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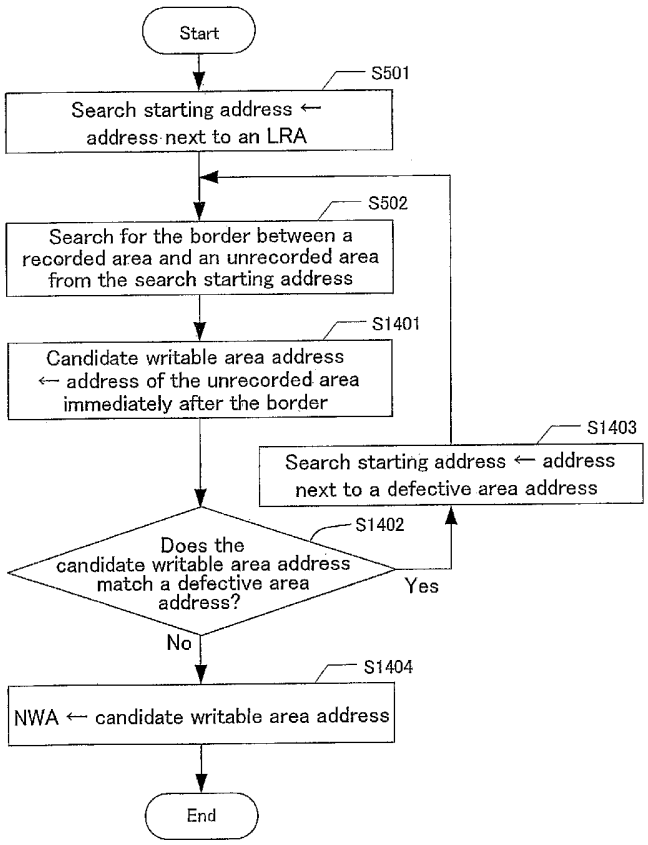
(54) Title: APPARATUS AND METHOD FOR SEARCHING FOR WRITABLE AREA, APPARATUS AND METHOD FOR UPDATING RECORDING MANAGEMENT INFORMATION, INTEGRATED CIRCUIT, AND WRITE-ONCE INFORMATION RECORDING MEDIUM



(57) Abstract: An apparatus is provided for searching for a writable area of a write-once information recording medium, comprising a searching portion and a control portion. The searching portion searches for an unrecorded area using a prescribed address as a reference. The control portion provides a candidate address indicating a candidate for a writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in defect management information. When it is determined that there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

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DESCRIPTION

APPARATUS AND METHOD FOR SEARCHING FOR WRITABLE AREA, APPARATUS AND METHOD FOR UPDATING RECORDING MANAGEMENT INFORMATION, INTEGRATED CIRCUIT, AND WRITE-ONCE INFORMATION RECORDING MEDIUM

CROSS REFERENCE TO RELATED APPLICATIONS

This non-provisional application claims priority under 35 U.S.C. §119(a) on Patent Application No. 2003-178165 filed in Japan on June 23, 2003, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates to an apparatus and method for searching for a writable area, an apparatus and method for updating recording management information, an integrated circuit, and write-once information recording medium.

BACKGROUND ART

Optical discs which are information recording media are sorted into several groups, depending on the recording characteristics.

An example of a write-once information recording medium, in which information can be recorded only once into the same recording area, is a write-once optical disc. Generally, write-once optical discs are highly compatible with reproduction-only discs, and are relatively inexpensive,

and therefore are recently becoming widespread. Examples of write-once optical discs representatively include DVD-R, CD-R, and the like ("80 mm (1.23 Gbytes per side) and 120 mm (3.95 Gbytes per side) DVD-Recordable Disk (DVD-R)", Standard ECMA-279, December 1998). As an exemplary write-once optical disc, DVD-R will be described below.

Figure 1 shows a DVD-R disc **100**. The DVD-R disc **100** comprises an R-information area **101** and an information area **102**.

The R-information area **101** comprises a PCA (Power Calibration Area) **103** and a recording management area (RMA: Recording Management Area) **104**. The PCA **103** is an area for performing OPC (Optimum Power Control). The RMA **104** is an area in which information for managing the recorded state of a data area **106** is recorded.

The information area **102** comprises a lead-in area **105**, the data area **106**, and a lead-out area **107**. The lead-in area **105** and the lead-out area **107** are control information recording areas in which a parameter required for accessing the data area **106** is recorded. In the data area **106**, user data is recorded. The data area **106** is divided into recording sections called RZones. Information indicating the recorded state of each RZones **161** to **163** is recorded in the RMA **104**.

In the accompanying drawings, symbol #n (n is an integer) indicates a serial number of an area or information. The serial number of information is, for example, an update counter value. In Figure **1**, symbol #n indicates the serial number of an area.

Figure 2 is a diagram showing the RMA **104**. The RMA **104** stores at least one piece of recording management information (RMD: Recording Management Data) indicating the recorded states of RZones (e.g., RMD's **191**, **192**, **200**).

An RMD is updated, for example, when a new RZone is generated or when a disc is unloaded from a recording/reproduction apparatus. An RMD is recorded from the beginning of the RMA **104**. Therefore, the latest RMD **200** is recorded at the terminating end of the recorded area of the RMA **104** (immediately before an unrecorded area **190**).

In the latest RMD **200**, starting addresses **211** to **213** of RZones, and last recorded addresses (LRA: Last Recorded Address) **221** to **223** which indicate the last position of the recorded areas of the RZones. When no RZone exists or no information is recorded in an RZone, the corresponding LRA indicates 0.

The latest RMD is not recorded in the RMA **104** every time the LRA is updated. Therefore, for example, when a recording/reproduction apparatus is unexpectedly powered off, the position of a read LRA may differ from the true position lastly recorded. To avoid this, by searching for the border between a recorded area and an unrecorded area, a true position lastly recorded is detected.

Figure **3** is a flowchart showing a procedure performed by a recording/reproduction apparatus from when the DVD-R disc **100** is loaded into the recording/reproduction apparatus until when information is recorded thereonto.

In step 301, the latest RMD **200** is read out from the RMA **104**.

In step 302, the RMD **200** read out in step 301 is referenced, and a writable address (NWA: Next Writable Address) corresponding to a writable RZone is sought.

Figure **4** is a flowchart showing details of a procedure in step 301 of Figure **3**.

In step 401, the starting address of the RMA **104** is designated as a search starting address for searching for the border between a recorded area and an unrecorded area.

In step 402, the recording/reproduction apparatus determines whether or not information has been recorded at a position irradiated with laser light, in sequence, based on a reproduced signal from the disc or the like, thereby searching for the border between a recorded area ranging from the search starting address, and an unrecorded area.

It is determined whether or not the address of the unrecorded area immediately after the border between the recorded area and the unrecorded area, which has been detected in step 402, matches the starting address of the RMA **104** (step 403). When it does not match, it is determined that an RMD has been recorded, and the process goes to step 404. When it matches, it is determined that an RMD has not been recorded, and the process goes to step 405.

An RMD located immediately before an unrecorded area is the latest RMD. Therefore, an RMD immediately before the border detected in step 402 is read out and stored into the

recording/reproduction apparatus (step 404).

When the address of an unrecorded area immediately after the detected border between the recorded area and the unrecorded area matches the starting address of the RMA **104**, an RMD has not been recorded in the RMA **104**. In this case, for example, the disc is determined to be brand-new, and a flag indicating such a state is stored in the recording/reproduction apparatus (step 405).

Figure **5** is a flowchart showing details of a procedure in step 302 of Figure **3**.

In step 501, the next address of an LRA of a writable RZone contained in the latest RMD read out in step 301 is designated as a search starting address.

In step 502, the border between a recorded area and an unrecorded area is sought from the search starting address.

In step 503, the address of an unrecorded area immediately after the border detected in step 502 is determined as an NWA.

According to the above-described procedure, the NWA which is a true writable address is determined. Data is recorded from the NWA as a starting position in response to a recording instruction from a higher level control means, such as a personal computer or the like.

Figure **6** is a flowchart showing an exemplary method for distinguishing a recorded area from an unrecorded area, which are used in procedures in steps 402 and 502.

In step 601, the amplitude of a reproduced signal read out from an optical disc is detected.

It is determined whether or not the amplitude detected in step 601 exceeds a prescribed value (step 602). When it exceeds the prescribed value, the process goes to step 603, it is determined that an area irradiated with laser light is a recorded area. When the amplitude of the reproduced signal is equal to or less than the prescribed value, the process goes to step **604**, it is determined that the area irradiated with laser light is an unrecorded area.

According to the above-described procedure, the border between a recorded area and an unrecorded area is sought.

Unlike write-once optical discs, information can be overwritten in the same area in rewritable optical discs. An example of a rewritable optical disc is DVD-RAM (see "120 mm (4.7 Gbytes per side) and 80 mm (1.46 Gbytes per side) DVD Rewritable Disk (DVD-RAM)", Standard ECMA-330, December 2001).

Figure **7** shows a DVD-RAM disc (4.7 GBytes) **700**. The DVD-RAM disc **700** comprises a lead-in area **701**, two spare areas **702** and **704**, a data area **703**, and a lead-out area **705**.

In the case of DVD-RAM, an area incapable of recording/reproduction (i.e., a defective area) may occur during the production of the disc or due to scratch or stain on a surface of the disc, or the like. To prevent a reduction in system reliability due to the presence of a defective

area, defect management is performed. In the defect management, when a defective area is detected in the data area **703**, information which was supposed to be recorded into the defective area is recorded into the spare area **702** or **704**. Defect management information (DMS: Defect Management Structure) for managing a defective area when the defective area is detected is recorded in defect management areas (DMA: Defect Management Area) **706** to **709** possessed by the lead-in area **701** and the lead-out area **705**.

Figure **8** is a diagram showing the DMA **706**. The DMA **706** comprises a DDS (Disc Definition Structure) **801** and a DFL (Defect List) **802** as defect management information. The DFL **802** comprises defective area addresses **821** and **822** indicating the address of a detected defective area, and replacement destination addresses **823** and **824** in a spare area.

The same information as that in the DMA **706** is recorded in each of DMA's **707** to **709**.

At present, defect management is not performed for a write-once optical disc, such as DVD-R or the like. As a semiconductor laser capable of outputting shorter-wavelength light is developed, the recording density of an optical disc is becoming higher. Therefore, a scratch or a stain on an optical disc is relatively large compared to a groove or a mark formed on the optical disc, likely leading to an increase in defective areas incapable of recording/reproduction.

As described above, an NWA is detected before recording for write-once optical discs. In this case, a

recorded area is distinguished from an unrecorded area based on the amplitude value of a reproduced signal. A defective area has a low quality of reproduced signal, i.e., a reproduced signal having a small amplitude. It is likely to determine such a defective area as a writable unrecorded area.

DISCLOSURE OF THE INVENTION

According to an aspect of the present invention, an apparatus is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The apparatus comprises: a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium; a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling operations of the head portion and the searching portion. The searching portion searches for the unrecorded area using a prescribed address as a reference. The control portion provides a candidate address indicating a candidate

for the writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information. When it is determined that there is the defective area address indicating an address matching the candidate address, the searching portion performs a second search for another unrecorded area using an address after the candidate address as a reference, and the control portion resets the candidate address based on a result of the second search and performs the determination procedure. When there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

According to another aspect of the present invention, an apparatus is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The apparatus comprises: a head portion for performing at least one of recording information onto the write-once information

recording medium and reproducing information from the write-once information recording medium; a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling operations of the head portion and the searching portion. When there is at least one defective area in a prescribed recording range of the data area, the control portion detects a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range. The control portion sets an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area. The searching portion searches for an unrecorded area using the candidate address as a reference, and the control portion determines the detected unrecorded area as the writable area.

According to another aspect of the present invention, an apparatus is provided for updating recording management information indicating a recorded state of a data area for recording user data of a write-once information recording medium. The write-once information recording medium further comprises a recording management area for recording the recording management information. The recording management information contains at least one recorded area address indicating at least one recorded area. The apparatus comprises: a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium; a searching portion for searching for an unrecorded area of the write-once

information recording medium; and a control portion for controlling operations of the head portion and the searching portion. The control portion determines whether or not there is a defective area in a prescribed recording range of the data area. When there is the defective area in the prescribed recording range, the control portion updates the recording management information so that a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after an address indicating the defective area.

In one embodiment of this invention the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area. When there is the defective area in the prescribed recording range, the control portion updates the defect management information so that the defect management information contains a defective area address indicating the defective area.

According to another aspect of the present invention, an integrated circuit is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect

management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The integrated circuit comprises: a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling an operation of the searching portion. The searching portion searches for the unrecorded area using a prescribed address as a reference. The control portion provides a candidate address indicating a candidate for the writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information. When it is determined that there is the defective area address indicating an address matching the candidate address, the searching portion performs a second search for another unrecorded area using an address after the candidate address as a reference, and the control portion resets the candidate address based on a result of the second search and performs the determination procedure. When there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

According to another aspect of the present invention, an integrated circuit is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing

at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The integrated circuit comprises: a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling an operation of the searching portion. When there is at least one defective area in a prescribed recording range of the data area, the control portion detects a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range. The control portion sets an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area. The searching portion searches for an unrecorded area using the candidate address as a reference, and the control portion determines the detected unrecorded area as the writable area.

According to another aspect of the present invention, an integrated circuit is provided for updating recording management information indicating a recorded state of a data area for recording user data of a write-once information recording medium. The write-once information recording medium further comprises a recording management area for recording the recording management information. The recording management information contains at least one recorded area address indicating at least one recorded area.

The integrated circuit comprises: a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling an operation of the searching portion. The control portion determines whether or not there is a defective area in a prescribed recording range of the data area. When there is the defective area in the prescribed recording range, the control portion updates the recording management information so that a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after an address indicating the defective area.

In one embodiment of this invention, the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area. When there is the defective area in the prescribed recording range, the control portion updates the defect management information so that the defect management information contains a defective area address indicating the defective area.

According to another aspect of the present invention, a method is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management

information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The method comprises the steps of: searching for the unrecorded area using a prescribed address as a reference; providing a candidate address indicating a candidate for the writable area based on a result of the search, and performing a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information; when it is determined that there is the defective area address indicating an address matching the candidate address, performing a second search for another unrecorded area using an address after the candidate address as a reference, and resetting the candidate address based on a result of the second search and performs the determination procedure; and when there is not the defective area address indicating an address matching the candidate address, determining an area indicated by the candidate address as the writable area.

According to another aspect of the present invention, a method is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address

indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The method comprises the steps of: when there is at least one defective area in a prescribed recording range of the data area, detecting a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range; setting an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area; and searching for an unrecorded area using the candidate address as a reference, and determining the detected unrecorded area as the writable area.

According to another aspect of the present invention, a method is provided for updating recording management information indicating a recorded state of a data area for recording user data of a write-once information recording medium. The write-once information recording medium further comprises a recording management area for recording the recording management information. The recording management information contains at least one recorded area address indicating at least one recorded area. The method comprises the steps of: determining whether or not there is a defective area in a prescribed recording range of the data area; and when there is the defective area in the prescribed recording range, updating the recording management information so that a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after an address indicating the defective

area.

In one embodiment of this invention, the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area. The method further comprises the step of: when there is the defective area in the prescribed recording range, updating the defect management information so that the defect management information contains a defective area address indicating the defective area.

According to another aspect of the present invention, a write-once information recording medium is provided, comprising: a data area for recording user data; and a recording management area for recording recording management information indicating a recorded state of the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. Where there is a defective area in a prescribed recording range of the data area, a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after the defective area.

In one embodiment of this invention, the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area.

According to the present invention, it is determined whether or not a detected unrecorded area matches a defective

area, thereby preventing a defective area from being determined to be a writable area. Therefore, information can be consistently recorded into a normal recording area.

According to the present invention, a write-once information recording medium is realized such that there is no detected defective area in a recorded area after a last recorded address in a prescribed recording range. According to the present invention, the latest last recorded address is consistently an address indicating a recorded area on or after a defective area. Thereby, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required, resulting in a reduction in the time spent determining a writable area.

According to the present invention, a pointer indicating a starting position of information indicating a defect list or a recorded state is contained in a write-once information recording medium. Therefore, an RMD or a DMS can have a variable length. Therefore, an area can be more efficiently used.

According to the present invention, an RMD and a DMS are recorded together. Therefore, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required when the latest RMD and DMS are read out, resulting in a reduction in the procedure time.

Thus, the invention described herein makes possible the advantages of providing an apparatus, integrated circuit, and method for searching for a writable area on a write-once information recording medium; an apparatus, integrated circuit, and method for updating recording management

information; and a write-once information recording medium in which information is recorded using the apparatus, integrated circuit, or method of the present invention.

These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram showing a data structure of a DVD-R disc.

Figure 2 is a diagram showing data structures of an RMA and an RMD of a DVD-R disc.

Figure 3 is a flowchart showing a procedure performed by a recording/reproduction apparatus from when a DVD-R disc is loaded into the recording/reproduction apparatus until when information is recorded thereonto.

Figure 4 is a flowchart showing a procedure for reading the latest RMD.

Figure 5 is a flowchart showing a procedure for searching an NWA of a DVD-R disc.

Figure 6 is a flowchart showing an exemplary method for distinguishing a recorded area from an unrecorded area.

Figure 7 is a diagram showing a data structure of a DVD-RAM disc (4.7 GBytes).

Figure **8** is a diagram showing data structures of a DMA and a DMS of a DVD-RAM disc (4.7 GBytes).

Figure **9** is a diagram showing a write-once information recording medium according to the present invention.

Figure **10** is a diagram showing data structures of an RMA and an RMD of a write-once information recording medium according to the present invention.

Figure **11** is a diagram showing data structures of a DMA and a DMS of a write-once information recording medium according to the present invention.

Figure **12** is a flowchart showing an exemplary procedure performed by a recording/reproduction apparatus from when a write-once information recording medium of the present invention is loaded thereinto until the start of a recording operation.

Figure **13** is a flowchart showing an exemplary procedure for reading out the latest DMS according to the present invention.

Figure **14** is a flowchart showing an exemplary procedure for searching for an NWA according to the present invention.

