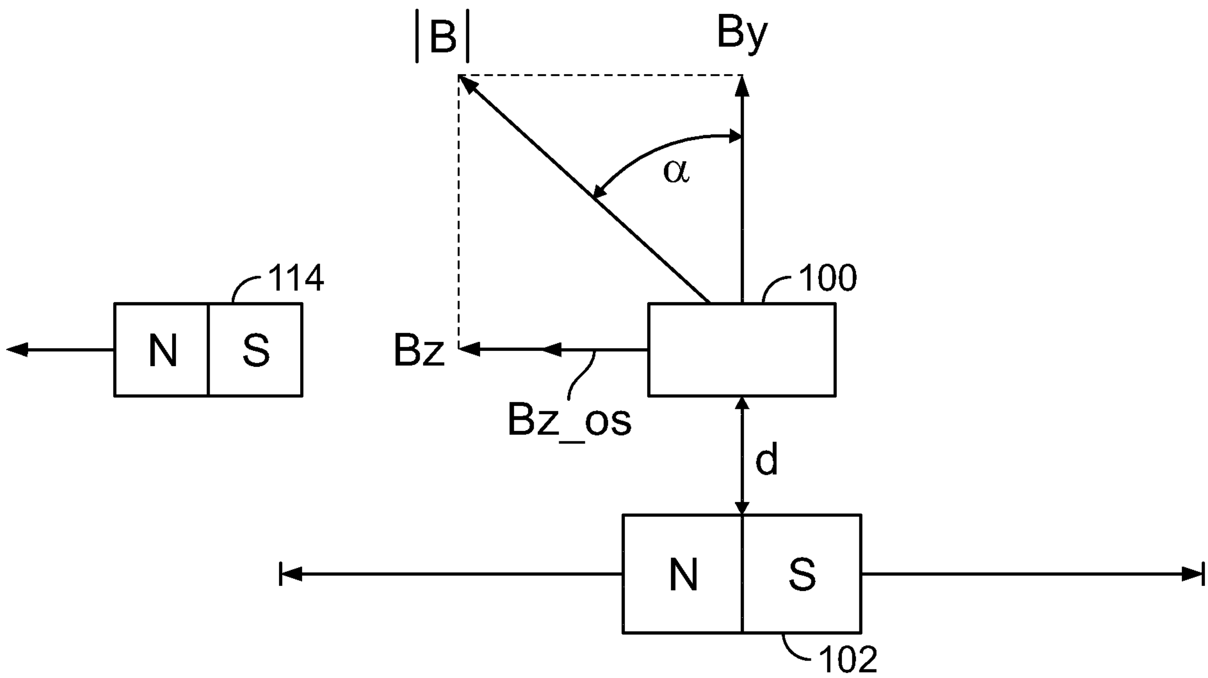

|B|
By
α
114
N
S
100
Bz
Bz_os
d
N
S
102

Fig. 13

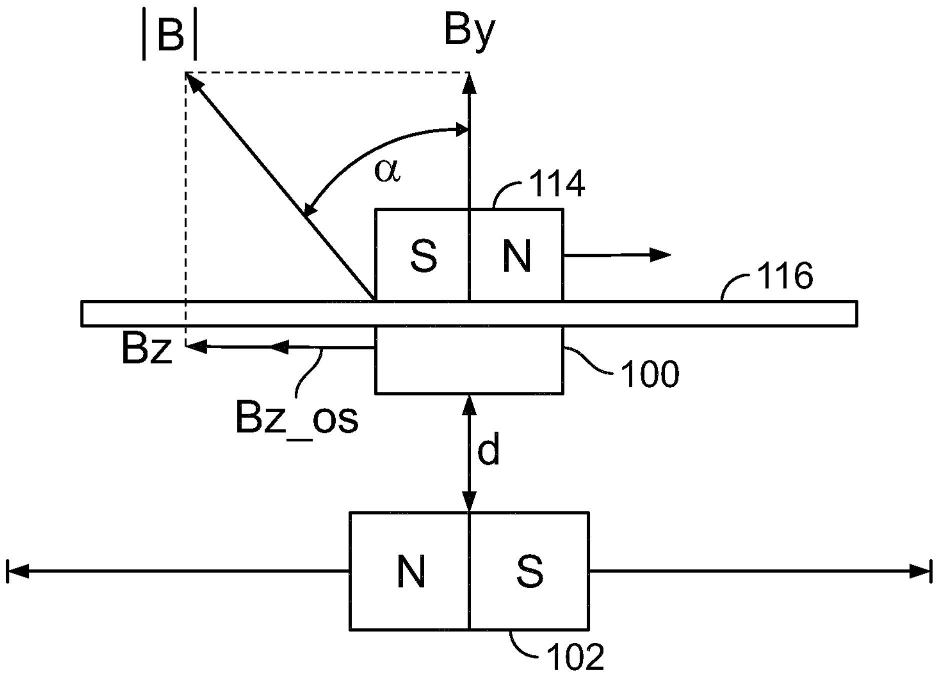

|B|
By
α
114
S
N
116
Bz
