US 20100134917A1

(19) United States

(12) Patent Application Publication

SAKAI

(10) Pub. No.: US 2010/0134917 A1

(43) Pub. Date: Jun. 3, 2010

(54) METHOD AND APPARATUS FOR OFFSET CONTROL IN A DISK DRIVE

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(21) Appl. No.: **12/421,539**

(22) Filed: **Apr. 9, 2009**

(30) Foreign Application Priority Data

Nov. 28, 2008 (JP) 2008-304835

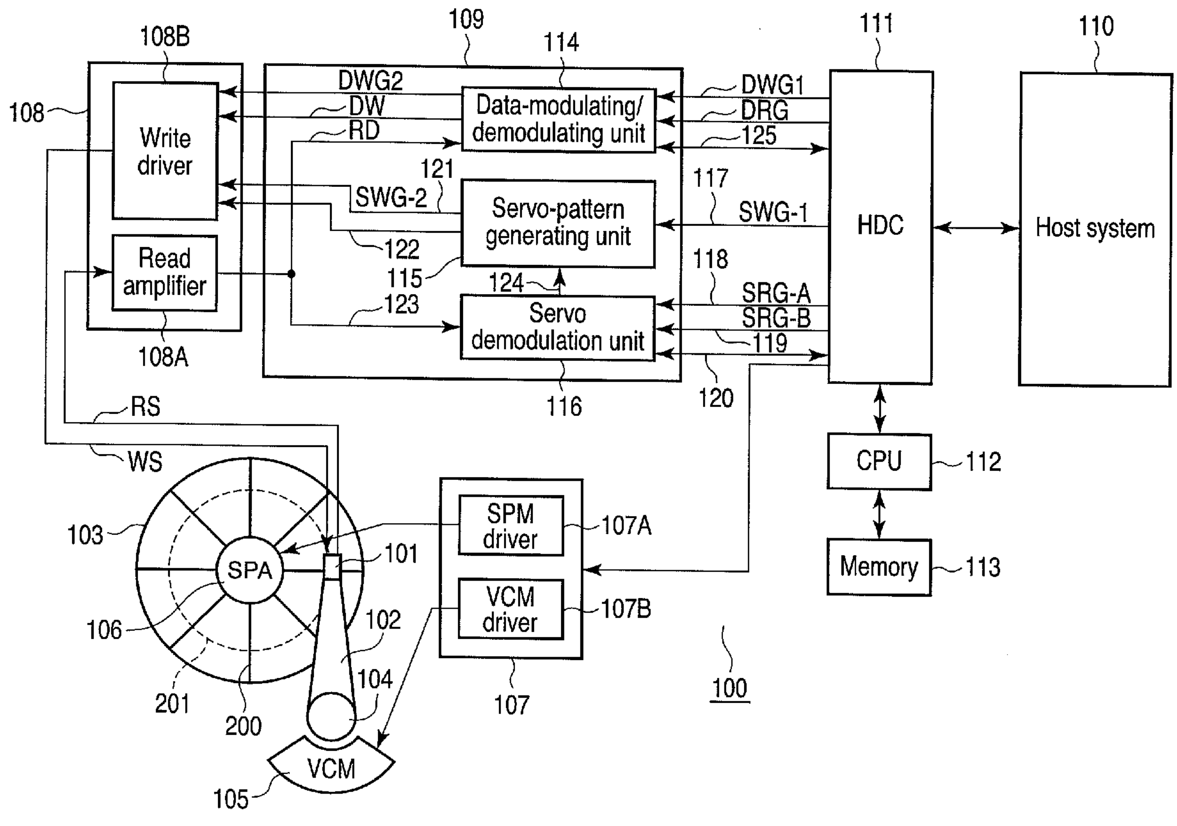
Publication Classification

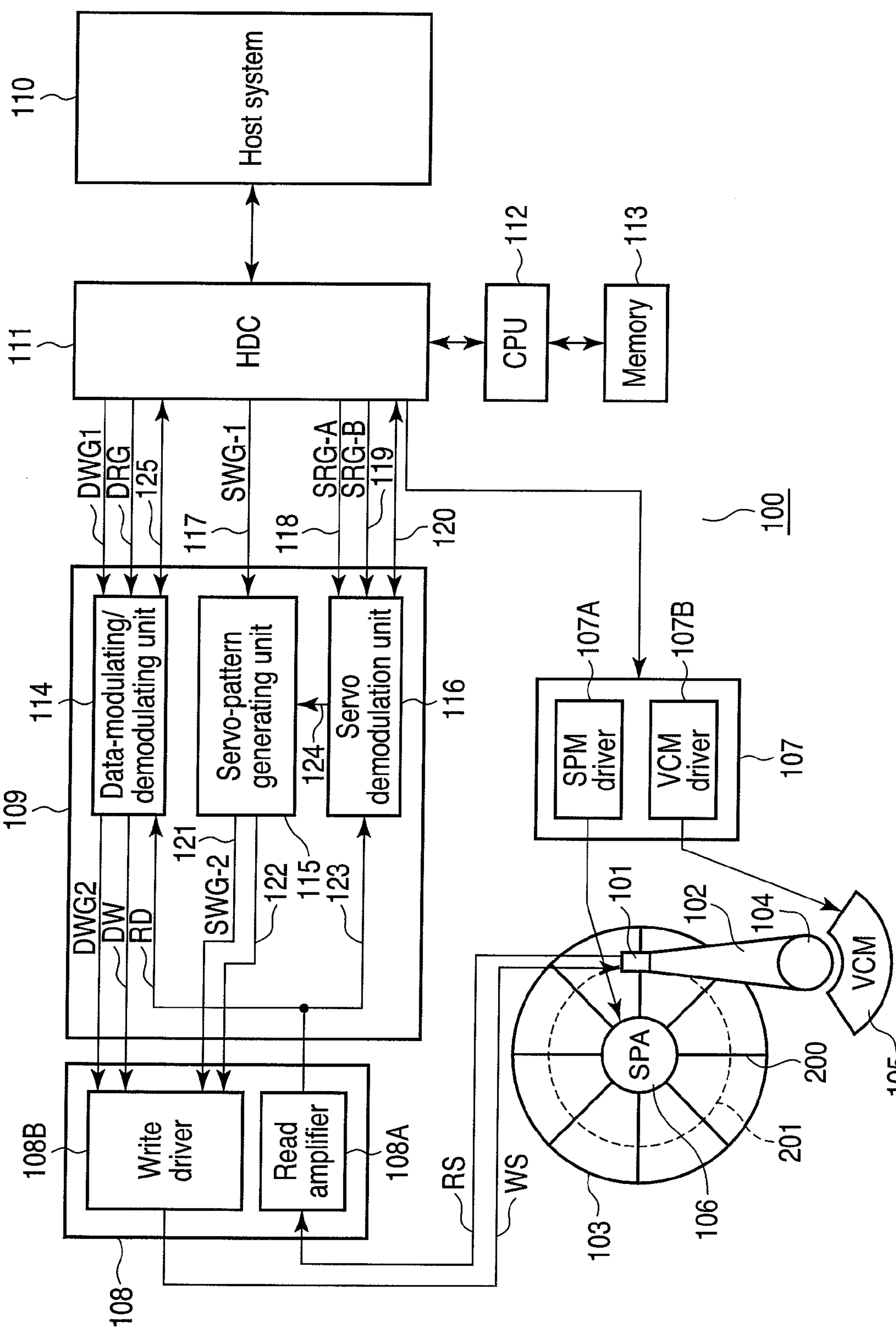
(51) Int. Cl.
G11B 5/596 (2006.01)

(52) U.S. Cl. **360/77.02**; G9B/5.216

(57) ABSTRACT

According to one embodiment, a disk drive capable of performing a dynamic offset control (DOC) is provided. The disk drive has an offset module and an updating module. The offset module calculates an offset value that changes during a one-rotation period of a disk, from the offset-measuring position data recorded in the disk. The updating module updates the offset value to a new one if a disk shift has occurred.





Host system
HDC
CPU
Memory
Data-modulating/demodulating unit
Servo-pattern generating unit
Servo demodulation unit
SPM driver
VCM driver
Write driver
Read amplifier
SPA
VCM
DWG1
DRG
SWG-1
SRG-A
SRG-B
DWG2
DW
RD
SWG-2
RS
WS
100
101
102
103
104
105
106
107
107A
107B
108
108A
108B
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
200
201