Figure **15** is a diagram showing data structures of an RMA and an RMD of a write-once information recording medium according to the present invention.

Figure **16** is a flowchart showing an exemplary procedure for searching for an NWA according to the present invention.

Figure **17** is a flowchart showing an exemplary procedure for searching for an NWA according to the present invention.

Figure **18** is a diagram showing a feature of a write-once information recording medium according to the present invention.

Figure **19** is a flowchart showing an exemplary procedure for updating a recording management area according to the present invention.

Figure **20** is a diagram showing a data structure of a write-once information recording medium according to the present invention.

Figure **21** is a diagram showing data structures of an RMA+DMA and an RMD+DMS of a write-once information recording medium according to the present invention.

Figure **22** is a flowchart showing an exemplary procedure performed by a recording/reproduction apparatus of the present invention from when a write-once information recording medium is loaded thereinto until the start of a recording operation.

Figure **23** is a flowchart showing an exemplary procedure for reading the latest RMD+DMS according to the

present invention.

Figure 24 is a flowchart showing an exemplary procedure for updating an RMA+DMA according to the present invention.

Figure 25 is a diagram showing an exemplary recording/reproduction apparatus according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the present invention will be described by way of illustrative examples with reference to the accompanying drawings. Like references indicate like parts or steps in Figures 1 to 25, and further description is omitted in the interest of brevity.

(Embodiment 1)

Figure 9 is a diagram showing a write-once information recording medium 900 according to Embodiment 1 of the present invention. A write-once information recording medium may also be called a write-once-read-many information recording medium.

The write-once information recording medium 900 comprises a data area 903 for recording user data, a recording management area (RMA) 901 for recording recording management information (RMD) indicating the recorded state of data area 903, and defect management areas (DMA) 902 and 904 for recording defect management information (DMS) for managing at least one defective area if it is detected in the data area 903. An RMD contains at least one recorded area address

(LRA) indicating at least one recorded area. Defect management information contains at least one defective area address indicating at least one defective area if it is detected.

The data area **903** is divided into a plurality of RZones **910**, **911**, **912**, and **913**, as in the data area **106** (Figure **1**). An RMD indicates the recorded state of each RZone.

Figure **10** is a diagram showing the RMA **901**. The RMA **901** stores a plurality of RMD **991**, **992**, and **1000**. The latest RMD **1000** is recorded immediately before an unrecorded area **990**. The latest RMD **1000** contains LRA's **1001**, **1002**, **1003**, and **1004**, each of which indicates the position of a lastly recorded area in the corresponding RZone.

Figure **11** is a diagram showing a data structure of the DMA **902**. The DMA **902** stores a plurality of DMS's **981**, **982**, and **1100**. The DMS's are sequentially recorded from the beginning of the DMA **902**. Therefore, the latest DMS **1100** is recorded immediately before an unrecorded area **980**. The latest DMS **1100** contains a DFL **1110** and a DDS **1120**. The DDS **1120** contains a pointer **1121** indicating the starting position of the DFL **1110**. The DFL **1110** contains defective area addresses **1111** and **1112** indicating a defective area. The DMA **904** stores the same information as that in the DMA **902**.

Figure **25** is a block diagram showing a recording/reproduction apparatus **2500** according to Embodiment 1 of the present invention.

The recording/reproduction apparatus **2500** comprises

an optical head portion 2502, a recording/reproduction control portion 2503, a searching portion 2504, a CPU (Central Processing Unit) 2505, a buffer 2506, and an internal bus 2507. The write-once information recording medium 900 (Figure 9) is loaded into the recording/reproduction apparatus 2500. The recording/reproduction apparatus 2500 searches for a writable area in the data area 903 contained in the write-once information recording medium 900.

The CPU 2505 controls the operations of all components of the recording/reproduction apparatus 2500 (e.g., the optical head portion 2502, the recording/reproduction control portion 2503, the searching portion 2504, the buffer 2506, etc.) in accordance with a control program incorporated in the CPU 2505. Note that the CPU 2505 and the recording/reproduction control portion 2503 may be integrated into a single control portion. The recording/reproduction control portion 2503, the searching portion 2504, the CPU 2505, the buffer 2506, and the internal bus 2507 may be, for example, contained in an integrated circuit LSI 2600. The LSI 2600 is provided in the recording/reproduction apparatus 2500.

The optical head portion 2502 performs at least one of recording information onto the write-once information recording medium 900 and reproducing information from the write-once information recording medium 900, by irradiating the write-once information recording medium 900 with laser light. The searching portion 2504 searches for an unrecorded area in the write-once information recording medium 900.

The recording/reproduction control portion **2503** reads out information, which has been recorded in an area having an address specified by the CPU **2505** on the write-once information recording medium **900**, using the optical head portion **2502**, and stores the information into the buffer **2506**. The recording/reproduction control portion **2503** also writes data stored in the buffer **2506** into an area having an address specified by the CPU **2505** using the optical head portion **2502**. In addition, when a defective area is detected, the recording/reproduction control portion **2503** outputs an address (defective area address) indicating the defective area to the CPU **2505**.

The searching portion **2504** searches for the border between a recorded area and an unrecorded area. The searching portion **2504** performs, for example, the determination method described with reference to Figure **6**. The searching portion **2504** detects the amplitude value of a reproduced signal output by the optical head portion **2502**, and determines whether or not the amplitude value exceeds a prescribed value. By this determination step, the searching portion **2504** detects the border between the recorded area and the unrecorded area and obtains a recorded area address (LRA) indicating a position immediately before the border. The searching portion **2504** outputs the obtained recorded area address to the CPU **2505**.

The buffer **2506** stores information read out from the write-once information recording medium **900**. The buffer **2506** also stores information which is to be written onto the write-once information recording medium **900**.

The internal bus **2507** interconnects the

recording/reproduction control portion **2503**, the searching portion **2504**, the CPU **2505**, and the buffer **2506**.

Figure **12** is a flowchart showing an exemplary procedure performed by the recording/reproduction apparatus **2500** from when the write-once information recording medium **900** is loaded thereinto until the start of a recording operation.

After the write-once information recording medium **900** is loaded into the recording/reproduction apparatus **2500**, the recording/reproduction apparatus **2500** reads the latest RMD. In step 301, the latest RMD **1000** (Figure **10**) is read out from the RMA **901**. This operation will be described with reference to Figure **4**.

After the write-once information recording medium **900** is loaded into the recording/reproduction apparatus **2500**, the CPU **2505** designates a starting address of the RMA **901** as a search starting address from which the searching portion **2504** starts searching for the border between a recorded area and an unrecorded area. The CPU **2505** instructs the searching portion **2504** to start searching from the starting address of the RMA **901** (step 401).

The searching portion **2504** starts searching for an unrecorded area from the starting address of the RMA **901**, detects the border between the recorded area and the unrecorded area, and obtains a recorded area address indicating a position immediately before the border. The searching portion **2504** outputs the obtained recorded area address to the CPU **2505** (step 402).

The CPU **2505** detects the address of the unrecorded area (unrecorded area address) immediately after the border, based on the obtained recorded area address, and determines whether or not the unrecorded area address matches the starting address of the RMA **901** (step 403).

When the two addresses do not match each other in step 403, the CPU **2505** designates the address of an RMD recorded position immediately before the detected border, and instructs the recording/reproduction control portion **2503** to reproduce an RMD recorded at that position. The recording/reproduction control portion **2503** uses the optical head portion **2502** to read the designated RMD (here, the latest RMD **1000**), and stores the data into the buffer **2506** (step 404).

When the two addresses match each other in step 403, the CPU **2505** determines that the loaded write-once information recording medium is brand-new, and stores a flag indicating the brand-new state into the buffer **2506** (step 405).

After the latest RMD **1000** is read out, the recording/reproduction apparatus **2500** reads the latest DMS from the DMA's **902** and **904** (step 1201). This operation will be described with reference to Figure **13**. Figure **13** is a flowchart showing an exemplary procedure of step 1201 (Figure **12**).

The CPU **2505** designates the starting address of the DMA **902** as a search starting address from which the searching portion **2504** starts searching for the border between a recorded area and an unrecorded area. The CPU **2505** instructs

the searching portion **2504** to search for the border from the starting address of the DMA **902** (step 1300).

The searching portion **2504** starts searching for an unrecorded area from the starting address of the DMA **902**, detects the border between a recorded area and the unrecorded area, and obtains and outputs a recorded area address indicating a position immediately before the border to the CPU **2505** (step 1301).

The CPU **2505** detects an address (unrecorded area address) of the unrecorded area immediately after the border based on the obtained recorded area address, and determines whether or not the unrecorded area address matches the starting address of the DMA **902** (step 1302).

When the two addresses do not match each other in step 1302 (a DMS has been recorded), the CPU **2505** designates the address of a DMS recorded position immediately before the detected border, and instructs the recording/reproduction control portion **2503** to reproduce the DMS recorded at the position. The recording/reproduction control portion **2503** uses the optical head portion **2502** to read the designated DMS (here, the latest DMS **1100**), and stores the data into the buffer **2506** (step 1303).

When the two addresses match each other (a DMS has not been recorded), the CPU **2505** stores a DMS in its initial state where a defective area address is 0, into the buffer **2506** (step 1304).

The CPU **2505** determines whether or not the DMS have

been read out from all DMA's. When a DMS has not been read out from any of the DMA's, the CPU **2505** instructs the searching portion **2504** to search for the borders in the remaining DMA's (step 1305), and the process returns to step 1300.

When a DMS has been read out from all of the DMA's, the CPU **2505** selects the latest DMS from a plurality of DMS's stored in the buffer **2506**. For example, when a DMS contains an update counter value indicating the number of updates, the CPU **2505** compares the update counter values read from each DMA with each other. In this case, the CPU **2505** determines a DMS having the greatest update counter value to be the latest DMS, and causes the latest DMS to remain in the buffer **2506**.

In this embodiment, a DMS having the greatest update counter value is assumed to be the latest DMS. Alternatively, any operation may be used as long as it can determine whether or not a DMS is the latest. For example, a DMS storing the greatest defective area address among defective area addresses stored in the DMS's may be determined to be the latest DMS. Alternatively, for example, the size of the DFL recording area is detected and a DMS having the greatest size may be determined to be the latest DMS.

After the latest DMS is read out, the recording/reproduction apparatus **2500** searches for a writable address (NWA). In step 1202 (Figure **12**), a NWA is detected in a writable RZone with reference to the RMD and the DMS read out from step 301 and step 1201. This operation will be described with reference to Figure **14**. Figure **14** is a flowchart showing an exemplary procedure of step 1202 of Figure **12**.

The CPU **2505** reads out an LRA from an RMD stored in the buffer **2506**, and determines an address after the LRA (e.g., an address next to the LRA). Here, the CPU **2505** instructs the searching portion **2504** to search for the address next to the LRA as a search starting address (step 501).

The searching portion **2504** searches for an unrecorded area using an address after the LRA as a reference. Here, the searching portion **2504** starts searching for an unrecorded area from an address next to the LRA toward addresses following that address, detects the border between a recorded area and an unrecorded area, and obtains a recorded area address indicating a position immediately before the border. The searching portion **2504** outputs the obtained recorded area address to the CPU **2505** (step 502).

The CPU **2505** detects the address (unrecorded area address) of an unrecorded area immediately after the border from the obtained recorded area address, and sets the unrecorded area address to be a candidate address indicating a candidate for a writable area (step 1401). The CPU **2505** determines whether or not a defective area address indicating an address matching the candidate address is present in a DMS stored in the buffer **2506** (step 1402).

When it is determined in step 1402 that such a defective area address is not present, the CPU **2505** determines the candidate address to be a NWA, and determines an area indicated by the NWA to be a writable area (step 1404).

When it is determined in step 1402 that such a defective area address is present, the CPU **2505** instructs

the searching portion **2504** to perform a search using an address after the defective area address (= the current candidate address) as a search starting address (step 1403).

Returning to step 502, the searching portion **2504** searches for another unrecorded area using an address after the defective area address (= the current candidate address) as a reference. Here, the searching portion **2504** starts searching an unrecorded area from an address next to the defective area address towards addresses following that address. The searching portion **2504** detects the border between a recorded area and an unrecorded area, and obtains a recorded area address indicating a position immediately before the border. The searching portion **2504** outputs the obtained recorded area address to the CPU **2505**.

The CPU **2505** and the searching portion **2504** repeatedly perform operations indicated in step 501 to step 1403 until detection of a candidate address which does not match a defective area address.

As described above, according to this embodiment of the present invention, by determining whether or not a detected unrecorded area matches a defective area, a defective area is prevented from being incorrectly determined to be a writable area. Therefore, information can be constantly written in a normal recording area.

Although the searching portion **2504** obtains a recorded area address immediately before the border between a recorded area and an unrecorded area in this embodiment, an unrecorded area address immediately after the border may be obtained.

By using a pointer indicating the starting position of a DFL, the length of the DFL can be variable, thereby making it possible to reduce the size of a DMS.

Although the write-once information recording medium of Figure 9 is described as an example in Embodiment 1, each area may be located anywhere on a medium. In addition, the number of areas of each type is not particularly limited as long as it is at least one.

Although a DMS is read out after an RMD is read out in Embodiment 1, either a DMS or an RMD may be read out earlier as long as it is before searching for an NWA.

(Embodiment 2)

Figure 15 is a diagram showing an RMA **901a** which is a variation of the RMA **901**. The data structure described in Figures 9 and 11 is common to the RMA **901a** and the RMA **901**.

The RMA **901a** stores a plurality of RMD's **991a**, **992a**, and **1000a**. The latest RMD **1000a** is recorded immediately before an unrecorded area **990a**. The latest RMD **1000a** contains LRA's **1001**, **1002**, and **1004** indicating the positions of lastly recorded areas in the respective RZones, and RZone range information **1011**, **1012**, and **1014** indicating the ranges of respective RZones.

Among procedures performed by a recording/reproduction apparatus from when a write-once information recording medium is loaded thereinto until the start of a recording operation, from step 301 to step 1201 of Figure 12 are common to Embodiments 1 and 2.

Figure 16 is a flowchart showing a variation of step 1202 of Figure 12.

In step 1601, the CPU 2505 designates the range of an RZone, into which information is to be recorded from now, as a search range, in which an NWA is to be searched for. The range of an RZone is obtained based on RZone range information contained in the RMD 901a. For example, when the RZone range information indicates the starting address of an RZone, the RZone ranges from the starting address of an RZone, in which an NWA is to be searched for, to an address immediately before the starting address of the next RZone. When the RZone range information indicates the last address of an RZone, the RZone ranges from an address next to the last address of an RZone located immediately before an RZone, in which an NWA is to be searched for, to the last address of the RZone, in which an NWA is to be searched for. When the RZone range information indicates both the starting address and the last address of an RZone, the RZone ranges from the starting address to the last address of an RZone, in which an NWA is to be searched for.

In step 1602, the CPU 2505 determines whether or not there is at least one defective area in a prescribed recording range in the data area 106 (here, the range of an RZone, in which an NWA is to be searched for). Specifically, the CPU 2505 determines whether or not there is a defective area address indicating an address within the range of an RZone, in which an NWA is to be searched for, among defective area addresses in a DMS.

When there is a defective area address indicating

an address within the range of an RZone, in which an NWA is to be searched for, the process goes to step 1603. When not, the process goes to step 501.

In step 1603, the CPU **2505** detects a defective area address (the greatest defective area address), which indicates a defective area located at the last address of at least one defective areas in a prescribed recording range.

In step 1604, the CPU **2505** compares an LRA corresponding to an RZone, in which an NWA is to be searched for, with the greatest defective area address detected. When the greatest defective area address is greater than the LRA, the process goes to step 1605. When the LRA is smaller than the greatest defective area address, the process goes to step 501. When the LRA is equal to the greatest defective area address, the process goes to either step 1605 or step 501.

In step 1605, the CPU **2505** designates an address next to the greatest defective area address as a search starting address.

In step 501, the CPU **2505** designates an address next to the LRA as a search starting address.

The CPU **2505** sets an address, located after both the greatest defective area address and the LRA to be a candidate address, via step 1605 or step 501.

In step 502, the searching portion **2504** searches for an unrecorded area using the candidate address (search starting address) as a reference. Here, the searching

portion **2504** starts searching for an unrecorded area from the candidate address toward addresses following the candidate address, detects the border between a recorded area and an unrecorded area, and obtains a recorded area address indicating a position immediately before the border. The searching portion **2504** outputs the obtained recorded area address to the CPU **2505**.

In step 503, the CPU **2505** detects the address of an unrecorded area immediately after the border based on the result of detection in step 502 and determines the address as an NWA, and determines an area indicated by the NWA as a writable area.

Figure **17** is a flowchart showing an exemplary procedure of step 1202 of Figure **12**. The flowchart of Figure **17** is the same as that of Figure **16**, except that step 1701 is performed instead of step 1601 and step 1604 is omitted.

In step 1701, the CPU **2505** designates, as a search range in which an NWA is to be searched for, a range from an LRA corresponding to an RZone, into which information is to be recorded from now, to the terminating end of the RZone. The range of the RZone is obtained based on RZone range information contained in the RMD **901a**. When the RZone range information indicates the starting address of the RZone, the search range extends from the LRA to an address immediately before the starting address of an RZone next to the RZone, in which an NWA is to be searched for. When RZone range information indicates the last address of an RZone, a search range extends from the LRA to the last address of the RZone, in which an NWA is to be searched for.

In step 1602, the CPU **2505** determines whether or not there is at least one defective area within a prescribed recording range in the data area **106** (here, a range from an LRA corresponding to an RZone, into which information is to be recorded from now, to the terminating end of the RZone). Specifically, the CPU **2505** determines whether or not there is a defective area address indicating an address within a prescribed recording range in defective area addresses contained in a DMS.

In step 1603, the CPU **2505** detects a defective area address (greatest defective area address) indicating the address of a defective area located at the last address of at least one defective area present in a prescribed recording range.

In the procedure of Figure **17**, the starting point of a search range is set to be an LRA. Therefore, when there is the greatest defective area address, the greatest defective area address is always greater than or equal to the LRA. Thus, the procedure of step 1604 (Figure **16**) is omitted.

