

Description

Field of Invention

This invention relates to computer systems in general and more particularly to methods for locating stored data on a magnetic disk.

Description of the Prior Art

Computer systems often use peripheral storage devices, such as magnetic disks, to store data. The data is stored on the disks in circular tracks. Each track is divided into a number of sectors usually consisting of either 512 or 576 bytes, that is, eight-bit symbols. Each sector, in turn, consists of two sections, an address section and a data section. The sector is uniquely identified by address symbols which are stored in the address section of the sector when the disk is formatted.

The disk drive has a read/write head which must be over a sector to perform a storage or retrieval ("write" or "read") operation in the sector. Thus the address of the sector rotating under the head is read and a determination is made whether or not the sector is the correct sector. This must be done in the time it takes the address portion of the sector to rotate under the read/write head. That is, if the drive is to perform a read or write operation in the sector, it must be ready to do so when the data portion of the sector, which closely follows the address portion, rotates under the head.

In order to determine if a sector is the correct sector, the drive reads the sector address and then compares it with the specified address of the sector in which data is to be read or written. If the addresses match, the data will be read from or written to the sector.

If an address read from a sector has errors in it, the sector may be mistakenly identified as another sector. Thus the disk drive may determine that the head is located over sector 100 when it is actually located over sector 101, and the read or write operation that is to occur at sector 100 will be performed on the wrong sector. If a sector address contains several errors or the address is corrupted due to a medium defect or soft error in the disk, the sector address may be unreadable. Thus the sector cannot be identified and it is unusable.

In order to avoid misinterpreting the address of a sector, the sector addresses must be written on the disk in such a way that even with a number of errors in the address, it will neither be read as the address of a different sector nor be rendered unidentifiable.

In a prior method for coping with errors in a sector address, the address is recorded several times in succession. The specified sector address is compared with each copy of the address stored in the sector,

and if some minimum number of stored addresses match the specified address the sector is determined to be the correct sector. Thus, if one of the copies of the address contains an error, the sector will still be identifiable.

The arrangement is feasible only if the system error rate is fairly low. Otherwise, the number of copies of the address that will be required in each sector to ensure some minimum number of error-free copies with a reasonable degree of certainty will be prohibitive due to the amount of storage space the addresses will occupy.

Another problem that can occur in reading a sector address is that the system can momentarily lose synchronization between sectors and thereby fail to sense correctly the beginning of an address section of a sector. It may therefore sense the wrong bits in reading the sector address. If this occurs, data may be read from or written to the wrong sector.

The use of multiple copies of the sector address does not prevent the drive from identifying the wrong sector due to mis-synchronization. If the disk drive interprets a data symbol of one or two bits "off" as a correct sector address, the next few copies of the address will also be incorrectly interpreted and the wrong sector can be identified. If the data is then written to the wrong sector, any data previously recorded in the sector is written over and thus lost. The data that is newly written to the wrong sector is also lost because it cannot later be retrieved at the appropriate address.

Thus mistakes in interpreting the sector addresses, due either to errors in the recorded sector addresses or mis-synchronization of the read/write head, can be costly in terms of lost data and/or lost time.

In EP-A-0248536 there is described a method of seeking a target address on a recording medium. This method uses a single encoding operation to generate and append redundancy symbols to sector addresses to form code words to be recorded on the medium. On retrieval, the method determines that a read sector is the target sector if the retrieved code word and the target code word differ by not more than the number of symbols which the system can correct. There is no protection provided for incorrect identification of a sector caused by mis-synchronisation.

Patent Abstracts of Japan, Vol. 12, No. 173 & JP-A-62283475 describes a similar technique with the same drawbacks as indicated above.

Summary of the Invention

Claims 1 and 6, respectively, define a method and an apparatus in accordance with the invention. The sector addresses, which are typically represented by six data symbols, are encoded over a Galois Field GF(2^p) using a large distance, "d", Reed-

Solomon code, that is, a code that will encode the sector addresses to produce code words which vary by at least d symbols for any two different encoded addresses. Specifically, the result of the encoding is a set of redundancy symbols, which are usually associated with error correction. The redundancy symbols are appended to the address symbols to produce address code words. Just as each sector address is unique, that is, identifies only one sector, each address code word is unique. The advantage of encoding the sector address is that each address code word differs from any other address code word by at least d symbols. Thus an address code word read from the disk can contain up to $(d-1)/2$ errors and still be identified as the correct sector address because it most closely resembles only one address code word.