FIG. 1

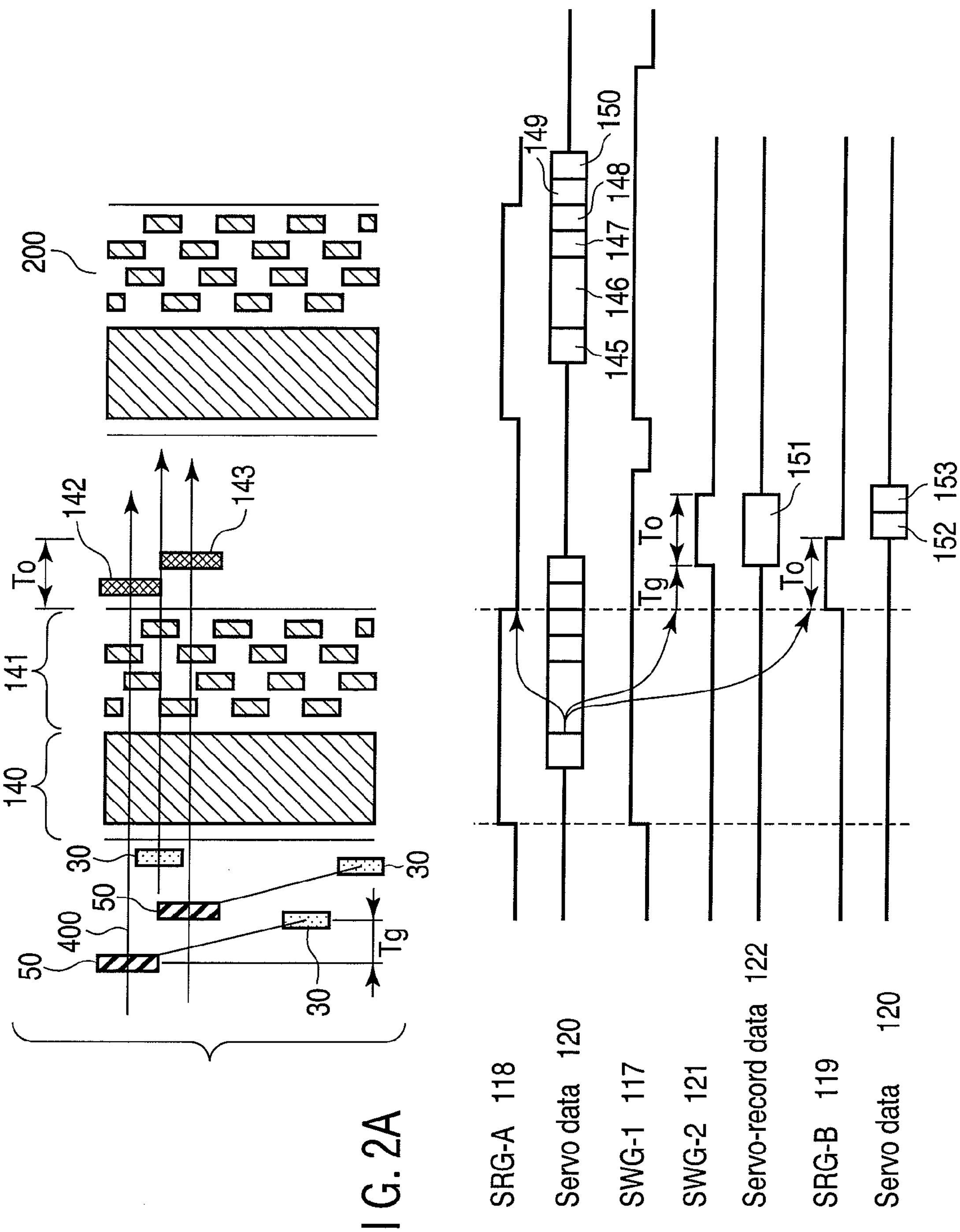


FIG. 2A

FIG. 2B
FIG. 2C
FIG. 2D
FIG. 2E
FIG. 2F
FIG. 2G
FIG. 2H

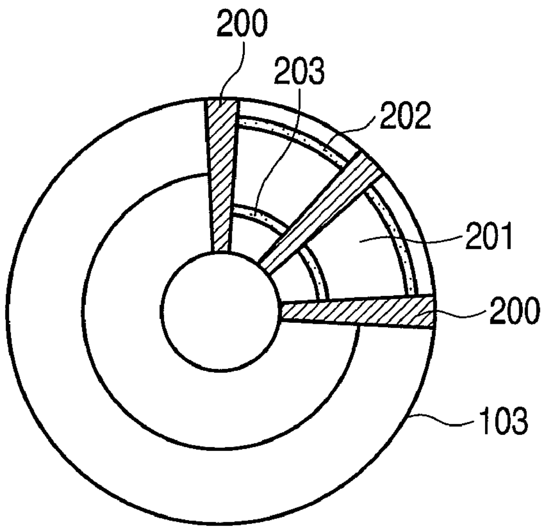


FIG. 3

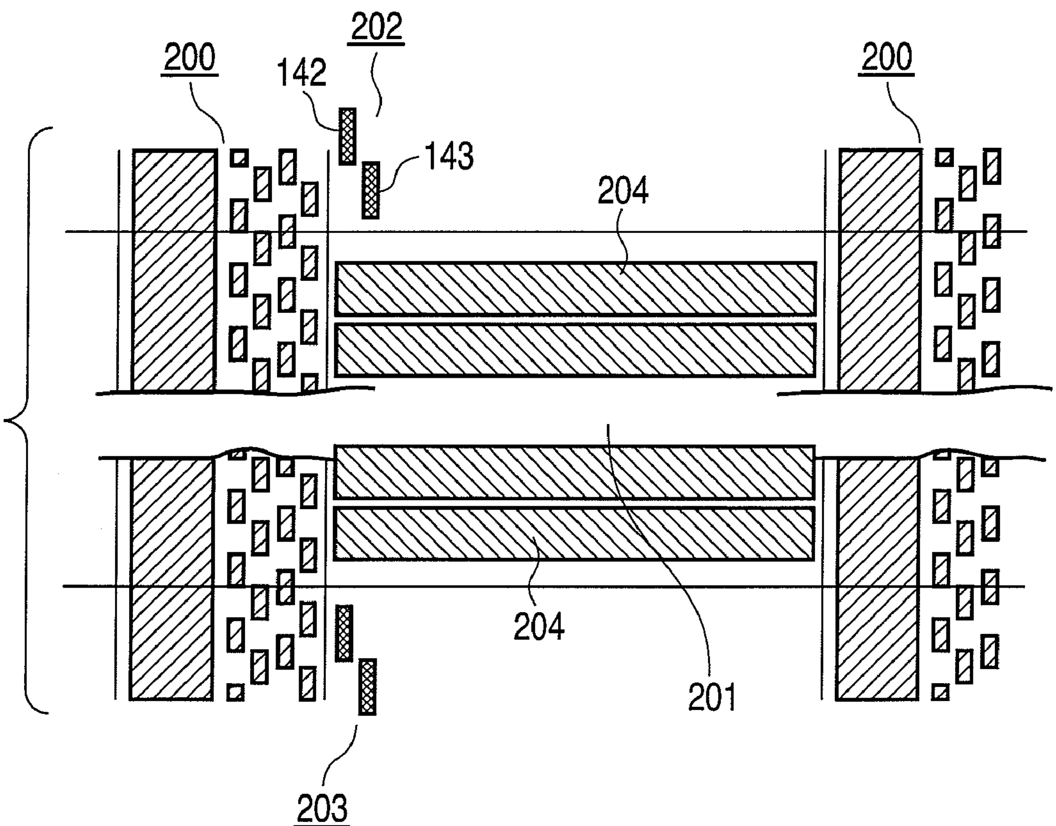


FIG. 4

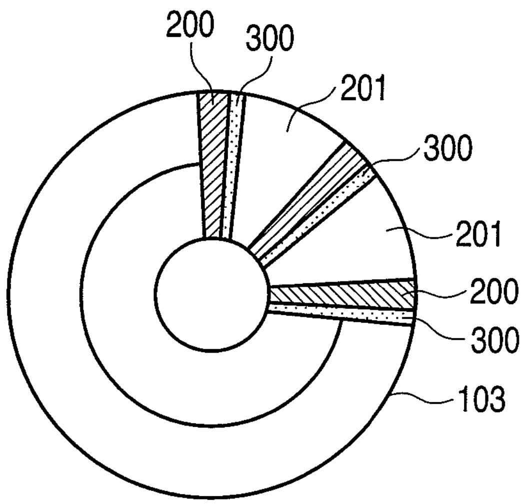

200
300
201
300
201
200
300
103

FIG. 5

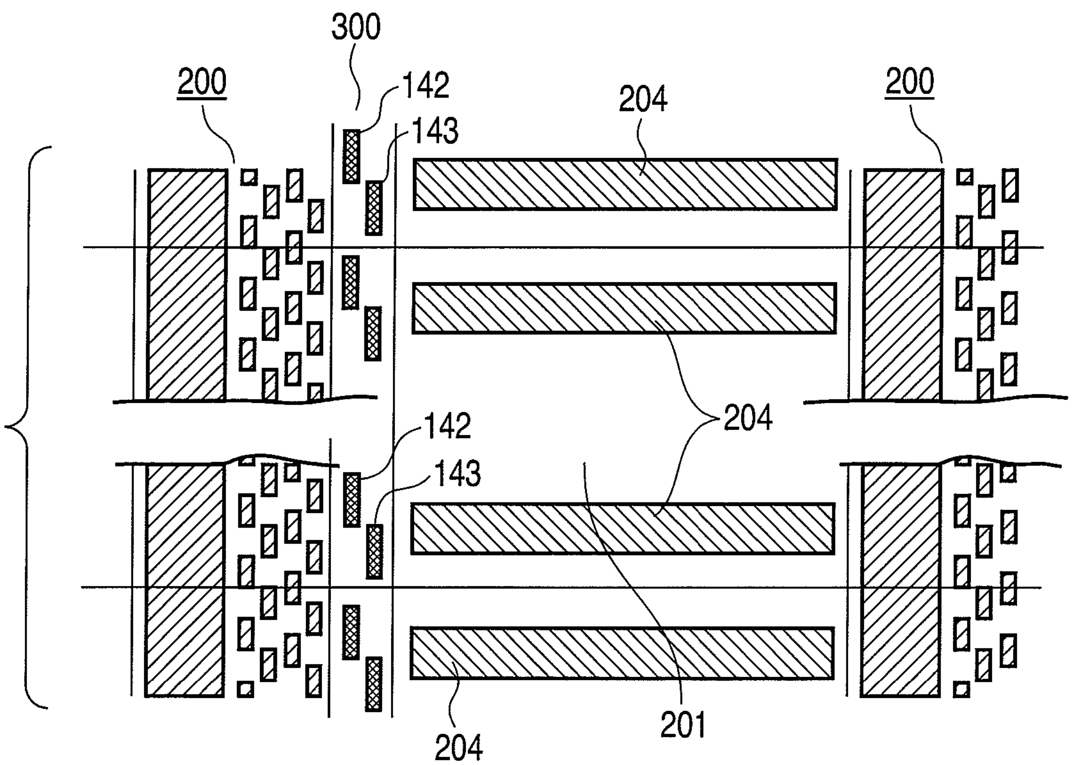
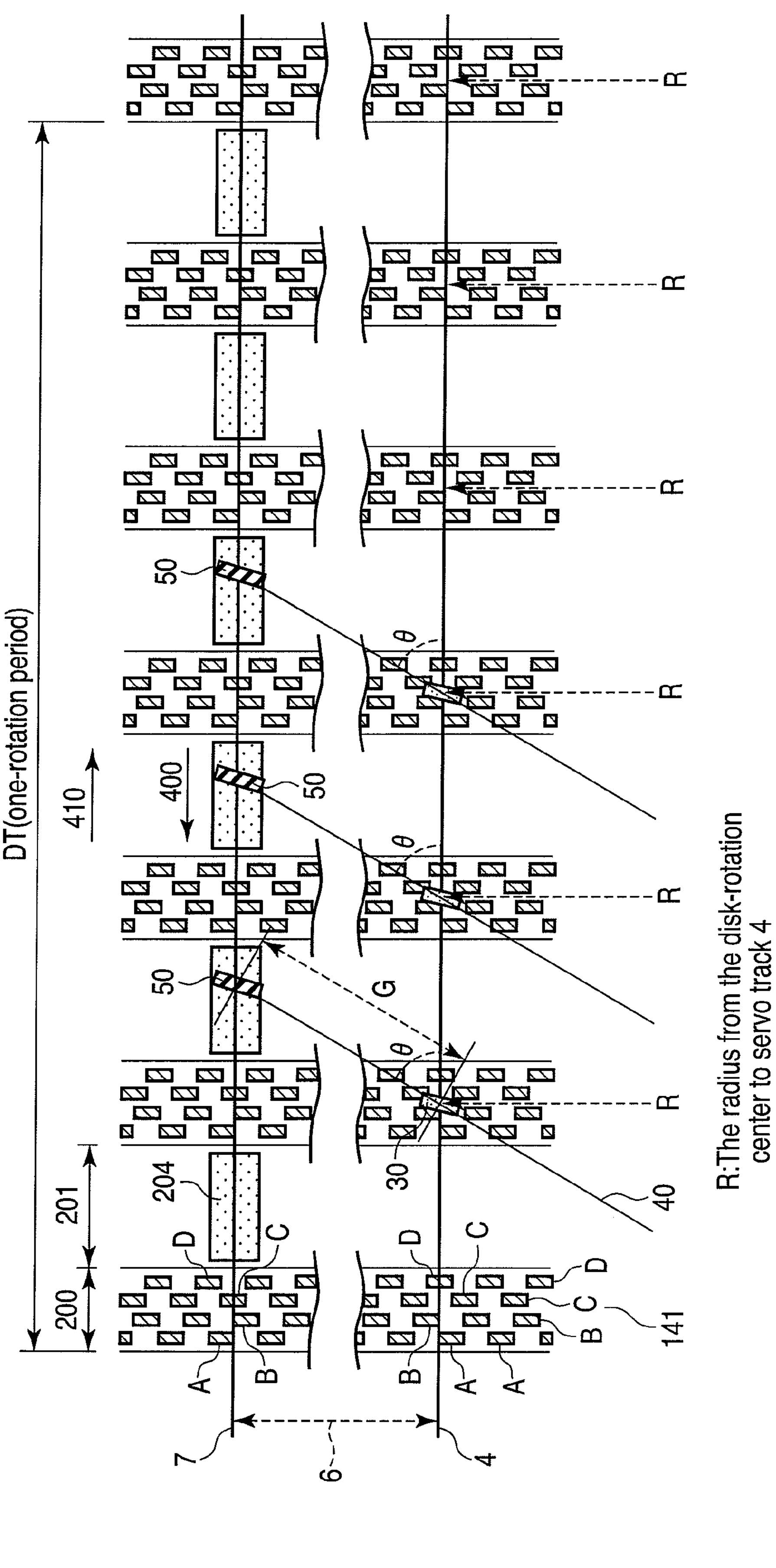