The subsequent steps are the same as those of Figure **16**, and their description is omitted.

According to Embodiment 2 of the present invention, there is no defective area already detected between a search starting address and an NWA. Therefore, only a single search operation for the border between a recorded area and an unrecorded area is required. A procedure for determining whether or not a detected unrecorded area address is a defective area may be performed in a semiconductor memory.

A procedure for searching for the border between a recorded area and an unrecorded area is performed on an optical disc. Therefore, when the determining procedure and the searching procedure are repeatedly performed, it takes a long time to determine an NWA. In this embodiment, it is not necessary to repeatedly perform the determining procedure and the searching procedure, whereby an NWA can be determined more quickly.

(Embodiment 3)

Figure **18** is a diagram showing the RZones **910**, **911**, and **912** which are a portion of the data area **903**. The RZone **910** contains a recorded area **1805** and an unrecorded area **1801**. The RZone **911** contains a recorded area **1807** and an unrecorded area **1802**. The RZone **912** contains a recorded area **1809** and an unrecorded area **1803**.

The latest RMD **1000** stores the LRA **1001** of the RZone **910**, the LRA **1002** of the RZone **911**, and the LRA **1003** of the RZone **912**. The LRA **1001** indicates the last address of a defective area **1804**. The LRA **1002** is located after a defective area **1806**, indicating an address which is not the last address of the recorded area **1807**. The LRA **1003** indicates a position immediately before the unrecorded area **1803**, i.e., the last address of the recorded area **1809**.

As shown in Figure **18**, there is no detected defective area in a recorded area following the LRA of each RZone. In other words, the LRA of an RZone indicates an address on or after a defective area address indicating a defective area present in the RZone.

Figure **19** is a flowchart showing an exemplary

procedure for updating recording management information, which is performed by the recording/reproduction apparatus **2500**.

The CPU **2505** sets the greatest address in an RZone, into which the recording/reproduction control portion **2503** is instructed to record information, to be an LRA, and rewrites an LRA within an RMD stored in the buffer **2506** (step 1901).

The recording/reproduction control portion **2503** determines whether or not a defect has been found during recording of user data (step 1902). When no defect has been found, the process goes to step 1907. When a defect has been found, the recording/reproduction control portion **2503** outputs an address indicating the detected defect (defective area address) to the CPU **2505**. The CPU **2505** adds the detected defective area address into a DFL stored in the buffer **2506** (step 1903).

The CPU **2505** instructs the recording/reproduction control portion **2503** to record, into a DMA, the latest DMS which has been updated by adding the defective area address to the DFL. The recording/reproduction control portion **2503** records the updated latest DMS into the DMA's **902** and **904** (step 1904).

The CPU **2505** determines whether or not the LRA of an RZone indicates an address on or after a defective area address indicating a defective area present in the RZone (step 1905). When the LRA indicates an address on or after the defective area address, the process goes to step 1907. When the LRA does not indicate an address on or after the defective area address, the LRA is updated so that the updated

LRA indicates an address on or after the defective area address (step 1906).

The CPU **2505** instructs the recording/reproduction control portion **2503** to record the latest RMD, which has been updated by rewriting the LRA, into the RMA **901**. The recording/reproduction control portion **2503** records the updated latest RMD into the RMA **901** (step 1907).

According to this embodiment, a write-once information recording medium is realized such that there is no detected defective area in a recorded area after an LRA contained in the latest RMD.

As described above, the greatest address in an RZone in which recording has been attempted in step 1901 is assumed to be an LRA. Alternatively, as shown in Figure **18**, an LRA may be an address at which there is no detected defective area in a recorded area after the LRA in an RZone.

According to Embodiment 3 of the present invention, there is no detected defective area in a recorded area after an LRA contained in the latest RMD. Therefore, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required, thereby making it possible to reduce the time spent finding an NWA. In addition, by this updating method, a write-once information recording medium having the data structure shown in Figure **18** is realized.

In Embodiment 3, after a defect has been detected, a defective area address is added to a DFL, and the latest DMS is recorded into a DMA. Alternatively, by simply updating

an LRA after a defect has been detected, the latest RMD clearly contains an LRA followed by a recorded area in which there is no detected defective area.

The updated latest RMD and DMS is preferably recorded until a medium is unloaded from a recording/reproduction apparatus. Particularly, the updated values are held in the apparatus, and are recorded into an RMA or DMA until the medium is unloaded.

(Embodiment 4)

Figure 20 is a diagram showing a write-once information recording medium 2000 according to Embodiment 4 of the present invention. The write-once information recording medium 2000 comprises a data area 903, an RMA+DMA 2001 for recording recording management information and defect management information, and a spare area 2003 which is a replacement destination of a defective area. Information indicating the recorded states of a plurality of RZones contained in the data area 903 is recorded in the RMA+DMA 2001. Note that the spare area 2003 is also contained in a write-once information recording medium 900.

Figure 21 is a diagram showing a data structure of the RMA+DMA 2001. The RMA+DMA 2001 stores a plurality of RMD+DMS's 2011, 2012, and 2100, which are information of a combination of an RMD and a DMS. In the RMA+DMA 2001, RMD+DMS is recorded from the beginning thereof. Therefore, the latest RMD+DMS 2100 is recorded immediately before an unrecorded area 2014. The latest RMD+DMS 2100 contains a DDS 2130, a DFL 2110, and an RMD 2120. The DDS 2130 contains pointers 2131 and 2132 indicating the starting positions of the RMD 2120 and the DFL 2110, respectively. The DFL 2110

contains defective area addresses **1111** and **1112** of detected defective areas, and replacement destination addresses **2111** and **2112** indicating addresses of positions in a spare area, in which data is recorded in place of defective areas. The RMD **2120** contains LRA's **1001**, **1002**, and **1004**.

Figure **22** is a flowchart showing an exemplary procedure performed by the recording/reproduction apparatus **2500** from when the write-once information recording medium **2000** is loaded thereinto until the start of a recording operation.

In step 2201, the latest RMD+DMS is read out from the RMA+DMA **2001**.

In step 1202, an NWA is searched for in a writable RZone with reference to the RMD+DMS read out in step 2201. The NWA is determined by, for example, the procedure shown in Figure **14** of Embodiment 1 or Figure **16** of Embodiment 2.

Figure **23** is a flowchart showing an exemplary procedure of step 2201 in Figure **22**.

In step 2300, the CPU **2505** designates the starting address of the RMA+DMA **2001** as a search starting address, from which a search for the border between a recorded area and an unrecorded area is started.

In step 2301, the searching portion **2504** starts searching for the border between a recorded area and an unrecorded area from the search starting address.

In step 2302, the CPU **2505** determines whether or not

the address of an unrecorded area immediately after the detected border matches the starting address of the RMA+DMA **2001**. When the two addresses do not match each other, it is determined that the RMD+DMS has been recorded, and the process goes to step 2303. When the two addresses match each other, it is determined that the RMD+DMS has not been recorded, and the process goes to step 2304.

An RMD+DMS recorded in an area immediately before the unrecorded area is the latest RMD+DMS **2100**. In step 2303, the recording/reproduction control portion **2503** reads out the RMD+DMS **2100** recorded in the area immediately before the detected border, and the CPU **2505** stores the latest DFL **2110** and the latest RMD **2120** into the buffer **2506**.

In step 2304 (no RMD+DMS has been recorded), for example, the CPU **2505** determines that the write-once information recording medium **2000** is a brand-new disc, generates a flag indicating the brand-new state and a DMS in an initial state indicating that a defective area address is 0, and stores the flag and the DMS into the buffer **2506**.

Figure **24** is a flowchart showing an exemplary method for recording an updated RMD+DMS into an RMA+DMA.

In step 1901, the CPU **2505** sets the greatest address in an RZone, in which recording has been attempted, to be an LRA.

In step 1902, the recording/reproduction control portion **2503** determines whether or not a defect has been found during recording of user data. When no defect has been found, the process goes to step 2403.

When a defect has been found in step 1902, the CPU **2505** instructs the recording/reproduction control portion **2503** to perform a replacement procedure, in which data which was otherwise to be recorded in the detected defective area, is recorded into a spare area (replacement destination). The recording/reproduction control portion **2503** performs the replacement procedure (step 2401).

In step 2402, the CPU **2505** sets the address of the detected defective area as a defective area address, sets the address of the spare area storing the data in that area as a replacement destination address, and adds these addresses into the DFL **2110**, i.e., updates the DFL **2110**.

In step 2403, the recording/reproduction control portion **2503** records the latest RMD+DMS containing the updated DFL and the updated LRA into the RMA+DMA **2001**.

In the procedure of Figure **24**, steps 1905 and 1906 of Figure **19** may be performed. In this case, in a recorded area after an LRA, an LRA in which there is no detected defective area is contained in the latest RMD of an RMA+DMA.

There is no detected defective area in a recorded area after an LRA contained in the latest RMD. Therefore, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required. Therefore, the time required for detecting an NWA can be reduced. With this updating method, a write-once information recording medium is realized such that there is no detected defective area in a recorded area after an LRA contained in the latest

RMD.

In Embodiment 4, a DFL and an RMD are recorded together into an RMA+DMA. Therefore, an area can be efficiently used as compared with when a DFL and an RMD are separated. In addition, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required when reading the latest DMS and the latest RMD, thereby making it possible to reduce a procedure time.

In Embodiment 4, after a defect is detected, data in the defective area is recorded into a spare area, and a replacement destination address is added to a DFL. Clearly, only by simply updating an LRA after a defect is detected, an LRA which has no detected defective area is contained in the latest RMD in a recorded area after the LRA.

As described in Embodiments 1 to 4, the recording/reproduction apparatus **2500** performs a method for searching for a writable area and a method for updating recording management information.

Note that the recording/reproduction control portion **2503**, the searching portion **2504**, the CPU **2505**, the buffer **2506**, and the internal bus **2507** are typically realized in an LSI which is an integrated circuit. These components may be separately provided in respective one-chips. Alternatively, a part or all of these components may be integrated into one-chip.

As used herein, an integrated circuit is called LSI. The integrated circuit may be called IC, system LSI, super LSI, or ultra LSI, depending on the scale of integrity.

The integrated circuit of the present invention is not limited to LSI, and may be realized with a specialized circuit or a general processor. A FPGA (Field Programmable Gate Array) which can be programmed after LSI manufacture, or a reconfigurable processor in which connections or settings of circuit cells can be reconfigured, may be used.

In addition, if integrated circuit technology appears due to a progress in semiconductor technology or another derivative technology and replaces current LSI technology, such new technology may be used for integration of functional blocks. Adaptation in biotechnology may be used.

The above-described embodiments of the present invention are provided for illustrative purposes only. Any data structure and algorithm may be used as long as they do not depart from the essence of the present invention.

For example, a DFL or an RMD may have a fixed length or a variable length.

For example, a DDS may not be recorded at the terminating end of a recorded area.

For example, an RMD may be recorded earlier than a DFL, or vice versa.

For example, the latest RMD may be found later than the latest DMS.

For example, a plurality of RMA's and DMA's having

the same contents may be recorded for multiplexing.

For example, a plurality of RMA's and DMA's may be provided and used in rotation.

For example, when a defect is detected, data in a defective area may or may not be recorded into a spare area.

For example, replacement to a spare area may be performed earlier than addition to a DFL, or vice versa.

For example, when replacement to a spare area is not performed, there may be no spare area.

For example, when the starting position of an RMD or a DFL is recorded at a prescribed position from a recording end position, a pointer indicating the starting position may not be recorded.

For example, a defective area address or a replacement destination address contained in a DFL, and an LRA or range information contained in an RMD, may be arranged in a prescribed data format, and are not limited to the data formats shown in Figures **15** and **21**.

A method for distinguishing a recorded area from an unrecorded area may not be limited to the distinguishing method of Figure **6**. For example, reproduced data is subjected to error correction, and it may be determined whether or not an error exceeds a correction limit. For example, it may be determined whether or not address information contained in data can be normally obtained. For example, a jitter value indicating the quality of a reproduced

signal, MLSE (Maximum Likelihood Sequence Error), or the like may be used.

According to an aspect of the present invention, an apparatus is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The apparatus comprises: a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium; a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling operations of the head portion and the searching portion. The searching portion searches for the unrecorded area using a prescribed address as a reference. The control portion provides a candidate address indicating a candidate for the writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information. When it is determined that there is the

defective area address indicating an address matching the candidate address, the searching portion performs a second search for another unrecorded area using an address after the candidate address as a reference, and the control portion resets the candidate address based on a result of the second search and performs the determination procedure. When there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

According to another aspect of the present invention, an apparatus is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The apparatus comprises: a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium; a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling operations of the head portion and the searching

portion. When there is at least one defective area in a prescribed recording range of the data area, the control portion detects a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range. The control portion sets an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area. The searching portion searches for an unrecorded area using the candidate address as a reference, and the control portion determines the detected unrecorded area as the writable area.

According to another aspect of the present invention, an apparatus is provided for updating recording management information indicating a recorded state of a data area for recording user data of a write-once information recording medium. The write-once information recording medium further comprises a recording management area for recording the recording management information. The recording management information contains at least one recorded area address indicating at least one recorded area. The apparatus comprises: a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium; a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling operations of the head portion and the searching portion. The control portion determines whether or not there is a defective area in a prescribed recording range of the data area. When there is the defective area in the prescribed

recording range, the control portion updates the recording management information so that a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after an address indicating the defective area.

In one embodiment of this invention the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area. When there is the defective area in the prescribed recording range, the control portion updates the defect management information so that the defect management information contains a defective area address indicating the defective area.

According to another aspect of the present invention, an integrated circuit is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The integrated circuit comprises: a searching portion for searching for an unrecorded area of the write-once information recording

medium; and a control portion for controlling an operation of the searching portion. The searching portion searches for the unrecorded area using a prescribed address as a reference. The control portion provides a candidate address indicating a candidate for the writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information. When it is determined that there is the defective area address indicating an address matching the candidate address, the searching portion performs a second search for another unrecorded area using an address after the candidate address as a reference, and the control portion resets the candidate address based on a result of the second search and performs the determination procedure. When there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

According to another aspect of the present invention, an integrated circuit is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area

address indicating the at least one defective area when the at least one defective area has been detected. The integrated circuit comprises: a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling an operation of the searching portion. When there is at least one defective area in a prescribed recording range of the data area, the control portion detects a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range. The control portion sets an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area. The searching portion searches for an unrecorded area using the candidate address as a reference, and the control portion determines the detected unrecorded area as the writable area.

According to another aspect of the present invention, an integrated circuit is provided for updating recording management information indicating a recorded state of a data area for recording user data of a write-once information recording medium. The write-once information recording medium further comprises a recording management area for recording the recording management information. The recording management information contains at least one recorded area address indicating at least one recorded area. The integrated circuit comprises: a searching portion for searching for an unrecorded area of the write-once information recording medium; and a control portion for controlling an operation of the searching portion. The control portion determines whether or not there is a defective area in a

prescribed recording range of the data area. When there is the defective area in the prescribed recording range, the control portion updates the recording management information so that a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after an address indicating the defective area.

In one embodiment of this invention, the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area. When there is the defective area in the prescribed recording range, the control portion updates the defect management information so that the defect management information contains a defective area address indicating the defective area.

According to another aspect of the present invention, a method is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The method comprises

the steps of: searching for the unrecorded area using a prescribed address as a reference; providing a candidate address indicating a candidate for the writable area based on a result of the search, and performing a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information; when it is determined that there is the defective area address indicating an address matching the candidate address, performing a second search for another unrecorded area using an address after the candidate address as a reference, and resetting the candidate address based on a result of the second search and performs the determination procedure; and when there is not the defective area address indicating an address matching the candidate address, determining an area indicated by the candidate address as the writable area.

According to another aspect of the present invention, a method is provided for searching for a writable area of a write-once information recording medium. The write-once information recording medium comprises: a data area for recording user data; a recording management area for recording recording management information indicating a recorded state of the data area; and a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. The defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected. The method comprises the steps of: when there is at least one defective area in

a prescribed recording range of the data area, detecting a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range; setting an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area; and searching for an unrecorded area using the candidate address as a reference, and determining the detected unrecorded area as the writable area.

According to another aspect of the present invention, a method is provided for updating recording management information indicating a recorded state of a data area for recording user data of a write-once information recording medium. The write-once information recording medium further comprises a recording management area for recording the recording management information. The recording management information contains at least one recorded area address indicating at least one recorded area. The method comprises the steps of: determining whether or not there is a defective area in a prescribed recording range of the data area; and when there is the defective area in the prescribed recording range, updating the recording management information so that a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after an address indicating the defective area.

In one embodiment of this invention, the write-once information recording medium further comprises a defect management area for recording defect management information

for managing the defective area when there is the defective area. The method further comprises the step of: when there is the defective area in the prescribed recording range, updating the defect management information so that the defect management information contains a defective area address indicating the defective area.

According to another aspect of the present invention, a write-once information recording medium is provided, comprising: a data area for recording user data; and a recording management area for recording recording management information indicating a recorded state of the data area. The recording management information contains at least one recorded area address indicating at least one recorded area. Where there is a defective area in a prescribed recording range of the data area, a recorded area address indicating the terminating end of a recorded area in the prescribed recording range indicates an address on or after the defective area.

In one embodiment of this invention, the write-once information recording medium further comprises a defect management area for recording defect management information for managing the defective area when there is the defective area.

INDUSTRIAL APPLICABILITY

According to the present invention, it is determined whether or not a detected unrecorded area matches a defective area, thereby preventing a defective area from being determined to be a writable area. Therefore, information can be consistently recorded into a normal recording area.

According to the present invention, a write-once information recording medium is realized such that there is no detected defective area in a recorded area after a last recorded address in a prescribed recording range. According to the present invention, the latest last recorded address is consistently an address indicating a recorded area on or after a defective area. Thereby, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required, resulting in a reduction in the time spent determining a writable area.

According to the present invention, a pointer indicating a starting position of information indicating a defect list or a recorded state is contained in a write-once information recording medium. Therefore, an RMD or a DMS can have a variable length. Therefore, an area can be more efficiently used.