100
Bz_os
d
N
S
102

Fig. 14

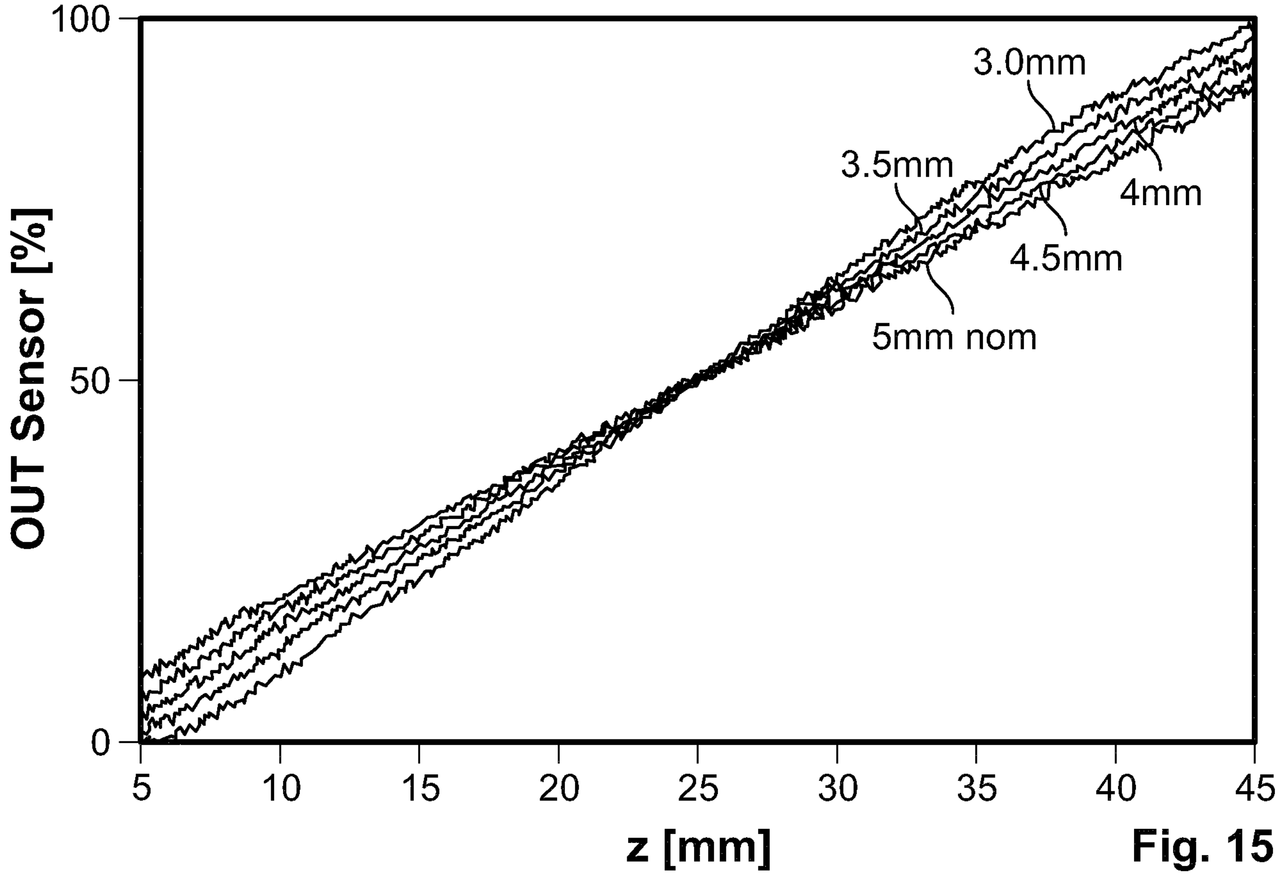

100
50
0
5
10
15
20
25
30
35
40
45
OUT Sensor [%]
z [mm]
3.0mm
3.5mm
4mm
4.5mm
5mm nom