300
200
142
143
204
200
204
142
143
204
201

FIG. 6


DT(one-rotation period)
410
400
50
50
50
G
θ
θ
θ
R
R
R
R
R
R
201
200
204
D
C
B
A
D
C
B
A
A
B
C
D
141
30
40
7
6
4
R:The radius from the disk-rotation center to servo track 4

F I G. 7

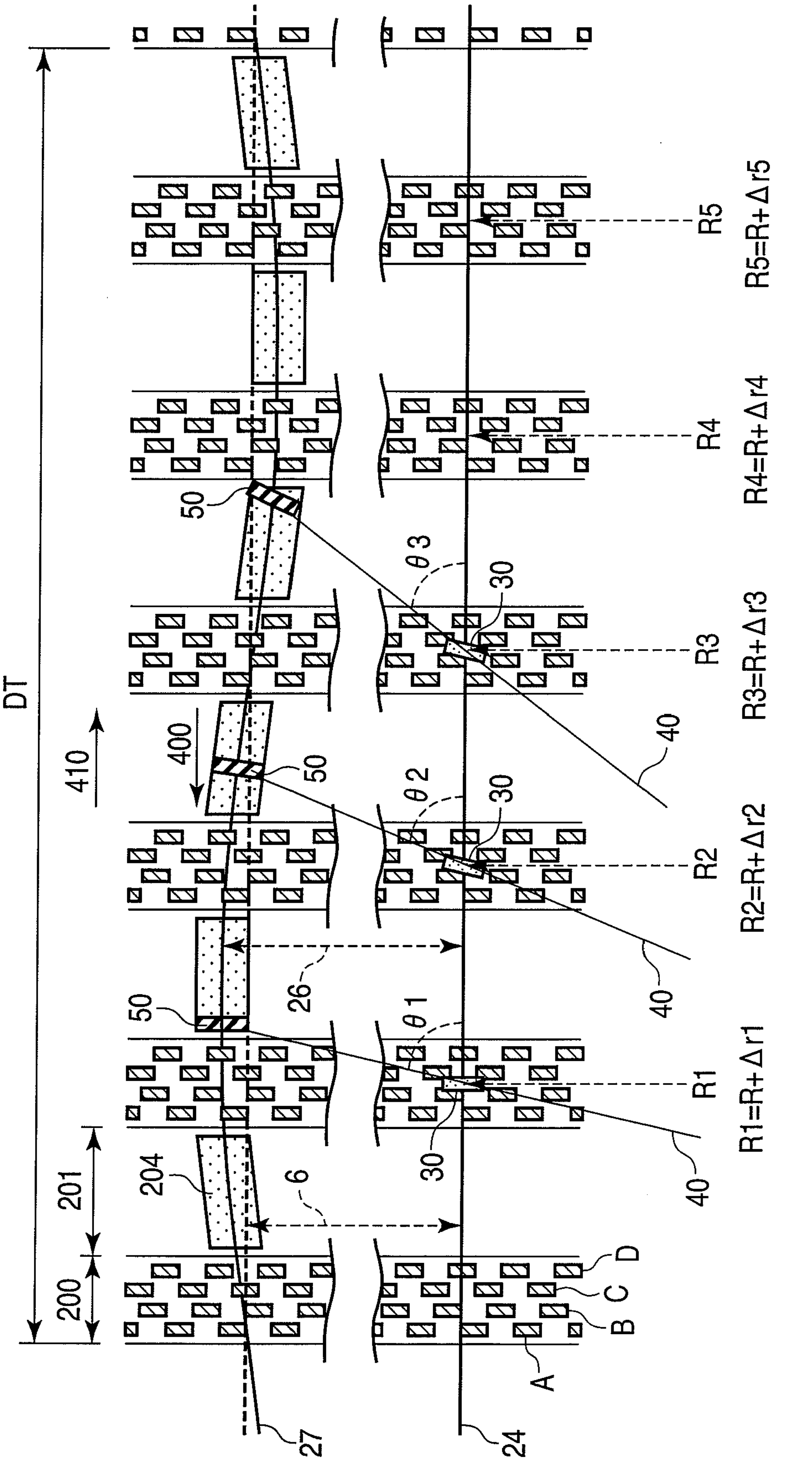
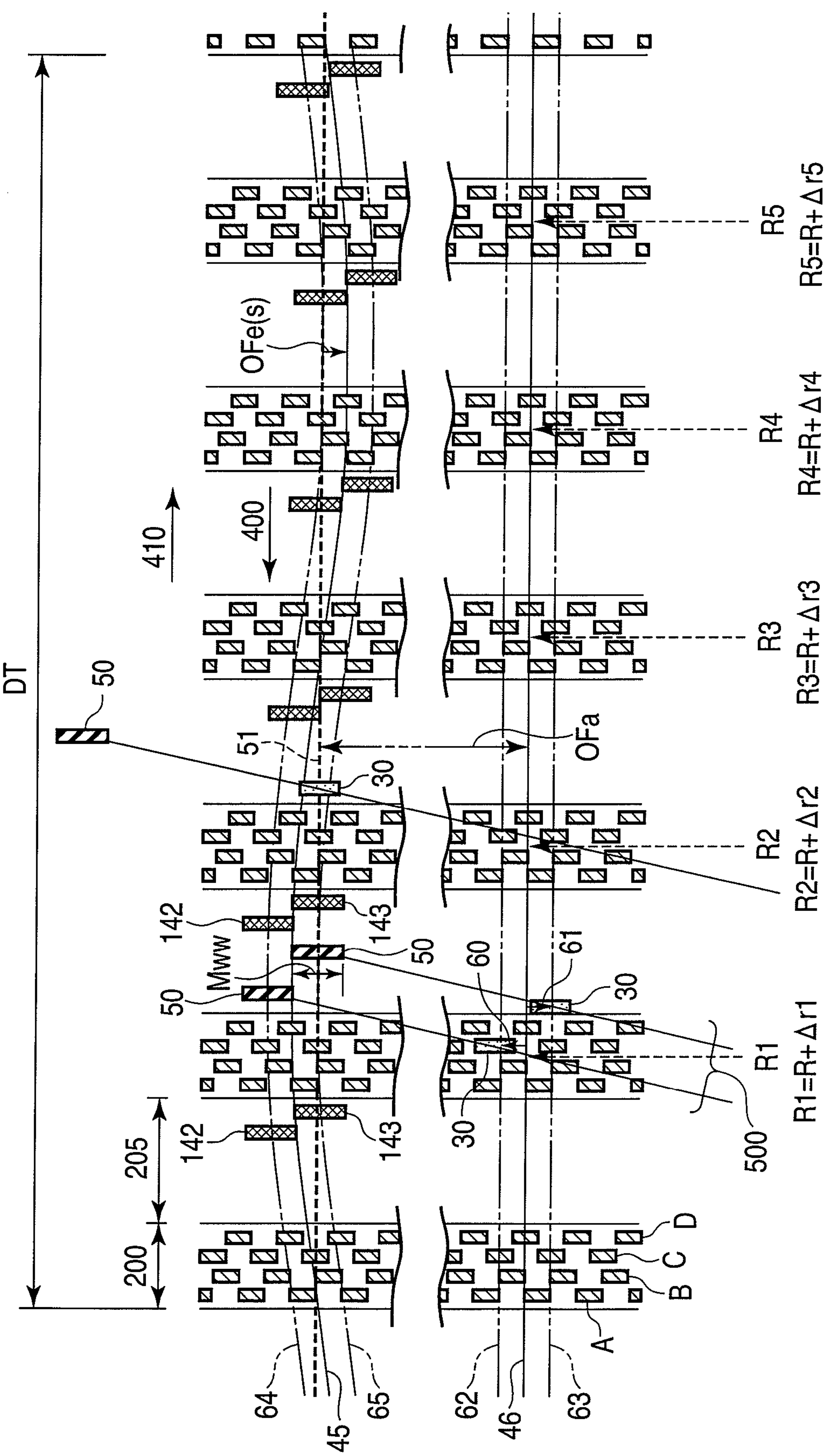