According to the present invention, an RMD and a DMS are recorded together. Therefore, only a one-time procedure for searching the border between a recorded area and an unrecorded area is required when the latest RMD and DMS are read out, resulting in a reduction in the procedure time.

Thus, the present invention is useful in the technical field of recording information onto a write-once information recording medium and reproducing information from a write-once information recording medium.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention.

Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly construed.

CLAIMS

1. An apparatus for searching for a writable area of a write-once information recording medium, wherein

the write-once information recording medium comprises:

a data area for recording user data;

a recording management area for recording recording management information indicating a recorded state of the data area; and

a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area,

the recording management information contains at least one recorded area address indicating at least one recorded area,

the defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected,

the apparatus comprises:

a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium;

a searching portion for searching for an unrecorded area of the write-once information recording medium; and

a control portion for controlling operations of the head portion and the searching portion,

the searching portion searches for the unrecorded area using a prescribed address as a reference,

the control portion provides a candidate address indicating a candidate for the writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information,

when it is determined that there is the defective area address indicating an address matching the candidate address, the searching portion performs a second search for another unrecorded area using an address after the candidate address as a reference, and the control portion resets the candidate address based on a result of the second search and performs the determination procedure, and

when it is determined that there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

2. An apparatus for searching for a writable area of a write-once information recording medium, wherein

the write-once information recording medium comprises:

a data area for recording user data;

a recording management area for recording recording management information indicating a recorded state of the data area; and

a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area,

the recording management information contains at least one recorded area address indicating at least one recorded area,

the defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected,

the apparatus comprises:

a head portion for performing at least one of recording information onto the write-once information recording medium and reproducing information from the write-once information recording medium;

a searching portion for searching for an unrecorded area of the write-once information recording medium; and

a control portion for controlling operations of the head portion and the searching portion,

when there is at least one defective area in a prescribed recording range of the data area, the control portion detects a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range,

the control portion sets an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area, and

the searching portion searches for an unrecorded area using the candidate address as a reference, and the control portion determines the detected unrecorded area as the writable area.

3. An integrated circuit for searching for a writable area of a write-once information recording medium, wherein

the write-once information recording medium comprises:

a data area for recording user data;

a recording management area for recording recording management information indicating a recorded state of the data area; and

a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area,

the recording management information contains at least one recorded area address indicating at least one recorded area,

the defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected,

the integrated circuit comprises:

a searching portion for searching for an unrecorded area of the write-once information recording medium; and

a control portion for controlling an operation of the searching portion,

the searching portion searches for the unrecorded area using a prescribed address as a reference,

the control portion provides a candidate address indicating a candidate for the writable area based on a result of the search, and performs a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information,

when it is determined that there is the defective area address indicating an address matching the candidate address, the searching portion performs a second search for another unrecorded area using an address after the candidate

address as a reference, and the control portion resets the candidate address based on a result of the second search and performs the determination procedure, and

when it is determined that there is not the defective area address indicating an address matching the candidate address, the control portion determines an area indicated by the candidate address as the writable area.

4. An integrated circuit for searching for a writable area of a write-once information recording medium, wherein

the write-once information recording medium comprises:

a data area for recording user data;

a recording management area for recording recording management information indicating a recorded state of the data area; and

a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area,

the recording management information contains at least one recorded area address indicating at least one recorded area,

the defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected,

the integrated circuit comprises:

a searching portion for searching for an unrecorded area of the write-once information recording medium; and

a control portion for controlling an operations of the searching portion,

when there is at least one defective area in a prescribed recording range of the data area, the control portion detects a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range,

the control portion sets an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area, and

the searching portion searches for an unrecorded area using the candidate address as a reference, and the control portion determines the detected unrecorded area as the writable area.

5. A method for searching for a writable area of a write-once information recording medium, wherein

the write-once information recording medium comprises:

a data area for recording user data;

a recording management area for recording recording management information indicating a recorded state of the data area; and

a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been detected in the data area,

the recording management information contains at least one recorded area address indicating at least one recorded area,

the defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been

detected,

the method comprises the steps of:

searching for the unrecorded area using a prescribed address as a reference;

providing a candidate address indicating a candidate for the writable area based on a result of the search, and performing a determination procedure for determining whether or not there is a defective area address indicating an address matching the candidate address in the defect management information;

when it is determined that there is the defective area address indicating an address matching the candidate address, performing a second search for another unrecorded area using an address after the candidate address as a reference, and resetting the candidate address based on a result of the second search and performs the determination procedure; and

when it is determined that there is not the defective area address indicating an address matching the candidate address, determining an area indicated by the candidate address as the writable area.

6. A method for searching for a writable area of a write-once information recording medium, wherein

the write-once information recording medium comprises:

a data area for recording user data;

a recording management area for recording recording management information indicating a recorded state of the data area; and

a defect management area for recording defect management information for managing at least one defective area when the at least one defective area has been

detected in the data area,

the recording management information contains at least one recorded area address indicating at least one recorded area,

the defect management information contains at least one defective area address indicating the at least one defective area when the at least one defective area has been detected,

the method comprises the steps of:

when there is at least one defective area in a prescribed recording range of the data area, detecting a defective area address indicating an address of a defective area located at a last address in the at least one defective area of the prescribed recording range;

setting an address, located after both the detected defective area address and a recorded area address indicating a recorded area of the prescribed recording range, to be a candidate address indicating a candidate for the writable area; and

searching for an unrecorded area using the candidate address as a reference, and determining the detected unrecorded area as the writable area.

FIG. 1

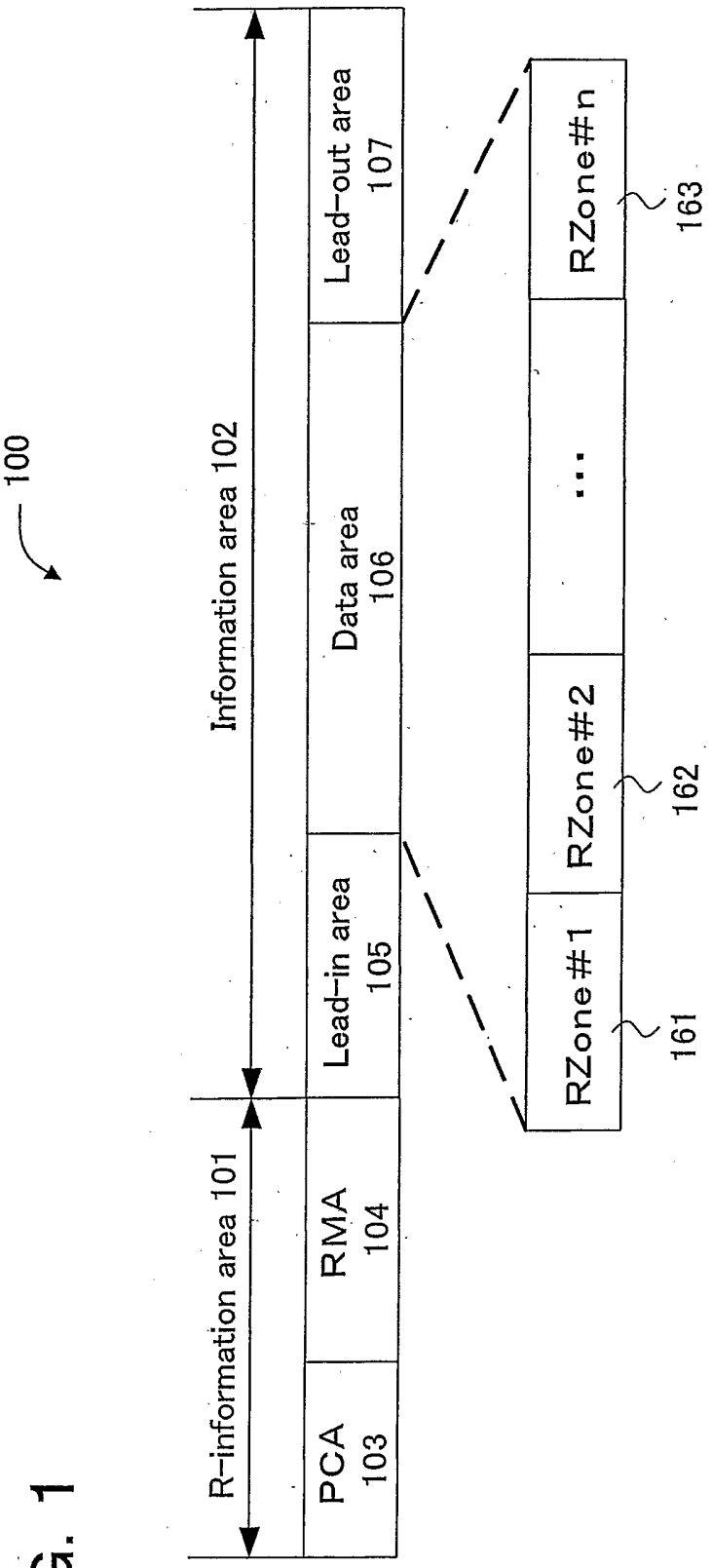

100
Information area 102
R-information area 101
PCA 103
RMA 104
Lead-in area 105
Data area 106
Lead-out area 107
RZone#1
RZone#2
...
RZone#n
161
162
163

FIG. 2

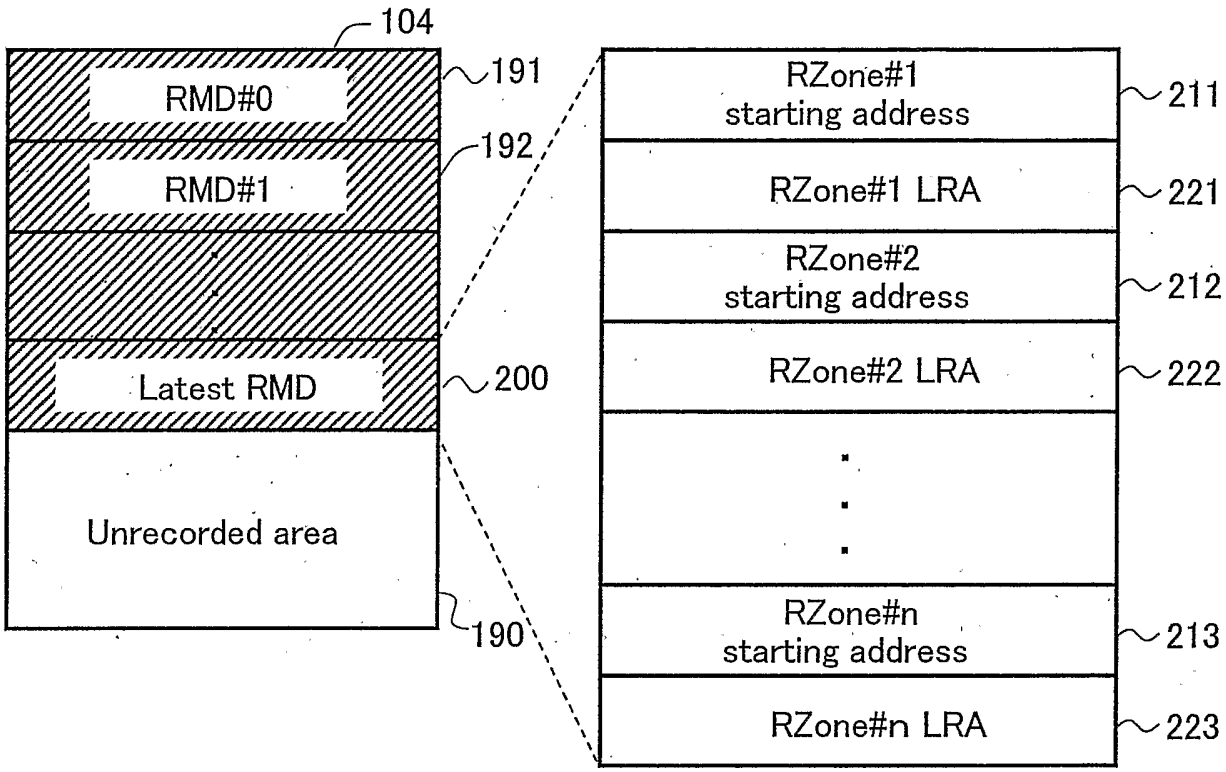

104
RMD#0
191
RMD#1
192
Latest RMD
200
Unrecorded area
190
RZone#1 starting address
211
RZone#1 LRA
221
RZone#2 starting address
212
RZone#2 LRA
222
RZone#n starting address
213
RZone#n LRA
223

FIG. 3

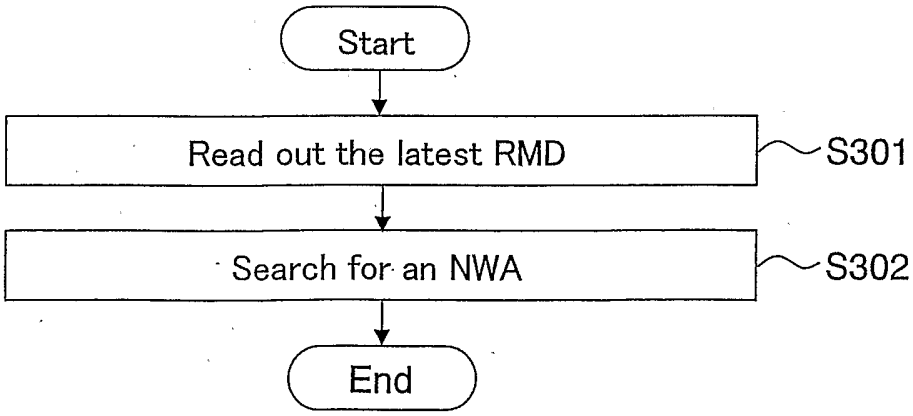

Start
Read out the latest RMD
S301
Search for an NWA
S302
End

FIG. 4

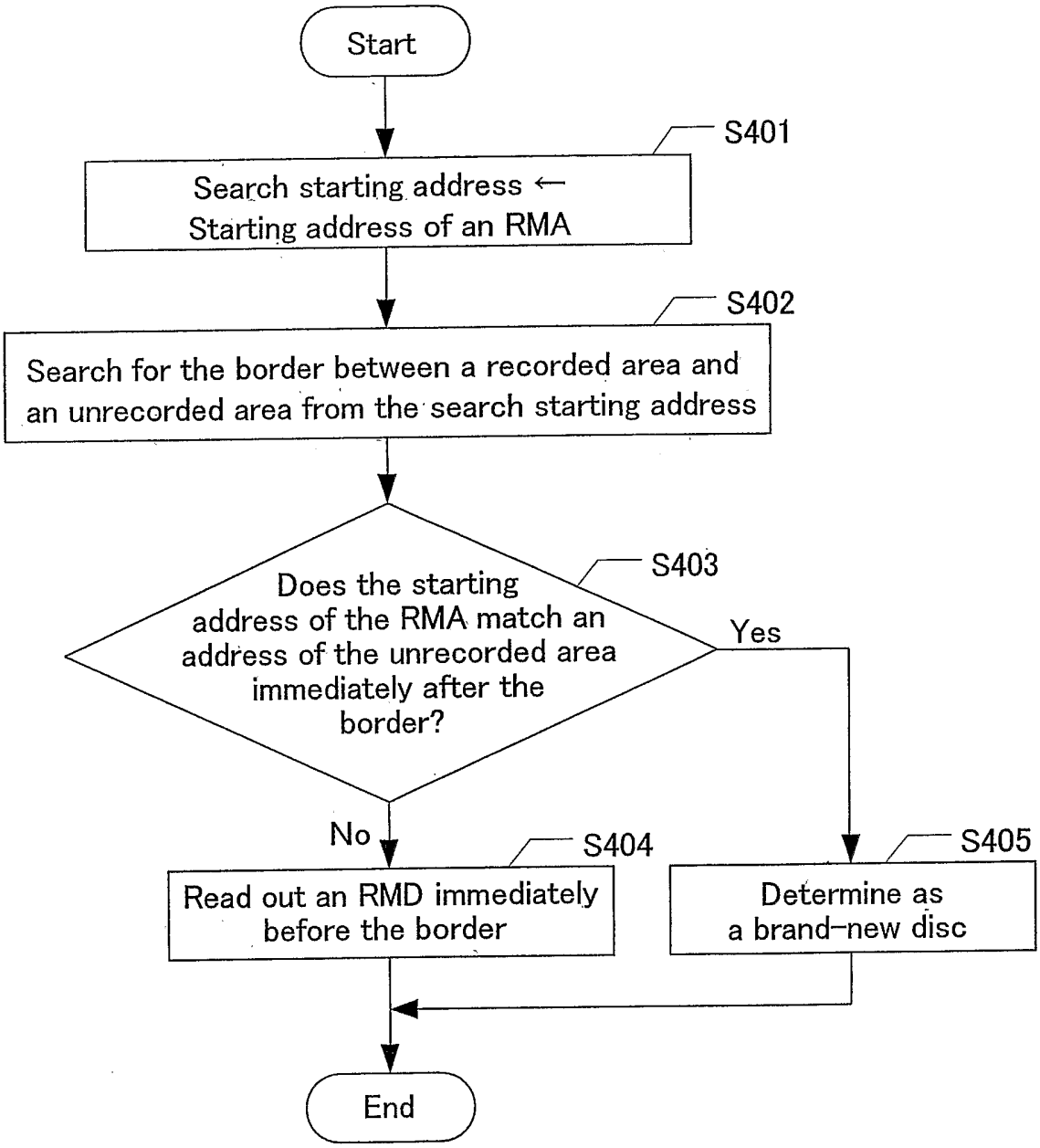

Start
S401
Search starting address ← Starting address of an RMA
S402
Search for the border between a recorded area and an unrecorded area from the search starting address
S403
Does the starting address of the RMA match an address of the unrecorded area immediately after the border?
Yes
No
S404
Read out an RMD immediately before the border
S405
Determine as a brand-new disc
End