If a head is not synchronized correctly with the address section of the sector, the address code word can be misinterpreted. That is, the portion of the address code word read from the address portion of the section will be concatenated with the appropriate number of bits preceding the address code word or following the address code word, depending on how the head is mis-synchronized, and the resulting string of bits will be interpreted as an address code word. The result may be that the sector is incorrectly identified. In order to prevent this, the address code words are further encoded by adding them to a coset leader to produce header code words. The coset leader is a code word of a super-code of the Reed-Solomon code, that is, the generator polynomial for the code containing the coset leader is a factor of the generator polynomial for the Reed-Solomon code, but the coset leader is not a code word of the Reed-Solomon code itself.

The header code words are then recorded in the address portions of the sectors. When a header code word is read from a sector, the coset leader is subtracted from the header code word to produce an address code word. If the head is synchronized incorrectly with the address portion of a sector, the comparison of the resulting address code word with the address code word for the specified address will always result in more than $(d-1)/2$ symbols which differ between the two code words and the sector will not be treated as the specified address.

Brief Description of the Drawings

This invention is pointed out with particularity in the appended claims. The above and further advantages of this invention may be better understood by referring to the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a flow chart of the steps involved in the operation of the preferred embodiment;

Figures 2A and 2B are a flow chart of the steps involved in the start-up operation of the preferred

embodiment; and

Figure 3 is an illustration of the address section of a sector.

Detailed Description

It should be understood that all addition, subtraction and multiplication operations performed during the encoding and comparison processes are Galois Field operations and the Galois Fields are of the form $GF(2^p)$.

With reference to Figure 1, a sector address in an exemplary system is encoded over a Galois Field $GF(2^5)$ to produce redundancy symbols (step 10), using the generator polynomial

$$g(x) = (x + \alpha^{-12}) * (x + \alpha^{-11}) * (x + \alpha^{-10}) * \dots * (x + \alpha^{10}) * (x + \alpha^{11}) * (x + \alpha^{12})$$

where α is the primitive element of the field and the field is based on the primitive polynomial $p(x) = x^5 + x^2 + 1$. Thus the generator polynomial is

$$x^{25} + \alpha^{22}x^{24} + \alpha^{21}x^{23} + \alpha^{25}x^{22} + \alpha^{13}x^{21} + \alpha^{28}x^{20} + \alpha^2x^{19} + \alpha^{16}x^{18} + \alpha^{23}x^{17} + \alpha^2x^{16} + \alpha^4x^{15} + \alpha^7x^{14} + \alpha^{27}x^{13} + \alpha^{27}x^{12} + \alpha^7x^{11} + \alpha^4x^{10} + \alpha^2x^9 + \alpha^{23}x^8 + \alpha^{16}x^7 + \alpha^2x^6 + \alpha^{28}x^5 + \alpha^{13}x^4 + \alpha^{25}x^3 + \alpha^{21}x^2 + \alpha^{22}x + \alpha^0$$

The redundancy symbols are then appended to the sector address to form address code words (step 12).

This generator polynomial is a distance twenty-six Reed-Solomon code generator polynomial that can correct up to twelve errors. The distance of a Reed-Solomon code is the minimum number of symbols that are dissimilar between any two code words. If two code words generated by a distance twenty-six Reed-Solomon code are compared, at least twenty-six of the symbols in the code words will not be the same. A code word in a distance twenty-six code and containing twelve or fewer errors can therefore be identified as the correct code word. The code word can be so identified because, with twelve or fewer errors, it is "closest" to, that is, has the largest number of symbols the same as, the correct code word.

In the present system, this principle is applied to the sector-seeking operation by comparing, symbol by symbol, the address code word read from the disk with the address code word for a specified address (steps 18-22). If the two code words differ in twelve $[(d-1)/2]$ or fewer symbols, the sector is the specified sector; otherwise, it is determined not to be the specified sector (steps 24-28). Comparing the sector address code word with a specified address code word to determine the number of symbols that differ is much faster than conventional decoding and error correction techniques. Thus, using the comparison method, sector identification can be completed in time to perform a read or write operation in the data section of the sector if the sector is identified as the correct sector.

Encoding the sector addresses into address code

words does not necessarily prevent an address from being misinterpreted if the head is mis-synchronized with the address portion of a sector. If the head is mis-synchronized with a sector address code by some number, m , bits, the portion of the address code read from the sector is concatenated with m bits immediately preceding or following the address code, depending on how the head is mis-synchronized. This may result in an address code for one of the other sectors. Thus the sector could be incorrectly identified as the sector specified for a read or write operation.