DT
410
400
200
201
204
6
26
27
24
50
30
40
A
B
C
D
θ1
θ2
θ3
R1
R2
R3
R4
R5
R1=R+Δr1
R2=R+Δr2
R3=R+Δr3
R4=R+Δr4
R5=R+Δr5

FIG. 8


DT
50
51
30
60
61
142
143
Mww
200
205
410
400
OFa
OFe(s)
R1
R2
R3
R4
R5
R1=R+Δr1
R2=R+Δr2
R3=R+Δr3
R4=R+Δr4
R5=R+Δr5
500
64
45
65
62
46
63
A
B
C
D

F I G. 9

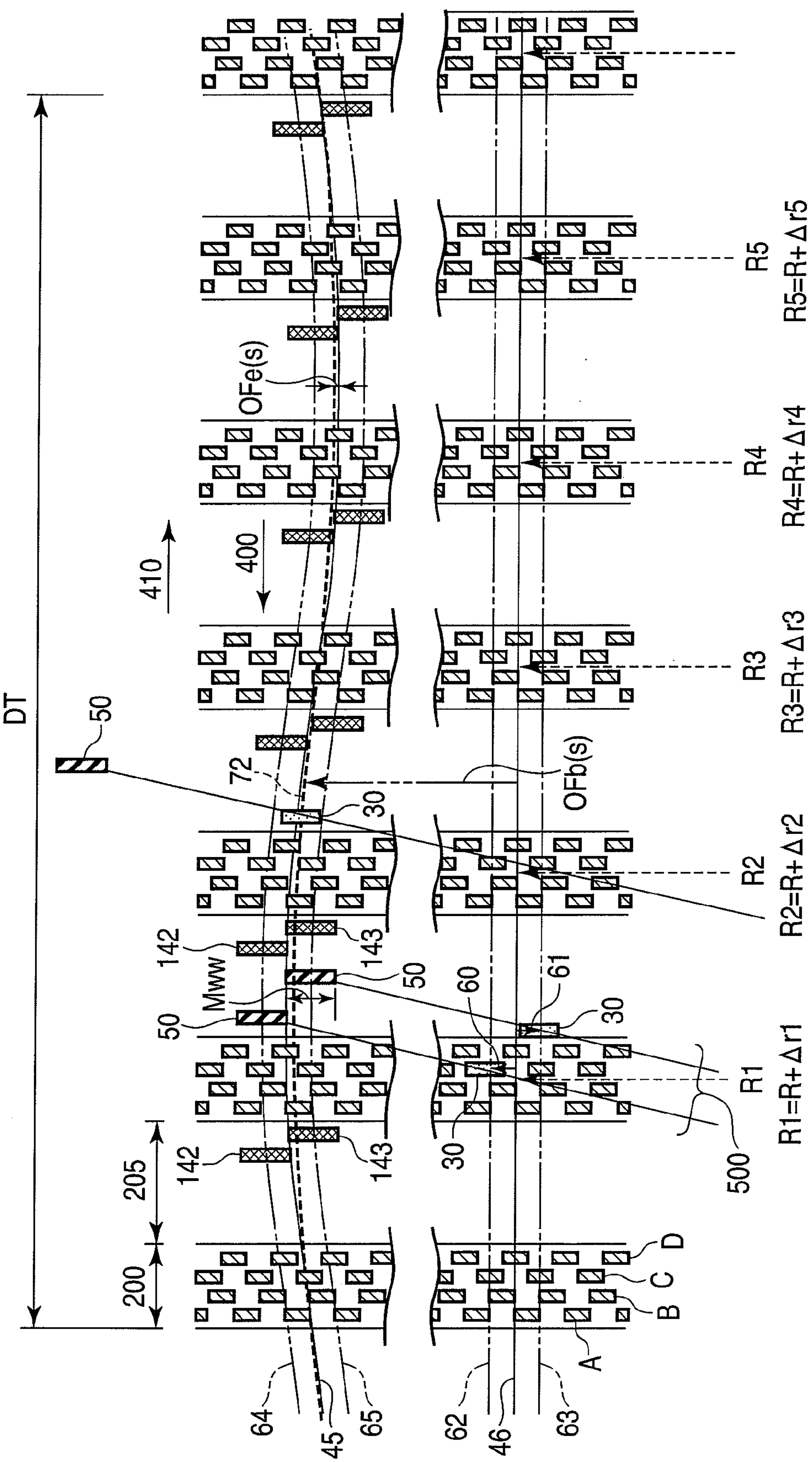

DT
50
200
205
142
143
Mww
50
60
61
30
72
OFb(s)
OFe(s)
400
410
R1
R2
R3
R4
R5
R1=R+Δr1
R2=R+Δr2
R3=R+Δr3
R4=R+Δr4
R5=R+Δr5
500
A
B
C
D
64
45
65
62
46
63

FIG. 10

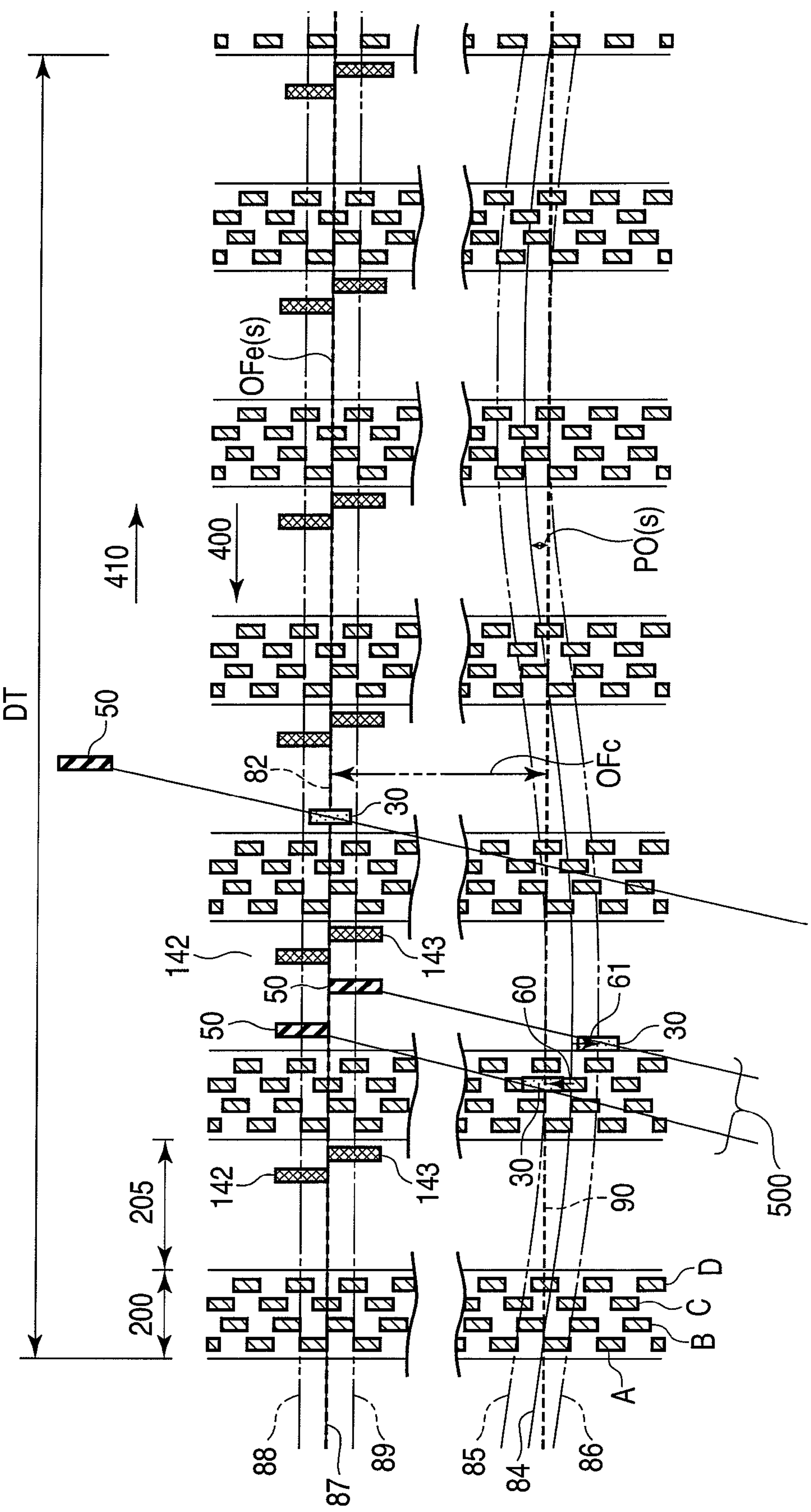

DT
50
30
82
OFc
OFe(s)
PO(s)
400
410
142
143
60
61
500
205
200
88
87
89
85
84
86
90
A
B
C
D