FIG. 5

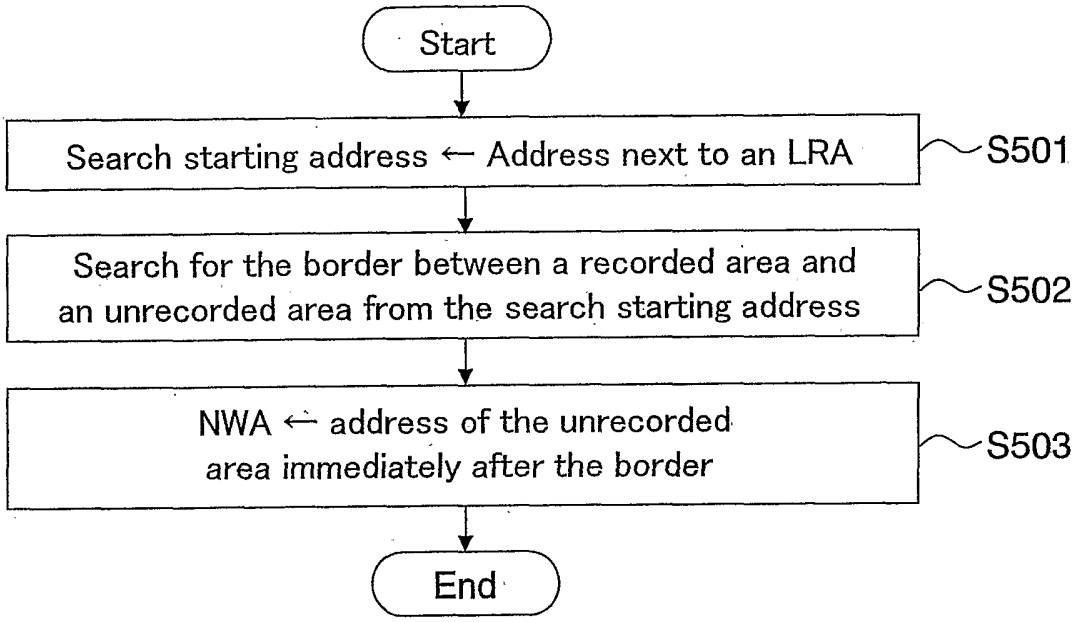
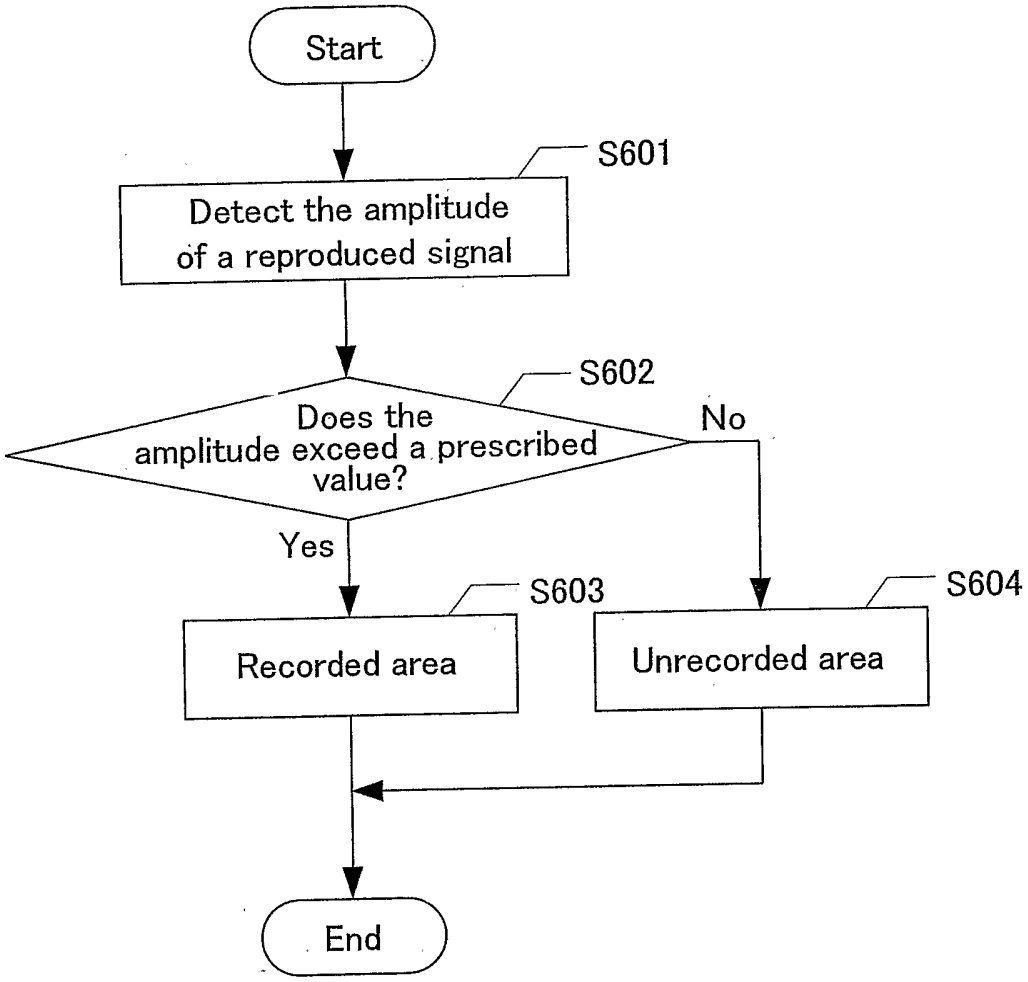

Start
Search starting address ← Address next to an LRA
S501
Search for the border between a recorded area and an unrecorded area from the search starting address
S502
NWA ← address of the unrecorded area immediately after the border
S503
End

FIG. 6


Start
S601
Detect the amplitude of a reproduced signal
S602
Does the amplitude exceed a prescribed value?
No
Yes
S603
Recorded area
S604
Unrecorded area
End

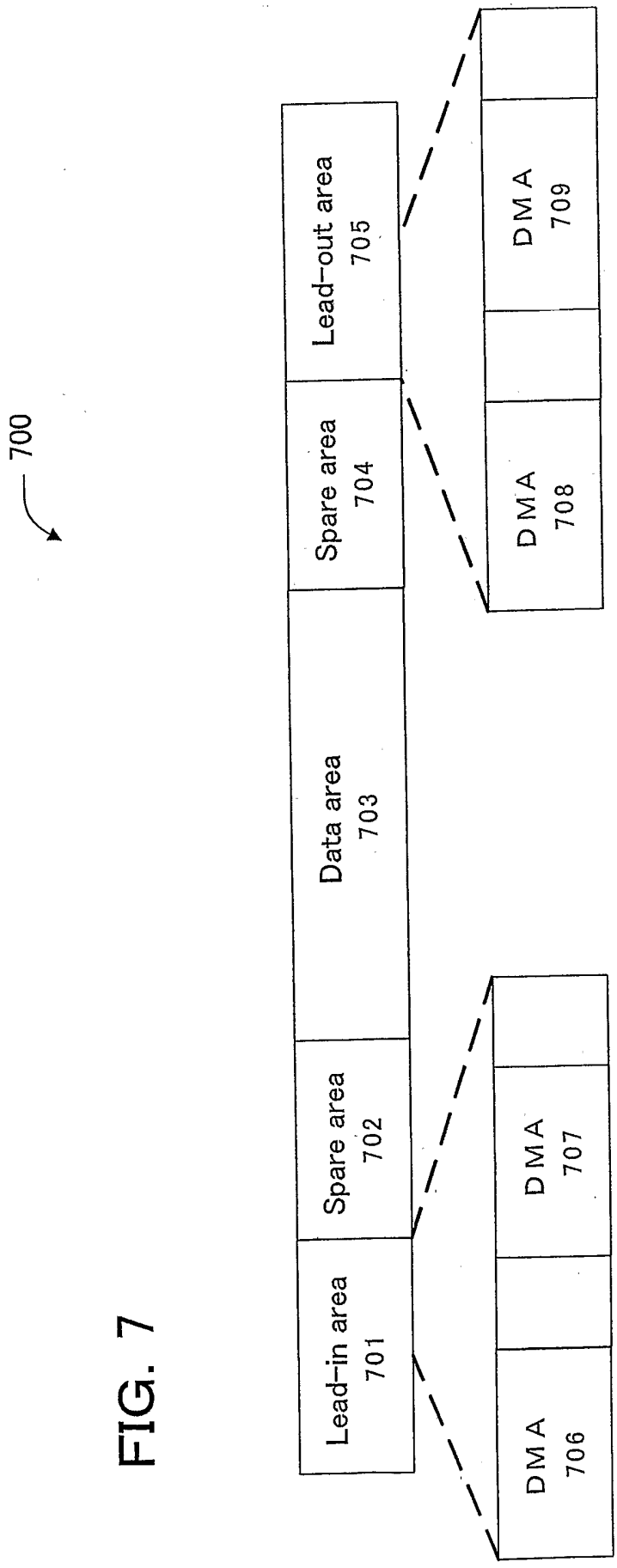
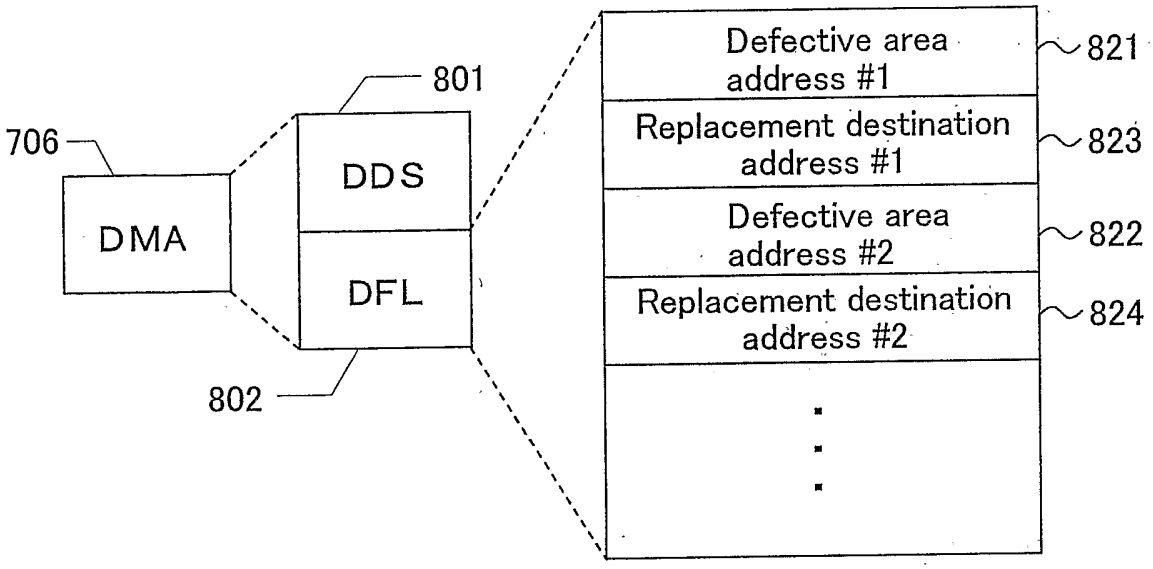

700
Lead-in area
701
Spare area
702
Data area
703
Spare area
704
Lead-out area
705
DMA
706
DMA
707
DMA
708
DMA
709

FIG. 7

FIG. 8


706
DMA
801
DDS
DFL
802
Defective area address #1
821
Replacement destination address #1
823
Defective area address #2
822
Replacement destination address #2
824

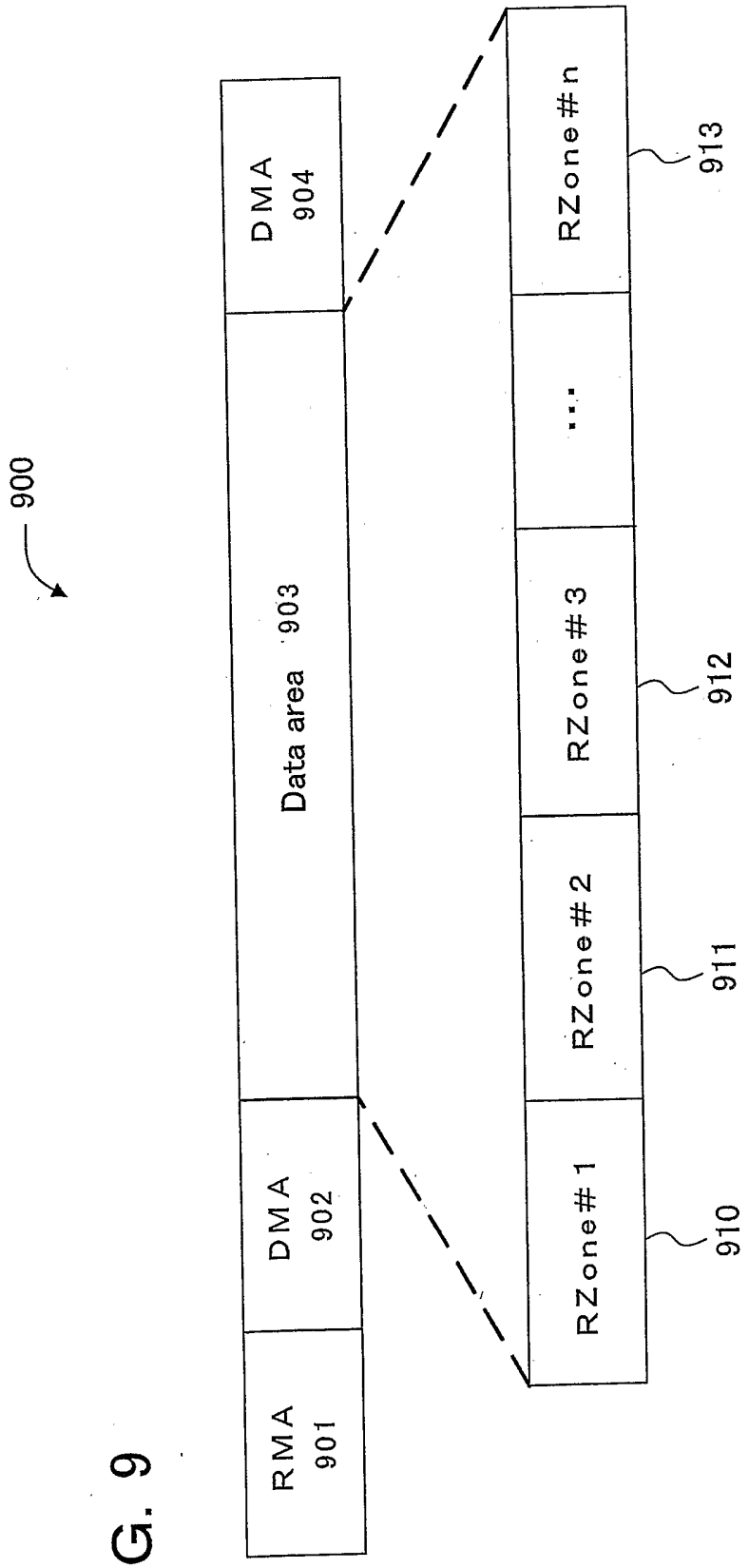

900
RMA
901
DMA
902
Data area
903
DMA
904
RZone#1
910
RZone#2
911
RZone#3
912
...
RZone#n
913

FIG. 9

FIG. 10

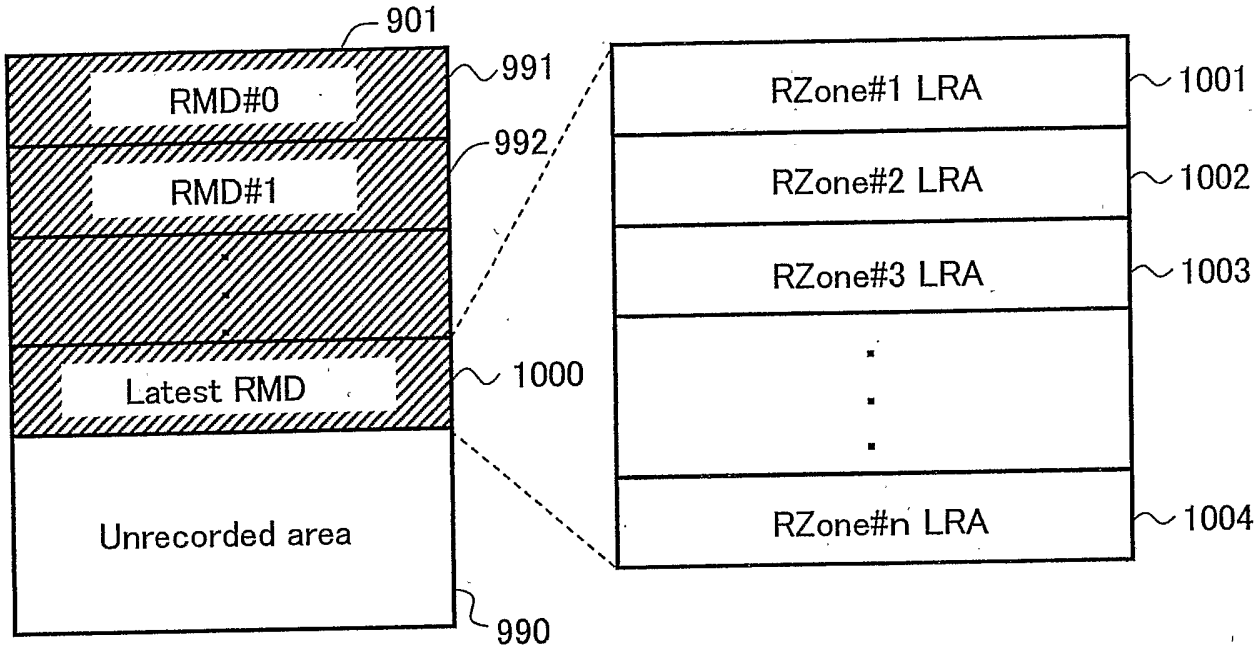

901
991
RMD#0
992
RMD#1
Latest RMD
1000
Unrecorded area
990
RZone#1 LRA
1001
RZone#2 LRA
1002
RZone#3 LRA
1003
RZone#n LRA
1004