Fig. 15

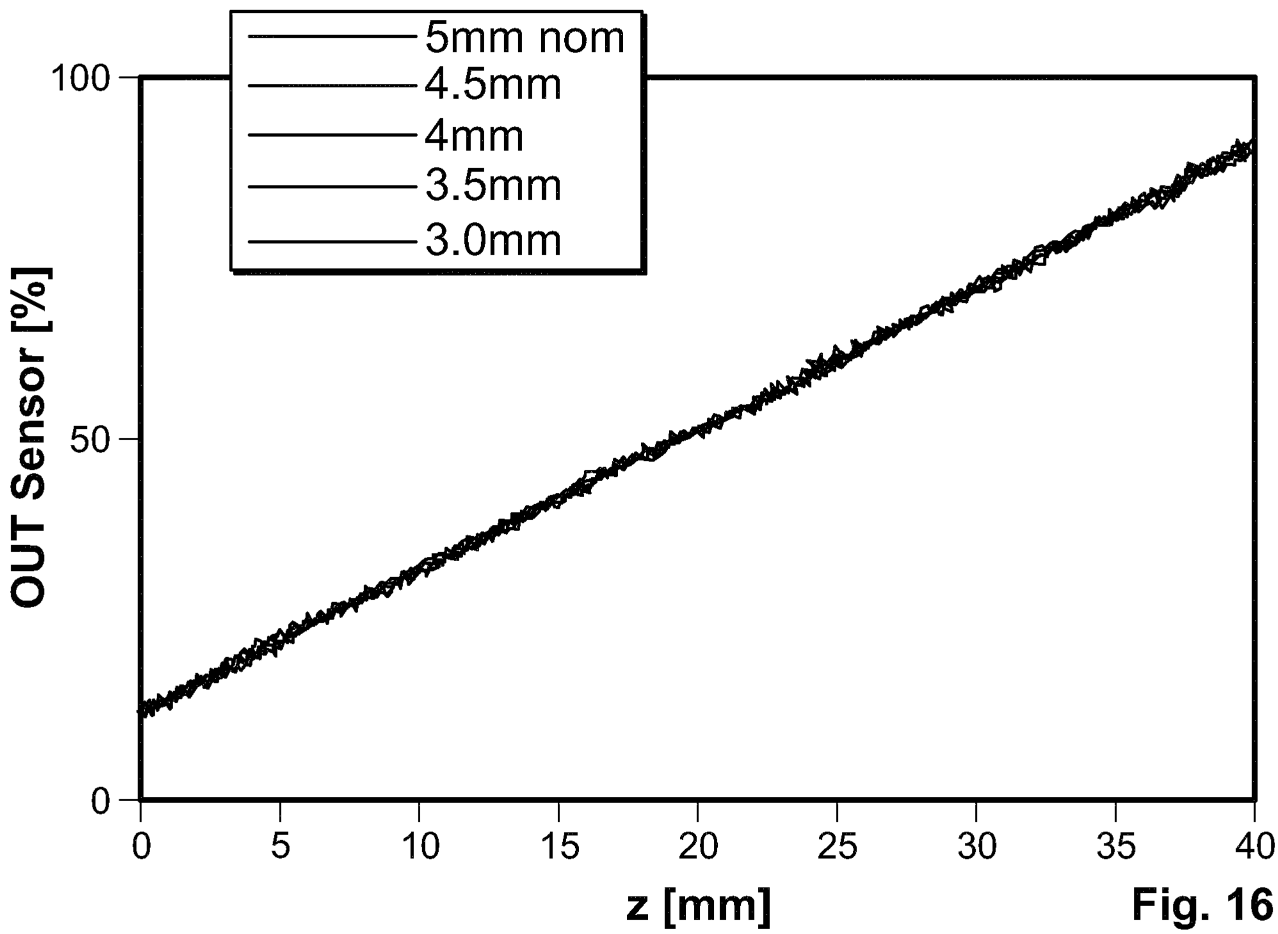

5mm nom
4.5mm
4mm
3.5mm
3.0mm
100
50
0
0
5
10
15
20
25
30
35
40
OUT Sensor [%]
z [mm]

Fig. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/068842

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01D5/14 G01D5/244
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01D

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	EP 1 243 897 A1 (SENTRON AG [CH]) 25 September 2002 (2002-09-25) cited in the application pages 2-6	1-5,8,9, 13-15 6,7, 10-12
Y A	WO 2007/092402 A2 (CALIFORNIA LINEAR DEVICES INC [US]; LINDBERG PAUL M [US]; SCHULTZE GAR) 16 August 2007 (2007-08-16) pages 13-37	1-5,8,9, 13-15 6,7, 10-12
Y A	US 4 737 710 A (VAN ANTWERP JOEL C [US] ET AL) 12 April 1988 (1988-04-12) column 2, line 21 - column 12, line 27	1-5,8,9, 13-15 6,7, 10-12
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December 2012	19/12/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kurze, Volker

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/227567 A1 (REIDMUELLER KURT [AT] ET AL) 22 September 2011 (2011-09-22) paragraphs [0011] - [0061] -----	1-15
A	EP 0 115 391 A2 (TRW INC) 8 August 1984 (1984-08-08) pages 3-22 -----	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/068842

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1243897	A1	25-09-2002	EP 1243897 A1	25-09-2002
			JP 4288373 B2	01-07-2009
			JP 2002328046 A	15-11-2002
			US 2002167306 A1	14-11-2002
WO 2007092402	A2	16-08-2007	AU 2007212485 A1	16-08-2007
			CA 2641407 A1	16-08-2007
			EP 1979704 A2	15-10-2008
			JP 5027821 B2	19-09-2012
			JP 2009525490 A	09-07-2009
			US 2007205736 A1	06-09-2007
			US 2010114518 A1	06-05-2010
			WO 2007092402 A2	16-08-2007
US 4737710	A	12-04-1988	NONE	
US 2011227567	A1	22-09-2011	DE 102010011723 A1	22-09-2011
			US 2011227567 A1	22-09-2011
EP 0115391	A2	08-08-1984	EP 0115391 A2	08-08-1984
			JP 59187202 A	24-10-1984