FIG. 11

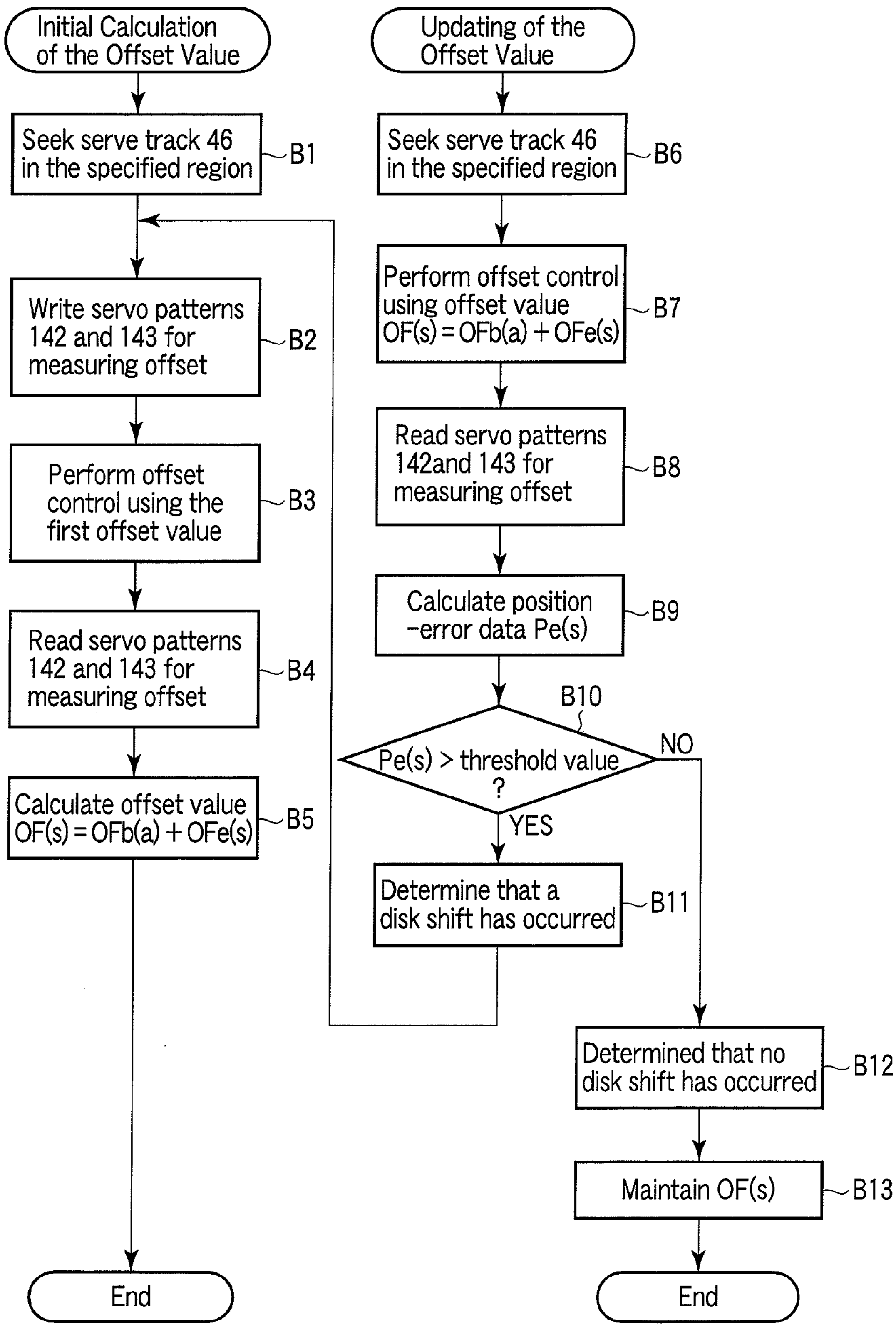

Initial Calculation of the Offset Value
Seek serve track 46 in the specified region
B1
Write servo patterns 142 and 143 for measuring offset
B2
Perform offset control using the first offset value
B3
Read servo patterns 142 and 143 for measuring offset
B4
Calculate offset value OF(s) = OFb(a) + OFe(s)
B5
End
Updating of the Offset Value
Seek serve track 46 in the specified region
B6
Perform offset control using offset value OF(s) = OFb(a) + OFe(s)
B7
Read servo patterns 142and 143 for measuring offset
B8
Calculate position -error data Pe(s)
B9
B10
Pe(s) > threshold value ?
NO
YES
Determine that a disk shift has occurred
B11
Determined that no disk shift has occurred
B12
Maintain OF(s)
B13
End

FIG. 12

METHOD AND APPARATUS FOR OFFSET CONTROL IN A DISK DRIVE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2008-304835, filed Nov. 28, 2008, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] 1. Field

[0003] One embodiment of the present invention relates to a disk drive such as a hard disk drive. More particularly, the invention relates to a technique of controlling the offset between the read head and the write head, both incorporated in a disk drive.

[0004] 2. Description of the Related Art

[0005] Most disk drives, a representative example of which is the hard disk drive, have a magnetic head that may record data in, and reproduce data from, a disk, i.e., magnetic recording medium. The magnetic head is mounted on a rotary-type actuator. The magnetic head can be moved in the radial direction of the disk and can be positioned at a target track (or cylinder) provided on the disk.

[0006] The magnetic head has a read head and a write head, which are mounted on one slider (head main body) and which are spaced apart from each other. The read head is, for example, a GMR element and is configured to read data recorded in the disk. The write head is configured to write data in the disk. Depending on the position the magnetic head assumes in the radial direction of the disk, a specific offset (positional deviation) develops between the track loci of the read head and the write head.

[0007] In order to position the magnetic head at a target position over the disk, offset control is performed on both the read head and the write head, thereby adjusting the positions of the read head and write head in accordance with the offset. The offset control is performed in accordance with an offset value that changes with the position the magnetic head takes in the radial direction of the disk. Note that the offset value is a value that remains unchanged as long as the magnetic head remains in the same track while the disk is rotating 360°.

[0008] In the disk drive, a phenomenon called "disk runout" may occur if the spindle motor is secured at a wrong position. Once a disk runout has occurred, the servo track deviates from the circular locus with respect to the rotation center of the disk. This results in a servo-track runout. Consequently, accurate offset control can no longer be performed on the magnetic head in the same track, because the offset value remains unchanged while the disk is rotating 360°.

[0009] To perform accurate offset control, a technique known as "dynamic offset control (DOC) has been proposed (see, for example, Jpn. Pat. Appln. KOKAI Publications Nos. 2005-216378 and 2007-172733, hereinafter referred to as "first and second publications," respectively). The dynamic offset control is performed by changing the offset value in accordance with the disk runout value. The first publication discloses a method of offset control that uses first and second offset values. The first offset value changes with the position the head takes in the track in the radial direction of the disk. The second offset value is calculated, changing as the disk rotates 360°. On the other hand, the second publication discloses a method that uses the first offset value identical to that described above, and monitors the second offset value that changes as the disk rotates 360°, directly on the basis of the error rate of data.

[0010] With regard to the dynamic offset control (DOC), a technique of measuring the disk runout has been proposed (see, for example, Jpn. Pat. Appln KOKAI Publication No. 11-126444 and Japanese Patent No. 3198490, hereinafter referred to as "third and fourth publications," respectively). More specifically, the third publication discloses a method in which the actuator holding a magnetic head is set at a specific position, the cylinder address information for one rotation of the disk from the servo sector, and the servo-track runout is measured from the cylinder address information. The fourth publication discloses a method of inferring a servo-track runout from a change in the time intervals of lock marks for one rotation of the disk.

[0011] As described above, the servo track that serves as the reference position for head positioning deviates, due to the disk runout, from the circular locus with respect to the rotation center of the disk (resulting in a servo-track runout). This means that the read head positioned at the servo track changes in the radial direction of the disk as the disk rotates 360°. Therefore, the offset between the read head and the write head must be changed as the disk rotates once.

[0012] The servo-track runout occurs mainly because of the disk runout that develops when a servo-track writer records servo data in the disk, thereby forming servo tracks on the disk. Further, another disk runout develops when the disk with the servo data recorded on it is incorporated into the disk drive. The two disk runouts combine, resulting in a larger disk runout.

[0013] Each of the above-identified publications proposes a method of changing the offset value as the disk rotates 360°. In this regard, a method is employed in which the offset value is indirectly calculated or inferred from the servo-track runout information and the sizes of the parts and mechanisms constituting the disk drive. However, the offset value calculated by this method is far from accurate. This method can hardly provide an accurate setoff value, particularly because the sizes of the parts and mechanisms greatly vary from one disk drive to another.

[0014] The third publication discloses a method of measuring directly the offset between the read and write heads, which changes as the disk rotates 360°, from a contour diagram being drawn while the both heads remain off the data track. However, this method takes a long time to measure the offset, and can hardly be put to practical use.

[0015] Moreover, when the disk drive receives an impact from outside, a disk shift occurs, inevitably changing the disk runout. It is therefore desirable to measure the offset value every time the magnetic head is loaded above the disk. Thus, the offset value must be measured frequently. Every time the offset value is measured, some time is spent. This ultimately impairs the data-access ability of the disk drive.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0016] A general architecture that implements the various feature of the invention will now be described with reference to the drawings. The drawings and the associated descriptions are provided to illustrate embodiments of the invention and not to limit the scope of the invention.

[0017] FIG. **1** is a block diagram explaining the configuration of a disk drive according to an embodiment of the present invention;

[0018] FIGS. **2**A to **2**H are diagrams explaining the timing of writing and reading a servo pattern for measuring the offset in the embodiment;

[0019] FIG. **3** is a diagram explaining recording areas in which to record the servo patterns for measuring an offset in the embodiment;

[0020] FIG. **4** is another diagram explaining the recording areas in which to record the servo patterns for measuring the offset in the embodiment;

[0021] FIG. **5** is a diagram explaining a modified recording area in which to record the servo pattern for measuring the offset in the embodiment;

[0022] FIG. **6** is another diagram explaining the modified recording area in which to record the servo pattern for measuring the offset in the embodiment;

[0023] FIG. **7** is a diagram explaining an offset measured when no disk runouts develop in the embodiment;

[0024] FIG. **8** is a diagram explaining an offset measured when a disk runout develops in the embodiment;

[0025] FIG. **9** is a diagram explaining how to calculate an offset value in the embodiment;

[0026] FIG. **10** is a diagram explaining a first modification of the method of calculating an offset value in the embodiment;

[0027] FIG. **11** is a diagram explaining a second modification of the method of calculating an offset value in the embodiment; and

[0028] FIG. **12** is a flowchart explaining a method of updating the offset value in the second embodiment.

DETAILED DESCRIPTION

[0029] Various embodiments according to the invention will be described hereinafter with reference to the accompanying drawings. In general, according to one embodiment of the invention, there is provided a disk drive in which the offset value that changes during a one-rotation period of the disk is directly measured, thereby measuring an offset value at high precision within a short time and accomplishing a practical offset control that results in no degradation of the data-accessing ability.

[0030] (Configuration of the Disk Drive)

[0031] According to an embodiment, FIG. **1** shows a block diagram explaining the configuration of a disk drive **100**.