FIG. 11

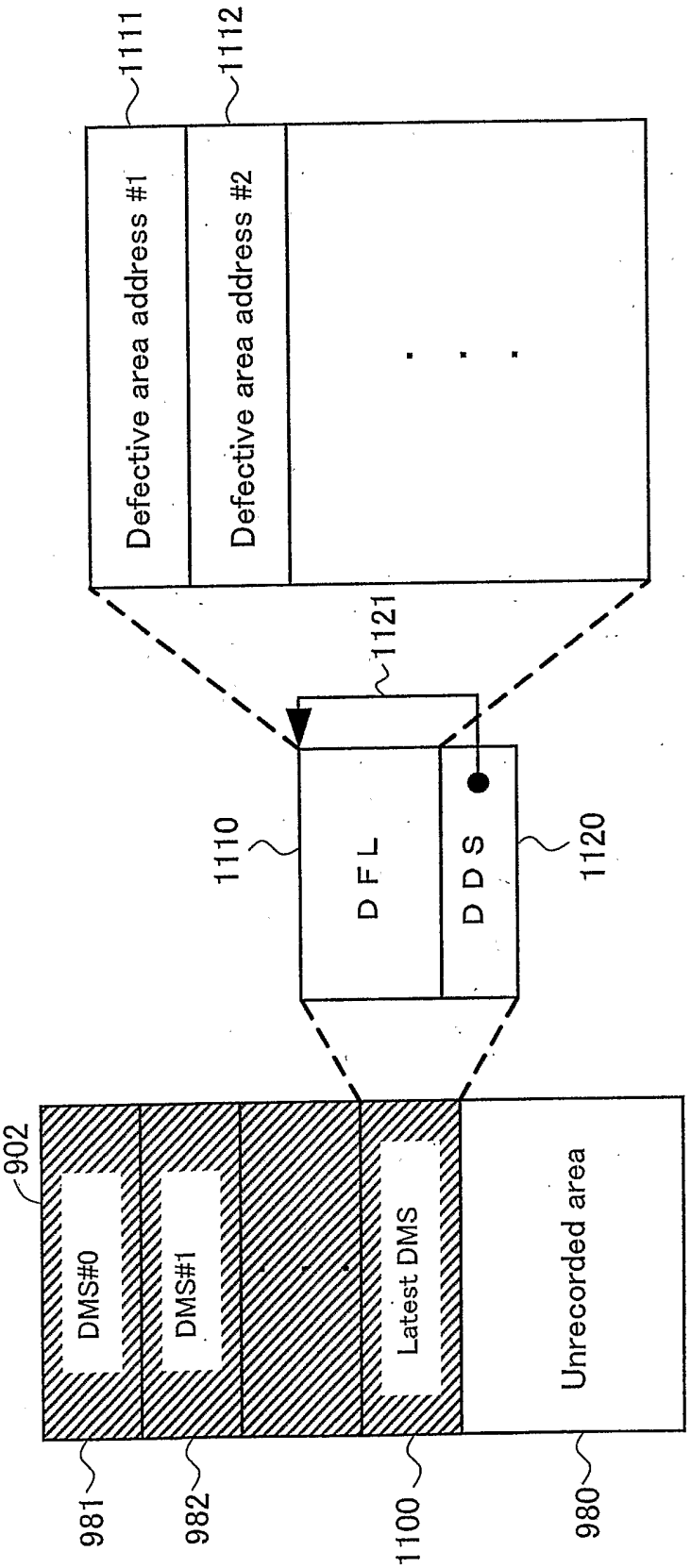

1111
1112
Defective area address #1
Defective area address #2
1121
1110
DFL
DDS
1120
902
DMS#0
DMS#1
Latest DMS
Unrecorded area
981
982
1100
980

FIG. 12

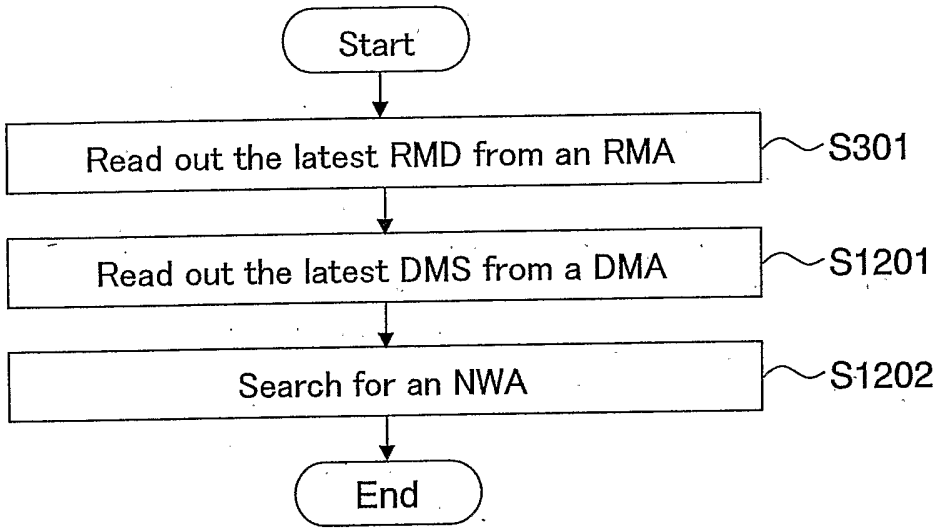

Start
Read out the latest RMD from an RMA
S301
Read out the latest DMS from a DMA
S1201
Search for an NWA
S1202
End

FIG. 13

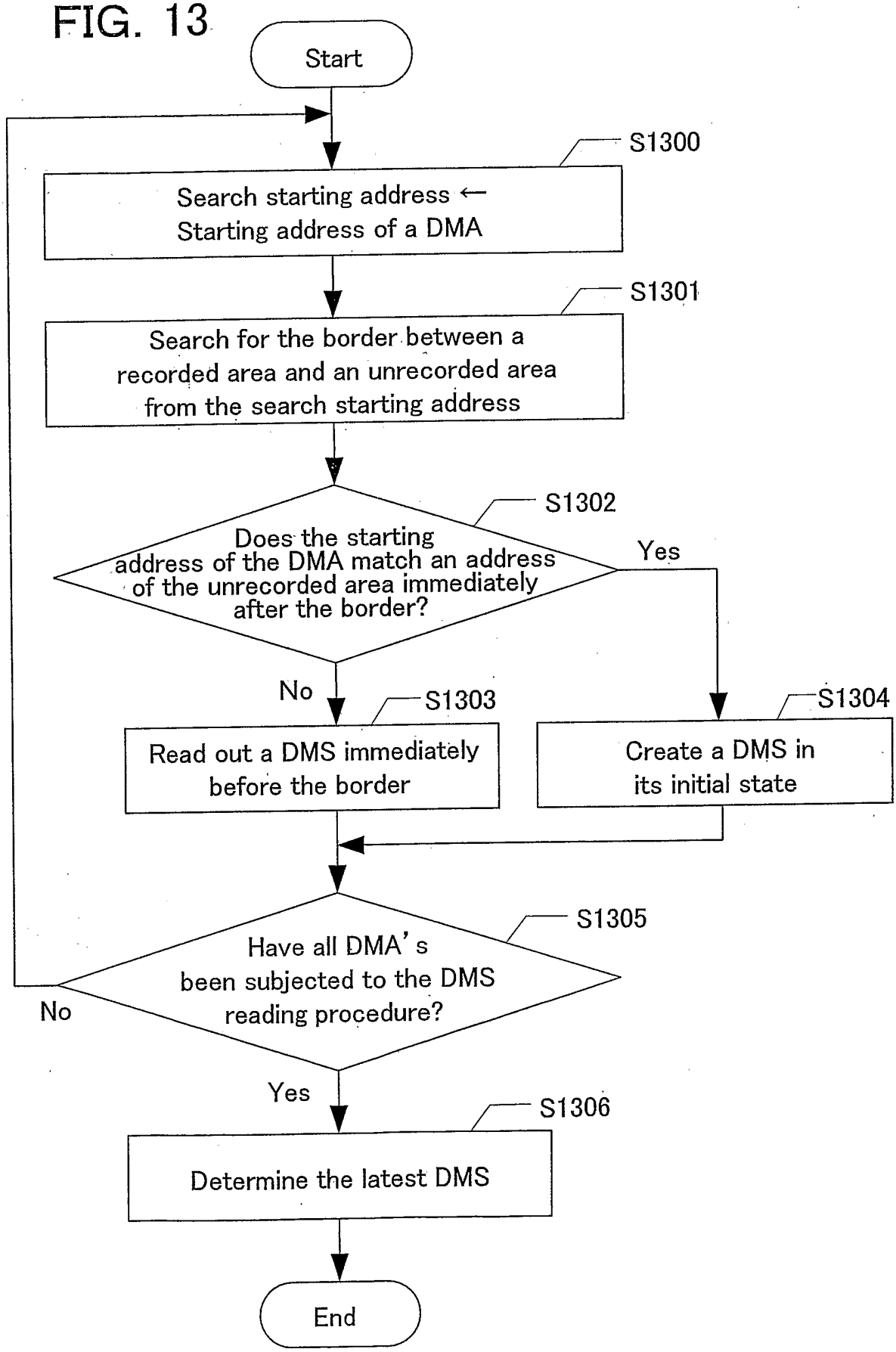

Start
S1300
Search starting address ← Starting address of a DMA
S1301
Search for the border between a recorded area and an unrecorded area from the search starting address
S1302
Does the starting address of the DMA match an address of the unrecorded area immediately after the border?
Yes
No
S1303
Read out a DMS immediately before the border
S1304
Create a DMS in its initial state
S1305
Have all DMA's been subjected to the DMS reading procedure?
No
Yes
S1306
Determine the latest DMS
End

FIG. 14

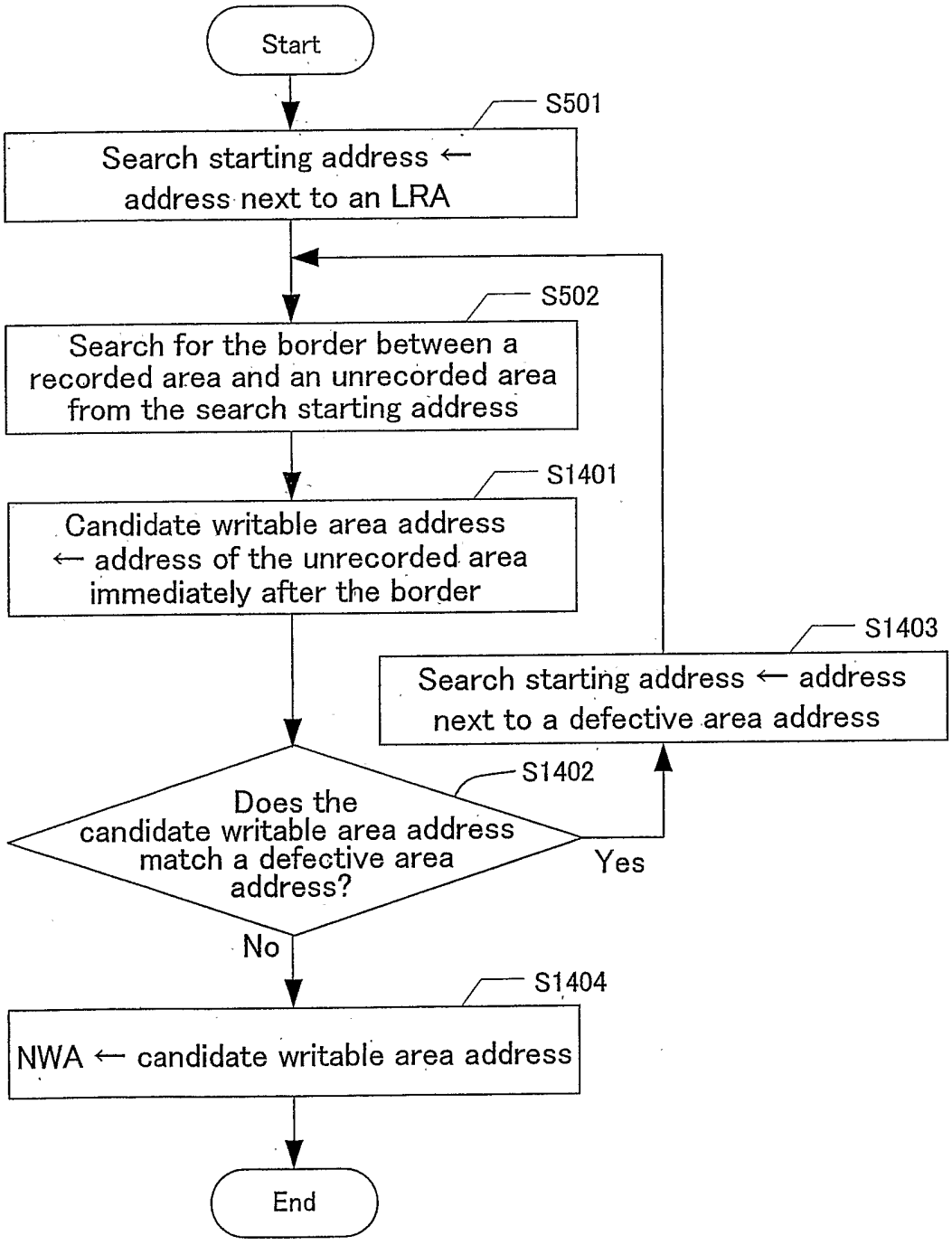

Start
S501
Search starting address ← address next to an LRA
S502
Search for the border between a recorded area and an unrecorded area from the search starting address
S1401
Candidate writable area address ← address of the unrecorded area immediately after the border
S1403
Search starting address ← address next to a defective area address
S1402
Does the candidate writable area address match a defective area address?
Yes
No
S1404
NWA ← candidate writable area address
End

FIG. 15

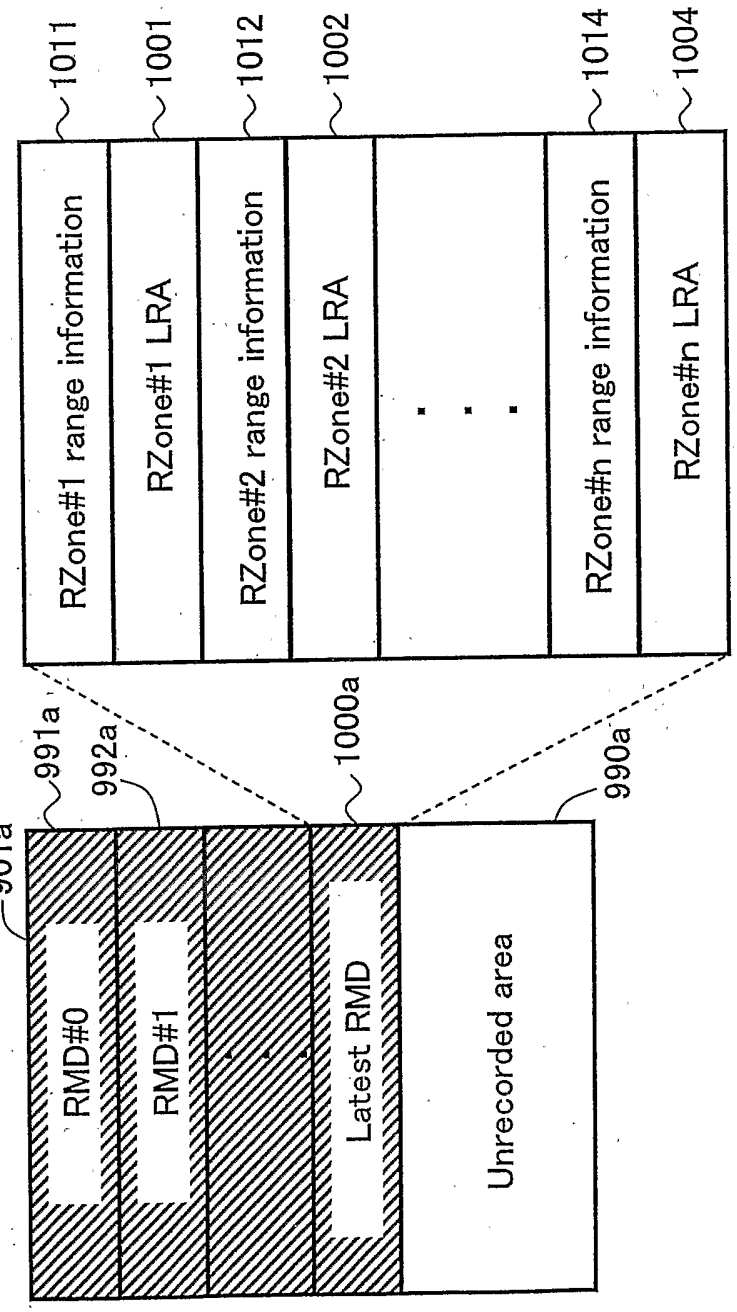

1011
1001
1012
1002
1014
1004
RZone#1 range information
RZone#1 LRA
RZone#2 range information
RZone#2 LRA
RZone#n range information
RZone#n LRA
991a
992a
1000a
990a
901a
RMD#0
RMD#1
Latest RMD
Unrecorded area