To avoid the mis-identification because of mis-synchronization, the redundancy symbols are further encoded by adding them to a coset leader to produce another set of redundancy symbols (step 14). The coset leader chosen is a code word of a super-code of the Reed-Solomon code. The coset leader chosen depends on the primitive polynomial used to generate the Galois Field. In the example described herein, the coset leader, β , is

$$x^{24} + \alpha^{30}x^{23} + \alpha^1x^{22} + \alpha^{12}x^{21} + \alpha^{21}x^{20} + \alpha^4x^{19} + \alpha^{10}x^{18} + \alpha^3x^{17} + \alpha^3x^{16} + \alpha^{10}x^{15} + \alpha^4x^{14} + \alpha^{21}x^{13} + \alpha^{12}x^{12} + \alpha^1x^{11} + \alpha^{30}x^{10} + x^9$$

The coset leader is added to the redundancy symbols in the sector address code word. Thus the sector address symbols are not effected. Considering all possible address code words as a group, adding the coset leader to the redundancy symbols in the code word, in effect, shifts the entire group by an amount β . When the coset leader is later subtracted from the redundancy symbols, the code words are shifted back by the same amount β to the original address code words. If, however, a code word is misread due to a mis-synchronization of the head, the result of subtracting the coset leader from the redundancy symbols will in no case result in the address code word for the specified sector.

The new set of redundancy symbols resulting from coset leader addition are appended to the sector address to form header code words (step 14). These header code words are written in the address portion of the sectors during the formatting of the disk (step 16). When a disk drive is to perform a read or write operation in a particular sector, the specified address of the sector is encoded to form an address code word as described above. The header code word of the sector rotating under the read/write head is read and the coset leader is subtracted, that is, it is again exclusive OR'd with the header code word (step 20). The resulting sector address code word is then compared with the address code for the specified sector address as set forth above to ascertain whether or not the sector is the specified sector (steps 22-28). If the head is over the wrong sector, or if the head is over the right sector but is mis-synchronized with the address portion of the sector, the comparison will result in at least thirteen symbols which differ and the sector will not be identified as the specified sector. It will be appre-

ciated by those skilled in the art that the same result may be achieved by adding the coset leader to the address code word for the specified address to form a specified header code word and then comparing this header code word with the header code word read from the disk.

When the disk drive is powered-up, that is, when the drive is made available to perform read or write operations, the drive must accurately locate the position of the head relative to the disk before any read or write operations can be performed. Therefore the system must read the header code of the sector rotating under the head and correctly interpret the code. If there are errors in the header code word, the sector might be identified incorrectly. Thus the system must first determine if there are errors in the address portion of the header code word, and if there are errors it corrects them, if possible, by means of error correction techniques.

Preferably a technique known as permutation decoding is used to "decode" the sector address code word, that is, the header code word with the coset leader subtracted from it, to determine if there are any errors in the sector address and to correct them. Permutation decoding is an uncomplicated, fast error correction technique which is suitable for codes with high redundancy, i.e., codes which have a large number of redundancy symbols to correct a small number of errors. That is, permutation decoding corrects fewer errors for a given number of redundancy symbols than do other, more complicated error correction techniques. However, permutation decoding is preferred here because the address code words in fact contain a large number (e.g. twenty-five) redundancy symbols for the sector-seeking operation, as described above. There are thirty-one symbols in an address code word, six address symbols and twenty-five redundancy symbols; up to five erroneous symbols, which is a relatively large fraction of the code word symbols, can be corrected using permutation decoding.

The method of permutation used in this exemplary system is a variation of standard permutation decoding. Although this method corrects fewer errors than standard permutation decoding, it is faster than the standard method. Referring to Figure 3, a sector header code word is first read from the disk and the coset leader is subtracted from it, resulting in the corresponding address code word (steps 30-32). Next, the six sector address symbols A (Figure 2), are encoded with the generator polynomial to form the redundancy symbols (step 34). These redundancy symbols are then compared, that is, exclusive OR'd, with the redundancy symbols in the sector address code word (step 36). If the redundancy symbols differ by "t" or fewer symbols, where $1 \leq t \leq 12$ and t represents the number of errors the code is designed to correct, there are no errors in the sector address contained in

the address code word as retrieved from the disk and the position of the head relative to the disk is thus known (steps 38-40).

The number "t" can have any value between one and twelve. However, the code can unconditionally correct only four or fewer errors using this error correction technique. If there are more than four errors, the code can correct them only if the errors are clustered such that at least six consecutive code word symbols are error-free.