[0032] As FIG. **1** shows, the disk drive **100** according to the embodiment has an apparatus mechanism and a control/signal-processing system. The apparatus mechanism includes a magnetic head **101**, a disk **103**, a spindle motor (SPM) **106**, and an actuator. The disk **103** is a magnetic recording medium. The SPM **106** can rotate the disk **103**. The actuator holds the magnetic head **101** and can move the magnetic head **101** over the disk **101** in the radial direction thereof. The control/signal-processing system will be described later.

[0033] The magnetic head **101** includes a read head and a write head, both mounted on a slider. The read head is configured to read (reproduce) data and servo data from the disk **103**. The write head is configured to write (record) data and a servo pattern for measuring an offset (i.e., position data for measuring the offset). The read head and write head are mounted, spaced apart from each other, on one slider that is the main body of the head **101**.

[0034] The actuator includes a suspension, an arm **102**, a pivot **104**, a coil, a magnet, a yoke, and a voice coil motor (VCM) **105**. The suspension holds the magnetic head **101**. The arm **102** can rotate around the pivot **104**. The VCM **105** generates a force for rotating the arm **102**. The actuator can move over the disk **103** in the radial direction of the disk **103** as a microprocessor (CPU) **112** (later described) performs head-positioning control (servo control). As the actuator moves, the magnetic head **101** is moved to a target position (target track) on the disk **103**.

[0035] A plurality of servo areas **200** are provided on the disk **103**. The servo areas **200** extend in the radial direction of the disk **103** and are spaced apart at regular intervals in the circumferential direction of the disk **103**. Further, a number of concentric tracks (cylinders) **201** are provided on the disk **103**. The tracks **201** are data tracks in which user data has been written by the write head. The tracks **201** are servo tracks, each including segments of servo areas **200**.

[0036] In each servo area **200**, an address code (cylinder code) and servo data are recorded. The address code identifies the track. The servo data contains servo-burst signals from which the position of the head **101** is detected. The CPU **112** uses the servo data read by the read head to perform the head-positioning control (servo control).

[0037] The control/signal-processing system has a motor driver **107**, a head amplifier unit **108**, a read/write channel **109**, a hard disk controller (HDC) **111**, a CPU **112**, and a memory **113**. The motor driver **107** has an SPM driver **107**A and a VCM driver **107**B. The SPM driver **107**A supplies a drive current to the SPM **106**. The VCM driver **107**B supplies a drive current to the VCM **105**.

[0038] The head amplifier unit **108** includes a read amplifier **108**A and a write driver **108**B. The read amplifier **108**A amplifies a read signal SR read by the read head of the magnetic head **101** and outputs the read signal SR to the read/write channel **109**. The write driver **108**B receives write data WD from the read/write channel **109** and converts the same to a write signal (write current) WS. The write signal WS is supplied to the write head of the magnetic head **101**. The write driver **108**B converts the write data WD to a write signal WS at the timing of a write-gate signal DWG**2** output from a data modulating/demodulating unit **114**.

[0039] The read/write channel **109** is a signal-processing unit that processes read signals and write signals. The read/write channel **109** has a data-modulating/demodulating unit **114**, a servo-pattern generating unit **115**, and a servo demodulation unit **116**. The servo-pattern generating unit **115** generates a servo pattern for measuring an offset.

[0040] The data-modulating/demodulating unit **114** receives the record data **125** transferred from the HDC **111** at the timing of a write-gate signal DWG**1** output from the HDC **111** and modulates (encodes) the same, generating write data WD. The unit **114** demodulates (decodes) a read-data signal RD output from the read amplifier **108**A and demodulates (decodes) the same, generating reproduced data **125**. The reproduced data **125** is output to the HDC **111** at the timing of a read-gate timing signal (DRG) coming from the HDC **111**.

[0041] The servo-pattern generating unit **115** generates servo-record data **122** at the timing of a servo-write gate signal **117** (SWG-**1**) output from the HDC **111**. The servo-record data **122** contains a servo-gate signal **121** (SWG-**2**) and an offset-measuring servo pattern (offset-measuring position data). At this point, the unit **115** receives a sync signal **124** from the servo demodulation unit **116**.

[0042] The servo demodulation unit **116** receives a servo-reproducing signal **123** output from the read amplifier **108**A. The servo demodulation unit **116** demodulates (decodes) this signal **123**, generating servo data **120** that contains an address code and servo-burst signals (A to D). The servo data **120** is output to the HDC **111**. The servo demodulation unit **116** demodulates the servo-burst signals (burst patterns A and B) at the timing of servo-read gate signal **118** (SRG-A) and servo-read gate signal **119** (SRG-B) output from the HDC **111**.

[0043] The HDC **111** constitutes an interface between the disk drive **100** and a host system (personal computer or digital apparatus) **110**. The HDC **111** controls the transfer of the user data (read data and write data) between the disk drive **100** and the host system **110**. The HDC **111** controls the read/write operation of the read/write channel **109**, too.

[0044] The CPU **112** is the main controller of the disk driver, or the main component of the servo system of the servo system that performs the head-positioning control (servo control). The CPU **112** performs not only the seek operation and tracking (position control) during the head-positioning control, but also dynamic offset control (DOC) that characterizes the embodiment.

[0045] The memory **113** includes a flash memory, a ROM, and a RAM. The memory **113** stores various data items that the CPU **112** uses to perform control.

[0046] (Method of Calculating the Offset Value)

[0047] A method of calculating the offset value in this embodiment will be explained with reference to FIGS. **2**A to **2**H and FIGS. **3** to **11**. FIGS. **2**A to **2**H are diagrams explaining the timing of writing, and the timing of reading, servo patterns **142** and **143** for measuring the offset (i.e., offset-measuring position data items).

[0048] First, the offset, which exists between the read head and write head of the magnetic head **101** if any disk runout (servo-track runout) has not developed, will be explained with reference to FIG. **7**. In FIG. **7**, reference number **400** denotes the direction in which the magnetic head **101** moves, and reference numeral **410** indicates the direction in which the disk **103** rotates.

[0049] In the disk drive **100**, the CPU **112** controls the position of the magnetic head **112** as described above, in accordance with the servo data recorded in the servo areas **200** provided on the disk **103**. In FIG. **7**, only servo-burst signals A to D, i.e., accurate position data **141**, for the sake of convenience. In fact, however, sync signals, servo address data (track address codes), and the like are recorded in the servo areas **200**.

[0050] In the head-positioning control, the read head **30** is positioned at the centerline of the servo track so that the components of a reproduced signal, which correspond to the servo-burst signals A and B, may have the same amplitude. That is, the read head **30** is located over the servo track **4** that is identical to the locus of the gap center of the read head **30**. Here, the centerline of the servo track is defined as servo track **4** or **7**, for convenience.

[0051] As seen from FIG. **7**, the radius R of the servo track **4**, as measured from the rotation center of the disk, remains unchanged for a one-rotation period DT during which the disk rotates 360°. This means that a servo-track runout (disk runout) does not develop at all if the servo track **4** does not deviate from the circular locus with respect to the rotation center of the disk.

[0052] As shown in FIG. **7**, the servo track **7**, which is identical to the locus of the gap center of the write head **50**, remains at a distance (i.e., read/write offset) **6** from the servo track **4** that is the positioning locus of the read head **30**, for the one-rotation period DT during which the disk rotates once. Thus, if the radius that the servo track **4** has with respect to the read head **30** remains constant for the one-rotation period DT, the skew angle θ will remain constant, which is an angle defined by the servo track **4** and the line connecting the gap center of the read head **30** and that of the write head **50**. Hence, the offset **6** can be calculated, using the following equation:

$$\text{Offset } 6 = \text{inter-gap distance } G \times \sin\theta = \text{constant}$$

[0053] FIG. **7** is based on the assumption that the magnetic head **101** is an in-line type and that the gap center of the read head **30** therefore lies on line **40** connecting the gap center of the write head **50** and the pivot **104** around which the actuator (arm) **102** holding the magnetic head **101** rotates. Therefore, when the write head **50** writes data, it forms a data track **204** in the servo track **7** provided in the track **201** (data area). To read the data, the read head **30** is adjusted in position by specific offset **6**. So positioned over the servo track **7**, the read head **30** starts reading data.

[0054] The offset will be further described, with reference to FIG. **8**, in the case where a disk runout (servo-track runout) develops in the disk drive **100**.

[0055] The read head **30** is positioned at the centerline of a servo track **24** so that the components of a reproduced signal, which correspond to the servo-burst signals A and B, may have the same amplitude. That is, the read head **30** is located over the servo track **24** that is the locus of the gap center of the read head **30** has a servo-track runout. That is, the radius of the servo track **24**, which is the distance from the center of rotation of the disk to the servo track **24**, changes during the one-rotation period DT (from R**1** to R**5**).

[0056] Such a servo-track runout (disk runout) usually develops in disk drives. The servo data is recorded in the servo areas **200** provided on the disk **103** during the manufacture of the disk drive by a servo-track writer (STW) that is dedicated to servo-data writing. During the manufacture of the disk drive, it is difficult to align the center of the servo track with the rotation center of the disk **103**, because the center of the disk **103** deviates from the rotation axis of the SPM **106**.

[0057] As shown in FIG. **8**, the radius of the servo track **24** changes (from R**1** to R**5**) with respect to the read head **30** during the one-rotation period DT. The change in the radius changes the skew angle θ defined by the servo track **24** and the line connecting the gap center of the read head **30** and that of the write head **50**, during the one-rotation period DT of the disk **1** (from θ**1** to θ**3**). Hence, the offset **26** between the read head **30** and the write head **50** changes during the one-rotation period DT. The offset **26** is the distance from the servo track **24**, i.e., locus of the gap center of the read head **30**, to the gap center of the write head **50**.

[0058] In this case, an error will develop with respect to a data-write locus **27** if the offset control (position control) is performed on the read head **30**, moving the read head **30** from the servo track **24** to another servo track (indicated by the broken line) located at a specific distance (i.e., offset **6**) from the servo track **24**.

[0059] In the disk drive **100** according to the embodiment, servo patterns **142** and **143** for measuring the offset (i.e., offset-measuring position data items) are written in a specified region of the non-servo area **205** provided on the disk **193** in addition to the servo areas **200**, as shown in FIGS. **2**A to **2**H and FIG. **9**. The servo patterns **142** and **143** for measuring the offset may be reproduced, and the offset value that changes during the one-rotation period may be calculated from the servo patterns **142** and **143** reproduced.

[0060] The timing of writing and reading the servo patterns **142** and **143** for measuring the offset will be explained with reference to FIGS. **2**A to **2**H.