FIG. 16

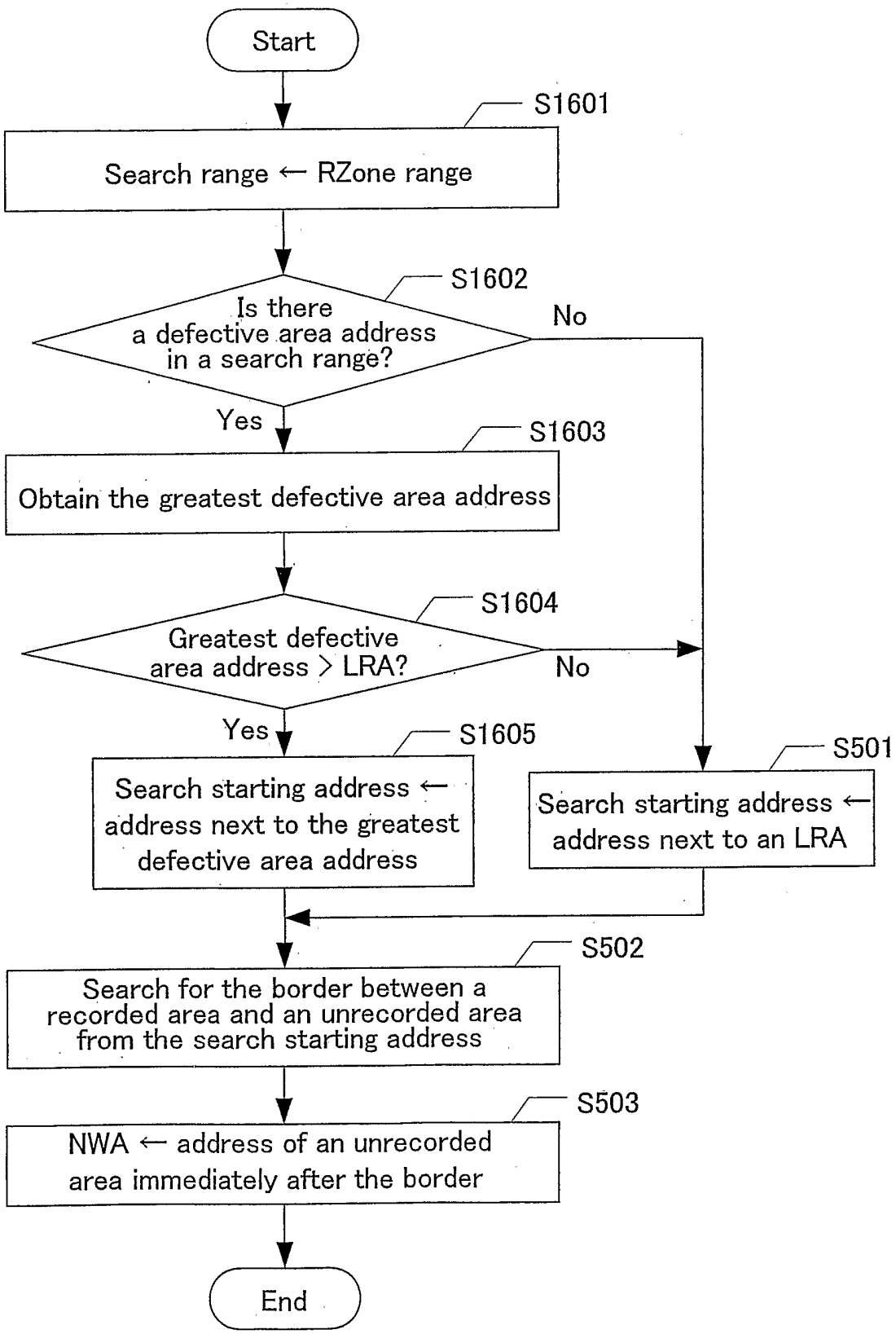
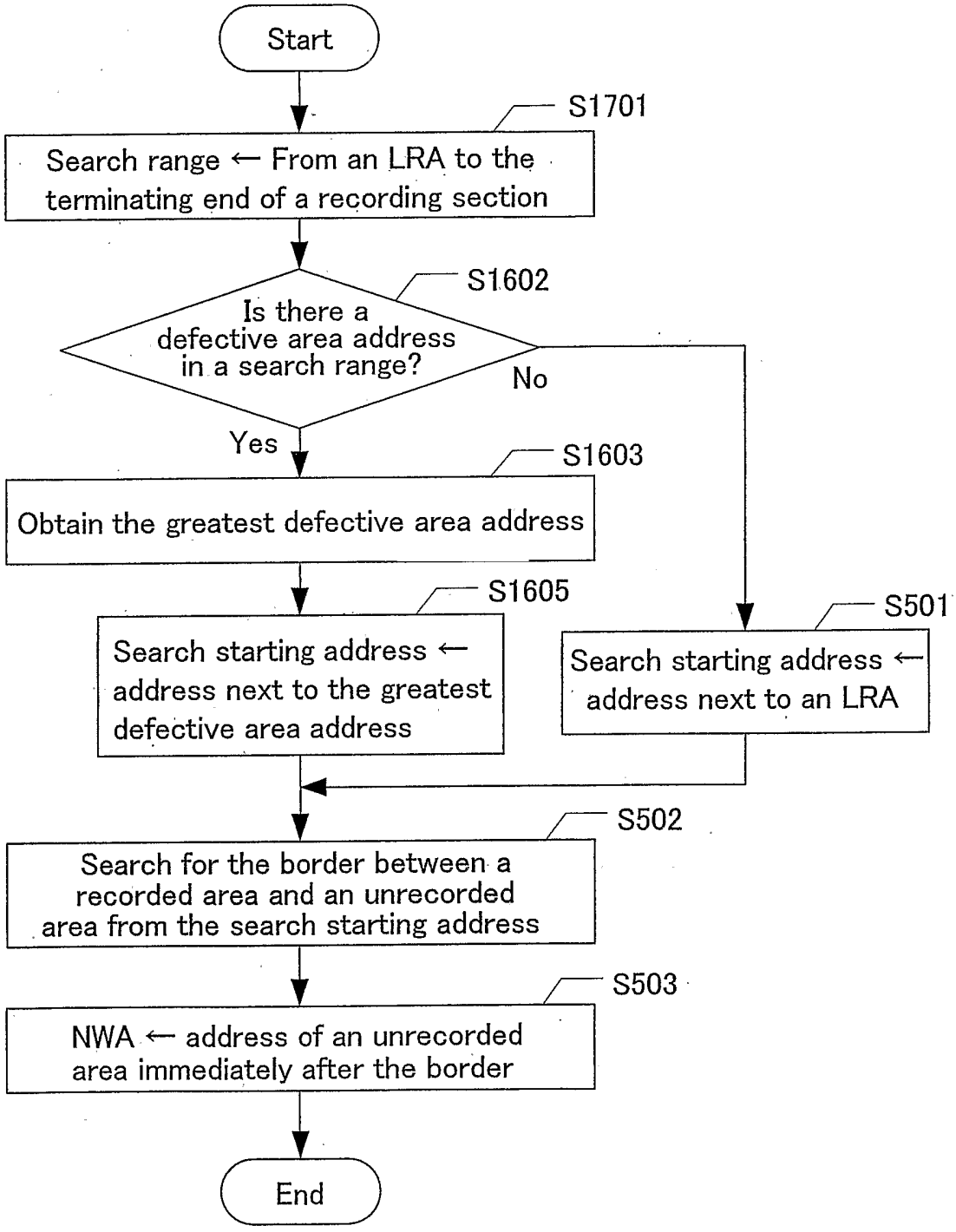

Start
S1601
Search range ← RZone range
S1602
Is there a defective area address in a search range?
No
Yes
S1603
Obtain the greatest defective area address
S1604
Greatest defective area address > LRA?
No
Yes
S1605
Search starting address ← address next to the greatest defective area address
S501
Search starting address ← address next to an LRA
S502
Search for the border between a recorded area and an unrecorded area from the search starting address
S503
NWA ← address of an unrecorded area immediately after the border
End

FIG. 17


Start
S1701
Search range ← From an LRA to the terminating end of a recording section
S1602
Is there a defective area address in a search range?
No
Yes
S1603
Obtain the greatest defective area address
S1605
Search starting address ← address next to the greatest defective area address
S501
Search starting address ← address next to an LRA
S502
Search for the border between a recorded area and an unrecorded area from the search starting address
S503
NWA ← address of an unrecorded area immediately after the border
End

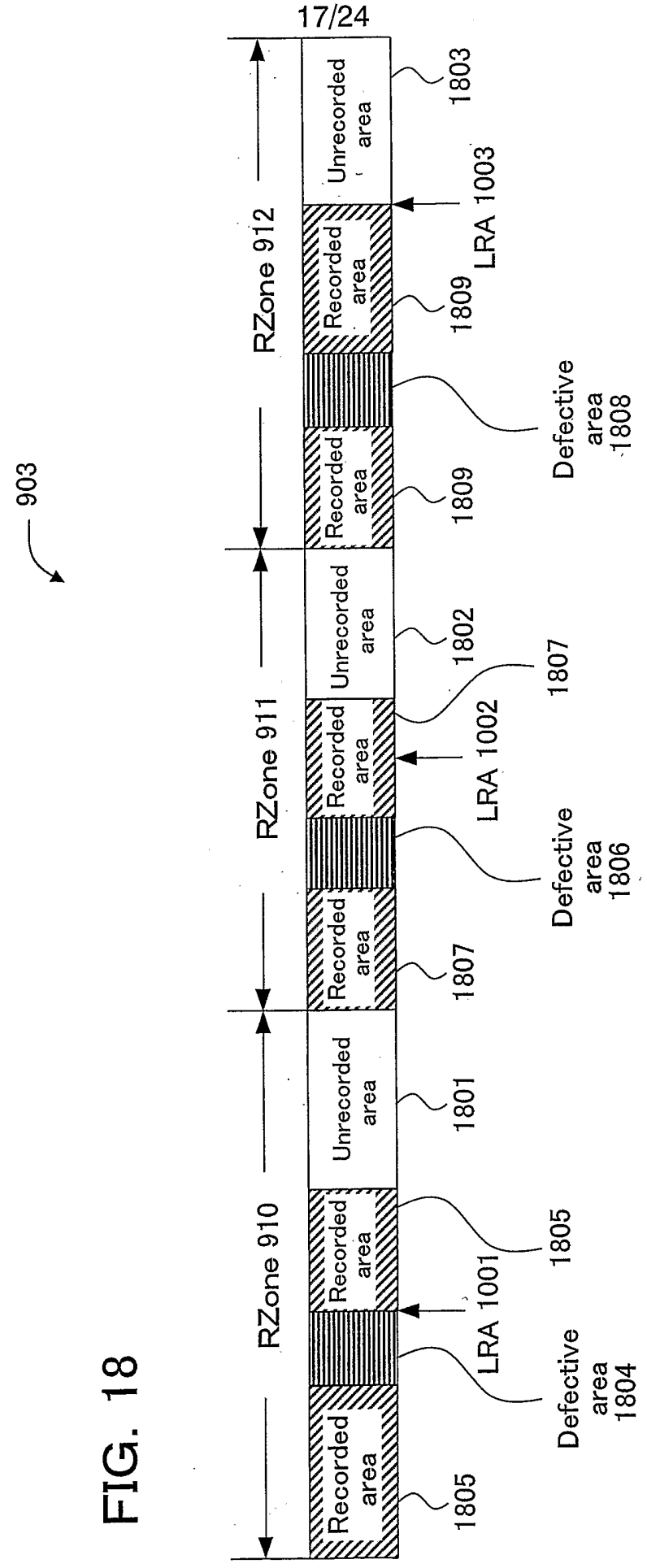
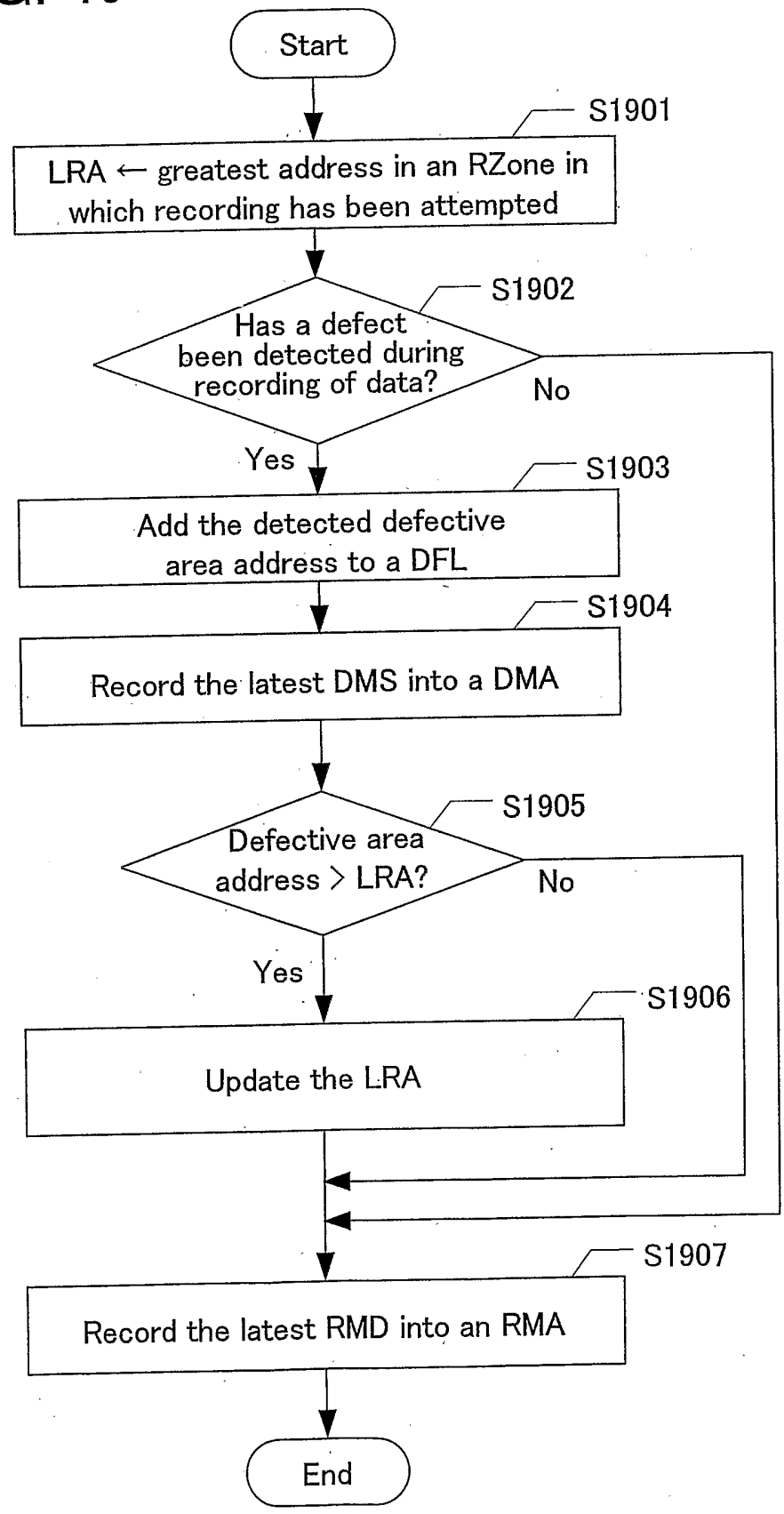

903
RZone 910
RZone 911
RZone 912
Recorded area
Unrecorded area
Defective area
LRA 1001
LRA 1002
LRA 1003
1801
1802
1803
1804
1805
1806
1807
1808
1809

FIG. 18

FIG. 19


Start
S1901
LRA ← greatest address in an RZone in which recording has been attempted
S1902
Has a defect been detected during recording of data?
No
Yes
S1903
Add the detected defective area address to a DFL
S1904
Record the latest DMS into a DMA
S1905
Defective area address > LRA?
No
Yes
S1906
Update the LRA
S1907
Record the latest RMD into an RMA
End

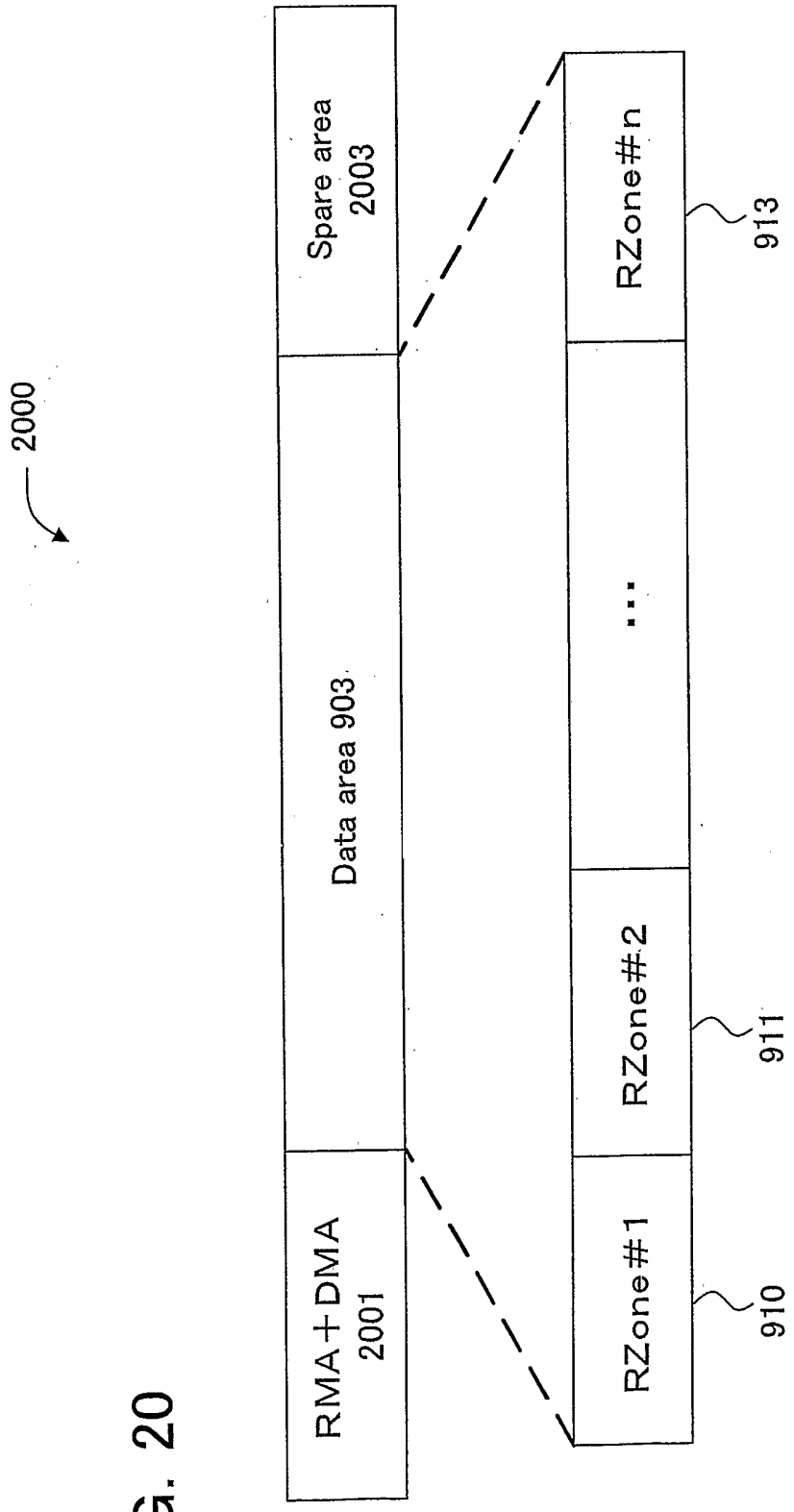

2000
Spare area
2003
Data area 903
RMA+DMA
2001
RZone#n
913
...
RZone#2
911
RZone#1
910

FIG. 20

FIG. 21

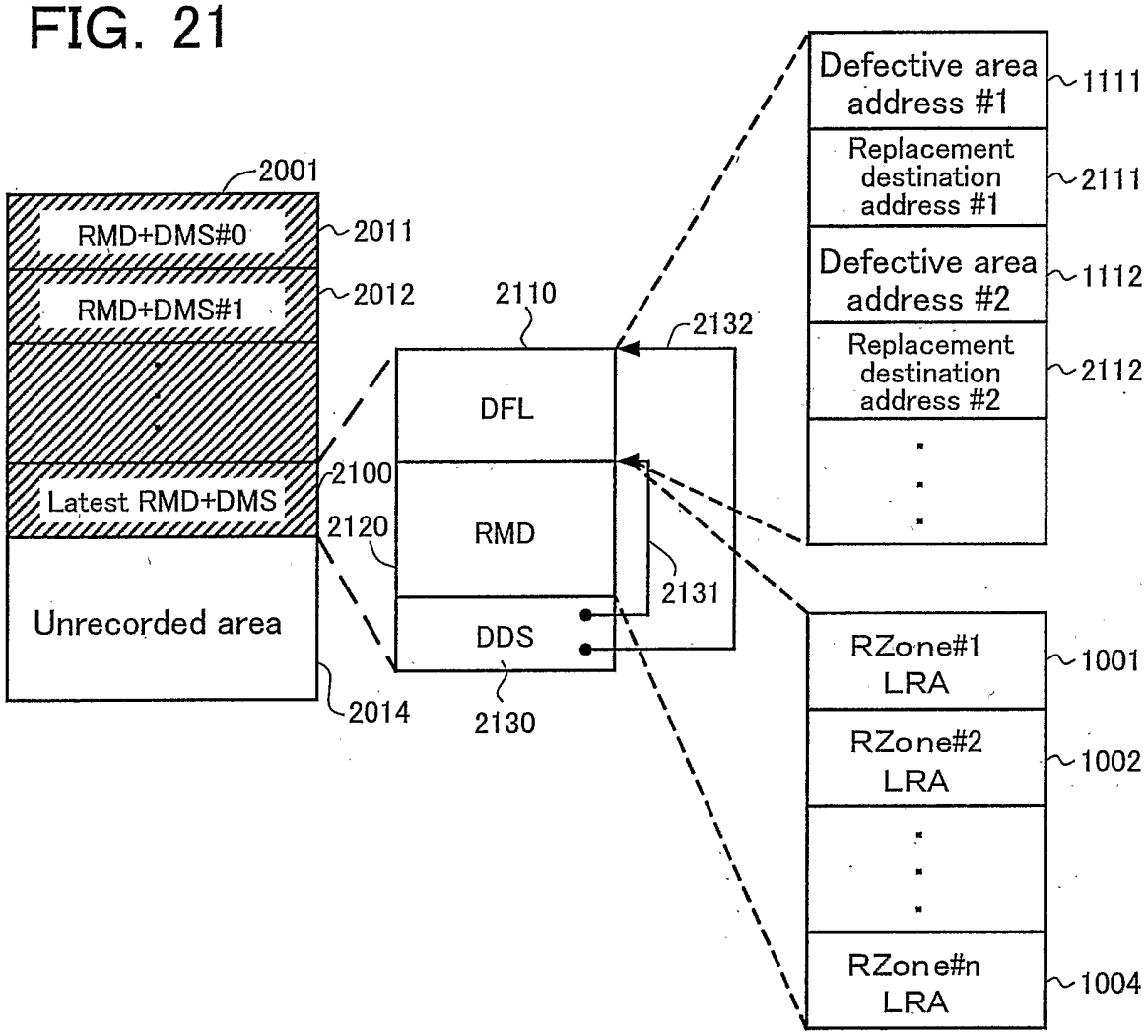

2001
RMD+DMS#0
2011
RMD+DMS#1
2012
2100
Latest RMD+DMS
2120
Unrecorded area
2014
2110
DFL
RMD
DDS
2130
2132
2131
Defective area address #1
1111
Replacement destination address #1
2111
Defective area address #2
1112
Replacement destination address #2
2112
RZone#1 LRA
1001
RZone#2 LRA
1002
RZone#n LRA
1004

FIG. 22

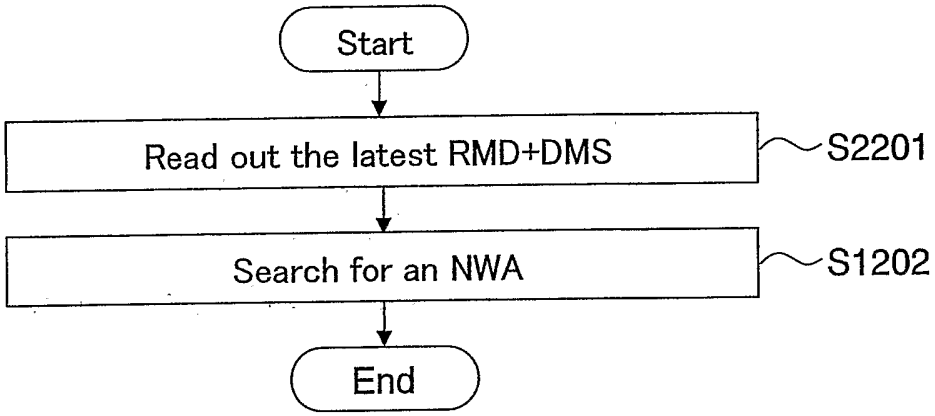

Start
Read out the latest RMD+DMS
S2201
Search for an NWA
S1202
End

FIG. 23

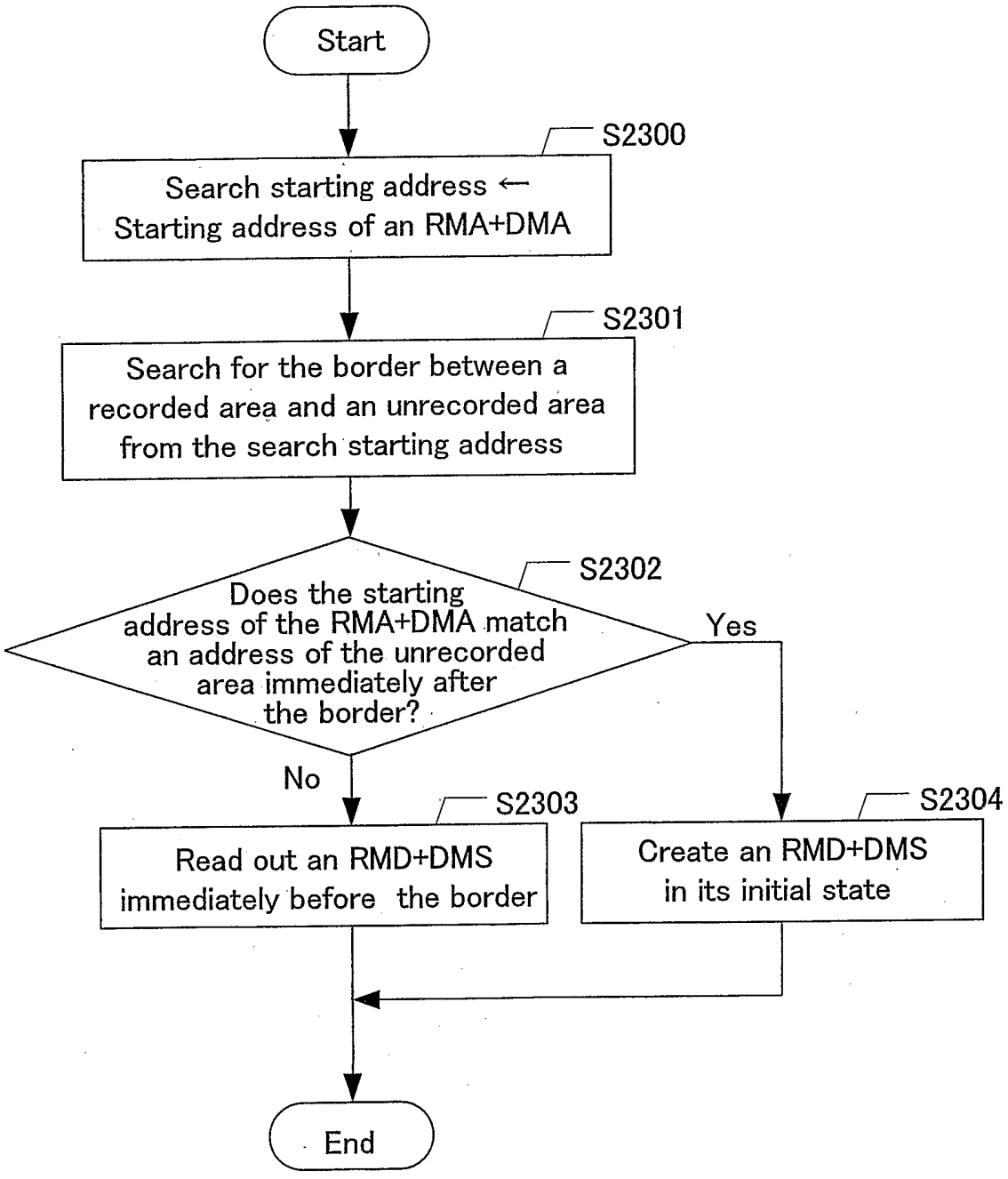
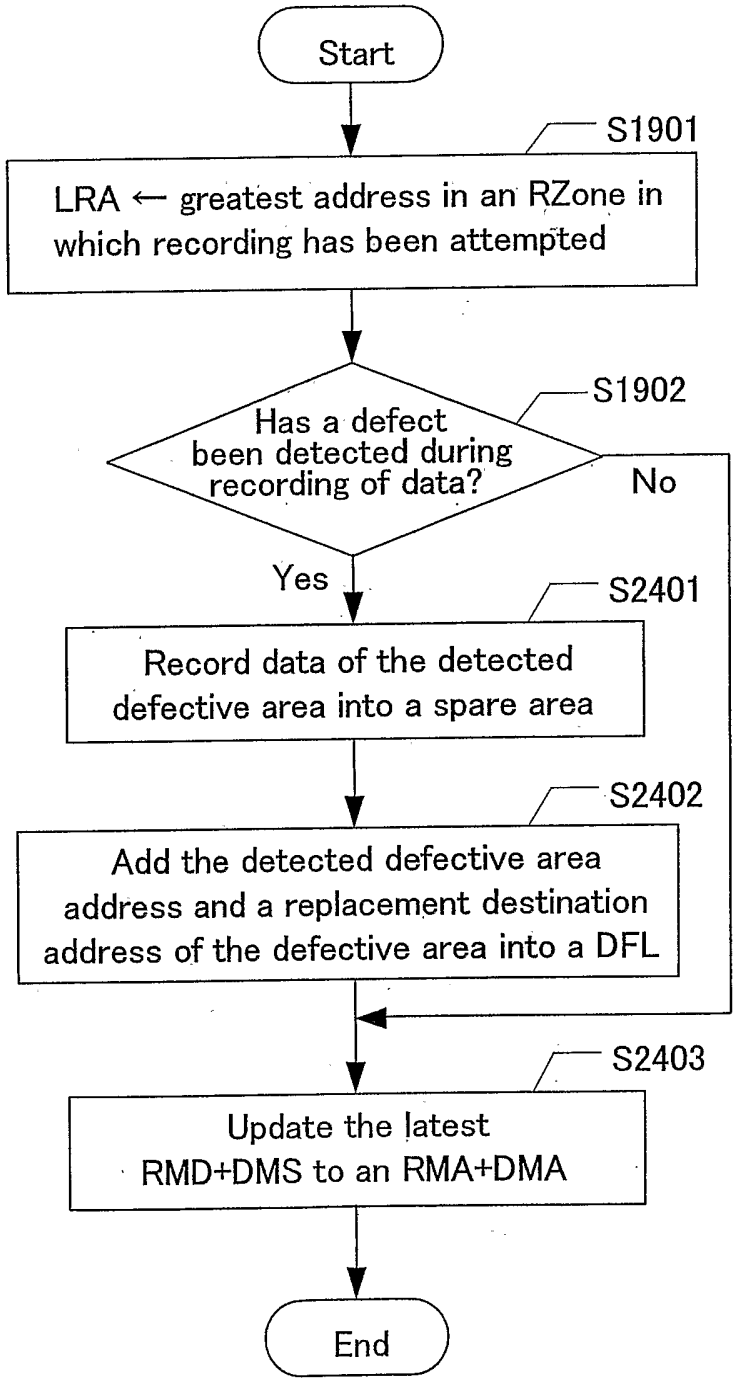

Start
S2300
Search starting address ← Starting address of an RMA+DMA
S2301
Search for the border between a recorded area and an unrecorded area from the search starting address
S2302
Does the starting address of the RMA+DMA match an address of the unrecorded area immediately after the border?
Yes
No
S2303
Read out an RMD+DMS immediately before the border
S2304
Create an RMD+DMS in its initial state
End

FIG. 24


Start
S1901
LRA ← greatest address in an RZone in which recording has been attempted
S1902
Has a defect been detected during recording of data?
No
Yes
S2401
Record data of the detected defective area into a spare area
S2402
Add the detected defective area address and a replacement destination address of the defective area into a DFL
S2403
Update the latest RMD+DMS to an RMA+DMA
End

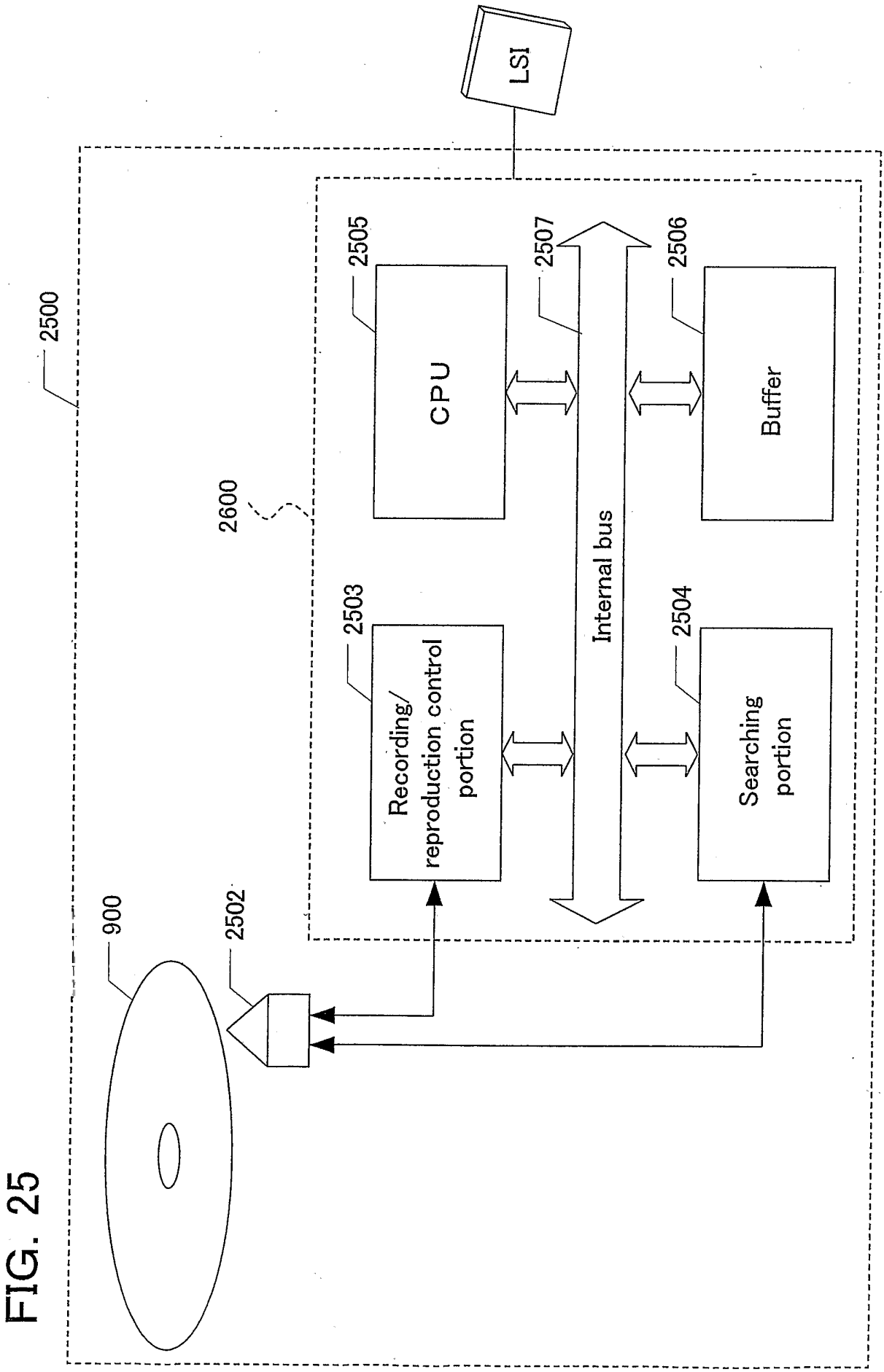

LSI
2500
2505
CPU
2507
2506
Buffer
2600
Internal bus
2503
Recording/
reproduction control
portion
2504
Searching
portion
900
2502

FIG. 25