[0061] Note that the servo patterns **142** and **143** for measuring the offset are burst signals (e.g., signals M and N, for convenience) that are equivalent to the burst signals A to D that are accurate position data contained in ordinary servo data.

[0062] At the timing of the servo-read gate signal **118** (SRG-A) output from the HDC **111**, the read/write channel **109** demodulates the servo data **120** read by the read head **30** from the servo area **200**, as illustrated in FIG. **2**B. As shown in FIG. **2**A, the servo area **200** includes two regions, **140** and **141**. In the region **140**, sync signal **145** and servo-address data **146** (track-address code and sector-address code) are recorded. In the region **141**, servo-burst signals A to D are recorded. As shown in FIG. **4**C, the servo data **120** demodulated contains sync signal **145**, servo-address data **146**, and servo-burst signals A to D (**147** to **149**).

[0063] As shown in FIGS. **2**D, **2**E and **2**F, the servo-pattern generating unit **115** generates servo-record data **122** at the timing of the servo-write gate signal **117** (SWG-**1**) output from the HDC **111**. The servo-record data **122** contains a servo-gate signal **121** (SWG-**2**) and an offset-measuring servo pattern (offset-measuring position data).

[0064] The write driver **108**B receives the servo-record data **122** output from the servo-pattern generating unit **115** and converts the same to a servo-data signal **151**. The servo-data signal **151** is supplied to the write head **50**. More precisely, the write driver **108**B supplies the servo-data signal **151** to the write head **50** at the timing of the servo-gate signal **121** (SWG-**2**). Thus, as FIG. **2**A shows, the servo patterns **142** and **143** for measuring the offset can be recorded outside the servo area **200**, for example in a specified region of the non-servo area **205** that is adjacent to the servo area **200**.

[0065] As shown in FIGS. **2**G and **2**H, the servo demodulation unit **116** demodulates the servo data **120** read by the read head **30**, at the timing of the servo-read gate signal **119** (SRG-B) output from the HDC **111**. The servo demodulation unit **116** therefore demodulates burst signals **152** and **153** that correspond to the servo patterns **142** and **143**, respectively.

[0066] The servo patterns **142** and **143** for measuring the offset, recorded in the specified region of the non-servo area **205**, are thus reproduced by the method described above. A method of calculating an offset value (i.e., offset **26** shown in FIG. **8**) that changes during the one-rotation period of the disk will be explained in detail with reference to FIG. **9**.

[0067] As described above, the CPU **112** uses the servo-pattern generating unit **115**, ultimately self-servo writing the servo patterns **142** and **143** for measuring the offset, on the locus (write-head locus **45**) of the write head **50** that is equivalent to the data-track locus. That is, the servo patterns **142** and **143** equivalent to burst signals A and B are recorded in the specified region of the non-servo area **205**, which lies outside the servo area **200** provided on the disk **103**. In FIG. **9**, reference number **500** denotes the position that the read head **30** and write head **50** assume when they perform self-servo writing.

[0068] Next, the CPU **112** moves the read head **30** by an offset distance OFa calculated beforehand, adjusting the position of the read head **30** with respect to the read-head locus **51**, or aligning the read head **30** at the locus **51**. Thus moved, the read head **30** reads the servo patterns **142** and **143** for measuring the offset. The CPU **112** causes the HDC **111** to acquire the position-error data about the read head **30**, in accordance with the servo patterns **142** and **143** for measuring the offset. The CPU **112** therefore directly monitors the offset value between the read head **30** and the write head **50** during the one-rotation period DT.

[0069] The CPU **112** controls the position of the read head **30** so that the components of the reproduced signal, which correspond to the servo-burst signals A and B, may have the same amplitude. At this point, as shown in FIG. **9**, the read head **30** and the write had **50** lie right above the right-head locus **46** and the write-head locus **45**, respectively.

[0070] Then, the read head **30** is set off by about half (½) the recording width Mww of the write head **50** (by offset value **61** from the read-head locus **63**). In this state, the write head **50** writes a burst signal **143** by means of self-servo writing, in synchronism with the servo data in the servo area **200**, at a position adjusted to the write-head locus **65**.

[0071] The read head **30** is further set off by about half (½) the recording width Mww of the write head **50** (by offset value **60** from read-head locus **62**), writing a burst signal **142** in the non-servo area **205**. In this state, the write head **50** writes the burst signal **142** by means of self-servo writing, in synchronism with the servo data in the servo area **200**, at a position adjusted to the write-head locus **64**.

[0072] The CPU **112** sets off the read head **30** by a prescribed distance, i.e., offset OFa. The CPU **112** then reproduces the burst signals **142** and **143**, both having been self-servo written, at the timing represented by the servo data recorded in the servo area **200**. The CPU **112** calculates position-error data OFe(s) from the burst signals **142** and **143**. Note that "(s)" is the value by which the offset value changes during the one-rotation period. The position-error data OFe (s) is equal to the offset error. Note that the offset OFa is a specific value (a specific distance) obtained from the position the read head **30** takes on the radius of the disk **103**. The CPU **112** calculates the offset value OF(s), using the following equation:

$$OF(s)=OFa+OFe(s)$$

[0073] FIG. **10** is a diagram explaining a first modification of the method of calculating, in the embodiment, an offset value that changes during the one-rotation period.

[0074] In the first modified method, too, the servo patterns for measuring the offset are written from the burst signals **142** and **143**, in the non-servo area **205** by means of self-servo writing, in the same manner as in the embodiment shown in FIG. **9**.

[0075] In the first modified method, the read head **30** is controlled in position by using the offset value OFb(s) changing during the one-rotation period, in order to acquire the position-error data OFe(s) from the burst signals **142** and **143** that have been self-servo written. That is, the CPU **112** adjusts the position of the read head **30** on a read-head locus **72** indicated by a broken line in FIG. **10**. The CPU **112** calculates the offset OF(s) from the burst signals **142** and **143** read by the read head **30**. In this case, the offset OF(s) that changes during the one-rotation period is calculated using the following equation:

$$OF(s)=OFb(s)+OFe(s)$$

[0076] FIG. **11** is a diagram explaining a second modification of the method of calculating an offset value that changes while the disk is rotating 360° in the embodiment described above.

[0077] In the second modified method, the CPU **112** adjusts the position of the read head **30** so that the components of the reproduced signal, which correspond to the servo-burst signals A and B, may have the same amplitude. More precisely, the CPU **112** adjusts the position of the read head **30** on the read-head locus **90** indicated by the broken line as shown in FIG. **11**.

[0078] At this point, the CPU **112** uses the position change PO(s), i.e., difference between a locus **84** and a locus **90**, setting the read head **30** to about half (½) the recording width Mww of the write head **50** (by offset value **61** from read-head locus **86**). Then, the CPU **112** causes the write head **50**, which is now on a write-head locus **89**, to write the burst signal **143** by means of self-servo writing. Similarly, the CPU **112** sets off the read head **30** by the same value as described above (by offset value **60** from the read-head locus **85**), and causes the write head **50**, which is now on a write-head locus **88**, to perform self-servo writing, thus writing the burst signal **142**.

[0079] Next, the CPU **112** sets off the read head **30** with respect to the read-head locus **90** by a prescribed offset OFc (prescribed distance). The CPU **112** obtains the position-error data OFe(s) from the burst signals **142** and **143** that the read head **30** have read. In this case, the offset OF(s) between the read head **30** and the write head **50**, which changes during the one-rotation period, is calculated, using the following equation:

$$OF(s)=PO(s)+OFc(s)+OFe(s)$$

[0080] (Recording Areas of Servo Patterns for Measuring the Offset)

[0081] FIG. **3** and FIG. **4** are diagrams explaining recording areas in which to record the servo patterns **142** and **143** for measuring an offset in the embodiment.

[0082] In this embodiment, the recording areas for the servo patterns **142** and **143** are, respectively, the outermost track of the disk **103** and the innermost track of the disk **103**, as illustrated in FIG. **3** and FIG. **4**. In other words, they are one-track areas **202** and **203**, in and from which no user data is recorded and reproduced. Alternatively, the recording areas for the servo patterns **142** and **143** may be two outermost one-track areas **202** and **203** or two innermost one-track areas **202** and **203**. The latter alternative case is preferable.

[0083] The offset value OF(s) between the read head **30** and the write head **50** is measured by using the burst signals **142** and **143** read from the innermost one-track area **202** and the outermost one-track area **203**, respectively. In this case, the offset value in the data area **201** is offset value OF**2**(*s*) that has been corrected through theoretical calculation based on the sizes of the mechanism-system components. To calculate the offset value OF**2**(*s*), the offset acquired at the innermost track or the outermost track is used. Alternatively, both offsets acquired at the innermost and outermost tracks may be used to calculate the offset value OF**2**(*s*).

[0084] FIG. **5** and FIG. **6** are diagrams explaining modified recording areas in which to record the servo patterns **142** and **143** for measuring the offset in the embodiment. In the modification, recording areas **300** for recording the servo patterns **142** and **143** are provided, each between a servo area **200** and a data area **201** as shown in FIG. **5** as is illustrated in FIG. **5** and FIG. **6**. No user data is recorded in, or reproduced from, the recording areas **300**.

[0085] As has been described, the present embodiment can directly calculate the offset between the read head and the write head, which changes during the one-rotation period of the disk. Therefore, the offset value that changes during the one-rotation period can be accurately calculated within a short time. This is useful in actual practice, and does not impair the data-access ability of the disk drive **100** that performs DOC. Further, it suffices to provide, for example, only about two tracks on the disk **103**, as specified regions in which to record the servo patterns for measuring the offset (i.e., offset-measuring position data). Therefore, the track density will not decrease.

[0086] (Method of Updating the Offset Value)

[0087] As described above, the disk drive according to the present embodiment has a function of calculating the offset value OF(s) that changes during the one-rotation period of the disk **103**, from the offset-measuring position data recorded in the disk **103**. The offset value OF(s) is the sum of the first offset value OFa, called "first offset value" for convenience, and the position-error data OFe(s). The offset value OF(s) shall be called "second offset value," for convenience. The first offset value OFa is a constant value that depends on the position the head takes on the radius of the disk **103**. The position-error data OFe(s) is a value calculated from the burst signals **142** and **143** that constitute the offset-measuring position data.

[0088] The second offset value OF(s) results from the disk runout. In the disk drive **100**, the CPU **112** stores the second offset value OF(s) calculated, into the memory **113**, and performs DOC in order to accomplish head-positioning control. The second offset value OF(s) need not be updated if the disk runout does not change.

[0089] As in most disk drives, the disk **103** is pressed onto the SPM **106** by a member known as a disk clamper. An impact or vibration greater than the clamping force of the disk clamper may be applied to the disk **103**. If this happens, the disk **103** will be moved, resulting in a disk runout, or a disk shift. Once a disk shift has occurred, the second offset value OF(s) must be updated.

[0090] A method of updating an offset value OF(s) in the present embodiment will be explained with reference to the flowchart of FIG. **12**.

[0091] During the manufacture of the disk drive **100**, the CPU **112** uses the equation of using the above-given equation of OF(s)=OFa+OFe(s), calculating an offset value OF(s) for the first time. That is, the CPU **112** causes the VCM driver **107**B to drive the actuator **102**. As the actuator **102** is driven, the read head **30** seeks the serve track (locus **46**) provided in the outermost one-track area **203** (i.e., offset-measuring position) of the disk **103** as is illustrated in FIG. **9** (Block B**1**). The CPU **112** causes the write head **50**, now positioned at the write-head locus **45**, to write burst signals (servo patterns) **142** and **143** in the non-servo area **205** of the disk **103** (Block B**2**). Recall that the burst signals **142** and **143** constitute the offset-measuring position data.

[0092] Next, the CPU **112** uses the first offset value OFa, performing an offset control on the read head **30**. That is, the CPU **112** causes the VCM driver **107**B to drive the actuator **102**, moving the read head **30** to the non-servo area **205** of the disk **103** (Block B**3**). The CPU **112** causes the read head **30** to read the burst signals **142** and **143** from the disk **10**, thus reproducing the offset-measuring position data (Block B**4**). The CPU **112** then calculates position-error OFe(s) from the burst signals **142** and **143** and adds the OFe(s) to the first offset value OFa, providing an offset value OF(s) that changes during the one-rotation period of the disk **103** (Block B**5**). The CPU **112** stores the offset value OF(s) into the memory **113**. The offset value OF(s) stored in the memory **113** will be used in the DOC to perform a head-positioning control during the read/write operation.

[0093] If an accelerometer, for example, detects an impact or vibration externally applied to the disk drive **100**, the CPU **112** updates the offset value OF(s). Alternatively, the offset value OF(s) may be updated when the head **101** is moved from the standby position to the target position over the disk **103** at the time of, for example, activating the disk drive **100**, before starting a read/write operation.

[0094] The CPU **112** causes the read head **30** to seek the servo track (locus **46**) provided in the provided in the outermost one-track area **203** (Block B**6**), as is illustrated in FIG. **9**. The CPU **112** acquires the offset value OF(s) calculated last, from the memory **113**. Using this offset value OF(s), the CPU **112** performs the DOC, adjusting the position of the read head **30** to the non-servo area **205** (Block B**7**). The CPU **112** causes the read head **30** to read the burst signals **142** and **143** (i.e., the offset-measuring position data) from the disk **10**, thus reproducing the offset-measuring position data (Block B**8**). The CPU **112** then obtains the calculated position-error data Pe(s) (Block B**9**).

[0095] The CPU **112** compares the calculated position-error data Pe(s) with a preset threshold value C, thereby determining whether a disk shift has occurred after the recording of the last offset-measuring position data (i.e., burst signals **142** and **143**) (Block B**10**). Note that the threshold value C is the upper limit of the range of tolerant head-position error.

[0096] If the position-error data Pe(s) calculated is smaller than the threshold value C, or is almost 0 (zero), far smaller than the value C (if NO in Block B**10**), the CPU **112** determines that no disk shift has taken place (Block B**12**). In this case, no disk runout has occurred, and the read head **30** moves over the locus **45** shown in FIG. **9**. Hence, the read head **30** reads the server burst patterns **142** and **143**, and the position-error data Pe(s) calculated becomes almost zero, far smaller than the threshold value C. Therefore, the offset value OF(s), if calculated, remains unchanged if calculated again, and need not be updated at all. Thus, the offset value OF(s) last calculated is maintained (Block B**13**).

[0097] On the other hand, if a disk shift may occur after the recording of the last offset-measuring position data. In this case, the read head **30** does not move over the track locus **45**. The read head **30** therefore reads the servo patterns **142** and **143**. The position-error data Pe(s) exceeds the threshold value C. The CPU **112** therefore determines that a disk shift has taken place and calculates the offset value OF(s) again by the above-described method (Block B**11**). Hence, the position-error data Pe(s) exceeds the threshold value C, indicating that a position error has been made. The CPU **112** therefore determines that a disk shift has taken place. Then, the CPU **112** performs the above-mentioned sequence of steps, calculating the offset value OF(s) again (Block B**11**). The CPU **112** stores the offset value OF(s) calculated anew, in the memory **113**. The offset value OF(s) is thus updated.

[0098] In the present embodiment, the position data (i.e., burst signals **142** and **143**) remain unchanged and stored in the outermost one-track area **202** and innermost one-track area **203** (see FIGS. **3** and **4**), respectively, until the offset value is updated completely.

[0099] As has been described, the offset value OF(s) is not updated if no disk shift has occurred after it has been calculated during the manufacture of the disk drive **100**. If the position error of the read head, resulting from the dynamic offset control (DOC), exceeds a preset threshold value, a disk shift is detected to have occurred. In this case, the offset-measuring position data (i.e., servo burst patterns **142** and **143**) is recorded again, and a new offset value OF(s) is calculated by performing a sequence of steps, thereby updating the offset value stored in the memory **113**.

[0100] In the method according to this embodiment, whether a disk shift has occurred can be determined at high precision, not influenced by temperature and the like, within a short time equivalent to a one-rotation period of the disk. In addition, the time required to update offset value can be shorted. This is because the offset value need not be updated if no disk shifts have occurred.

[0101] While certain embodiments of the inventions have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A disk drive comprising:

a disk comprising a servo region configured to store servo data;

a magnetic head comprising a write head and a read head configured to maintain a distance of a prescribed offset, the write head configured to write data in the disk, and the read head configured to read data from the disk;

a head-position controller configured to position the magnetic head at a target position over the disk, in accordance with the servo data read by the read head;

an offset calculator configured to write offset-measuring position data for measuring an offset value between the read head and the write head, on a locus of the write head corresponding to a locus of a data track in a predetermined region of the disk other than the servo area, and configured to calculate the offset value from the offset-measuring position data read by the read head;

a controller configured to store the offset value calculated by the offset calculator and to control an offset dynamically using the offset value;

a determination module configured to determine whether a disk shift has occurred after the offset calculator calculated the offset value; and

an updating module configured to update the offset value when the determination module determines that a disk shift has occurred.

2. The disk drive of claim **1**, wherein

the offset-measuring position data comprise burst signals corresponding to servo-burst signals in the servo data; and

the offset calculator is configured to adjust the position of the read head by a distance equivalent to the prescribed offset, to calculate the position error of the read head as an offset error from the offset-measuring position data read by the read head, and to add the prescribed offset to the offset error thereby calculating the offset value.

3. The disk drive of claim **1**, wherein

the offset-measuring position data comprise burst signals corresponding to servo-burst signals in the servo data; and

the offset calculator is configured to adjust the position of the read head by a distance corresponding to a change of the offset value during a one-rotation period of the disk, to calculate the position error of the read head as an offset error from the offset-measuring position data read by the read head, and to add the prescribed offset to the offset error thereby calculating the offset value.

4. The disk drive of claim **1**, wherein the offset-measuring position data comprise burst signals corresponding to servo-burst signals in the servo data; and

the offset calculator is configured to use a position change of the read head while the write head is writing the offset-measuring position data during a one-rotation period of the disk, to adjust the position of the read head by the prescribed offset to a locus of the write head while the write head is writing the offset-measuring position data, to calculate the position error of the read head as an offset error from the offset-measuring position data read by the read head, and to add the position change of the write head, the prescribed offset and the offset error, thereby calculating the offset value.

5. The disk drive of claim **1**, wherein the determination module is configured to use the offset value stored in the memory, to cause the controller to dynamically control the offset of the read head, and to determine whether a disk shift has occurred from the position error calculated from the read out offset-measuring position data.

6. The disk drive of claim **1**, wherein the determination module is configured to determine that no disk shift has occurred when the position error in the offset-measuring position data is smaller than a preset threshold value, and to determine that a disk shift has occurred when the position error exceeds the threshold value.

7. The disk drive of claim **1**, wherein the determination module and the updating module are configured to start operating after the magnetic head is moved from a standby position to any position over the disk and before data is either recorded in from the disk or reproduced from the disk.

8. The disk drive of claim **1**, wherein the determination module and the updating module are configured to start operating when the disk drive is detected to be subjected to impact or vibration.

9. An offset calculating method of a disk drive that comprises a disk comprising a servo region configured to store servo data and a magnetic head comprising a write head and a read head configured to maintain a distance of a prescribed offset, the write head configured to write data in the disk, and the read head configured to read data from the disk, the method comprising:

positioning the magnetic head in accordance with the servo data read by the read head and writing offset-measuring position data for measuring an offset value between the read head and the write head, on a locus of the write head corresponding to a locus of a data track in a predetermined region of the disk other than the servo area;

calculating the offset value from the offset-measuring position data read by the read head;

storing the offset value in a memory;

controlling an offset dynamically using the offset value stored in the memory;

determining whether a disk shift has occurred after the calculation of the offset value; and

updating the offset value when a disk shift has occurred.

10. The method of claim **9**, further comprising:

reading the offset-measuring position data using the offset value stored in the memory by the dynamically offset controlled read head; and

determining whether the disk shift has occurred from a position error calculated from the offset-measuring position data.

11. The method of claim **9**, further comprising:

determining that no disk shift has occurred when a position error calculated from the offset-measuring position data is smaller than a preset threshold value; and

determining that a disk shift has occurred when the position error exceeds the preset threshold value.

12. The method of claim **9**, wherein the determining whether a disk shift has occurred and the updating the offset value occur after the magnetic head is moved from a standby position to any position over the disk and before data is either recorded in the disk, or reproduced from the disk.

13. The method of claim **9**, wherein the determining whether a disk shift has occurred and the updating the offset value are configured to start when the disk drive is detected to be subjected to impact or vibration.

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