If the redundancy symbols differ by more than t symbols, the next six symbols B in the sector address code word are encoded to form a set of redundancy symbols (steps 38, 42). These symbols are then compared with the corresponding symbols in the sector address code word (step 44). That is, the generated redundancy symbols are compared with symbols C, D, E and A (Figure 3), where the redundancy symbols corresponding to A are at the low order end of the set of generated redundancy symbols. If the symbols differ by t or fewer symbols, the symbols in the set of generated redundancy symbols corresponding to the sector address symbols A are error-free (steps 46, 50). Thus these symbols are used as the correct sector address.

If this second comparison results in the symbols differing by more than t symbols, the process is repeated for each of the remaining sets of six symbols C, D, E in the sector address code word until a set of redundancy symbols with t or fewer errors is found (steps 48, 48a). If such a set is not found in the sector address code word, the process is repeated with header code words of successive sectors until an error-free sector address can be determined (steps 48b, 52).

Claims

1. A method for locating data sectors on a magnetic disk during sector seeking operations comprising the steps of:

A. encoding the addresses of the sectors to produce sector address code words such that sector address code words containing a number of errors not exceeding a predetermined number can be identified as the correct sector address;

B. encoding said sector address code words to produce sector header code words;

C. recording said sector header code words in the sectors during the formatting of the disk;

D. encoding, in the same manner as steps A and B, the specified address of the sector to be located to produce the corresponding address code word or the corresponding sector header code word read from said disk sector;

E. comparing said corresponding address

code word and an address code word corresponding to a sector header code word read from a disk sector rotating under the head, or comparing said corresponding header code word to a header code word read from said disk sector;

F.

(1) if the comparison results in a number of symbols that differ which is less than or equal to said predetermined number, identifying the sector as the correct sector; or

(2) if the comparison results in a number of symbols that differ which is greater than said predetermined number, not identifying the sector as the correct sector and repeating steps E and F for a next sector;

the encoding in step B being such that the comparison in step F will always be as is defined in step F(2) if a mis-synchronisation of the head has occurred while reading the sector header code word from the disk.

2. The method of claim 1 wherein said encoding step A includes encoding said sector addresses using a large distance, "D", Reed-Solomon code over Galois Field $GF(2^P)$ to produce redundancy symbols and appending said redundancy symbols to said sector addresses to produce sector address code words.

3. The method of claim 1 wherein said encoding step B includes encoding said address code words by adding to the code words, using Galois Field addition, an element, "p", of a super-code of said Reed-Solomon code to produce sector header code words.

4. The method of claim 1 wherein said comparison step E further includes exclusive OR'ing said address code word and said corresponding address code word.

5. The method of claim 1 wherein said method further includes a step of determining the position of a read/write head relative to the sectors of a magnetic disk by:

i. decoding a sector header code word read from a sector rotating under the head to produce a sector address code word;

ii. encoding the address portion of said sector address code word to form a set of generated redundancy symbols;

iii. comparing said set of generated redundancy symbols with a set of redundancy symbols in said sector address code word; and

iv.

(a) if the result of the comparison is that the two sets of redundancy symbols differ



the address code word as retrieved from the disk and the position of the head relative to the disk is thus known (steps 38-40).

The number "t" can have any value between one and twelve. However, the code can unconditionally correct only four or fewer errors using this error correction technique. If there are more than four errors, the code can correct them only if the errors are clustered such that at least six consecutive code word symbols are error-free.

If the redundancy symbols differ by more than t symbols, the next six symbols B in the sector address code word are encoded to form a set of redundancy symbols (steps 38, 42). These symbols are then compared with the corresponding symbols in the sector address code word (step 44). That is, the generated redundancy symbols are compared with symbols C, D, E and A (Figure 3), where the redundancy symbols corresponding to A are at the low order end of the set of generated redundancy symbols. If the symbols differ by t or fewer symbols, the symbols in the set of generated redundancy symbols corresponding to the sector address symbols A are error-free (steps 46, 50). Thus these symbols are used as the correct sector address.

If this second comparison results in the symbols differing by more than t symbols, the process is repeated for each of the remaining sets of six symbols C, D, E in the sector address code word until a set of redundancy symbols with t or fewer errors is found (steps 48, 48a). If such a set is not found in the sector address code word, the process is repeated with header code words of successive sectors until an error-free sector address can be determined (steps 48b, 52).

Claims

1. A method for locating data sectors on a magnetic disk during sector seeking operations comprising the steps of:

A. encoding the addresses of the sectors to produce sector address code words such that sector address code words containing a number of errors not exceeding a predetermined number can be identified as the correct sector address;

B. encoding said sector address code words to produce sector header code words;

C. recording said sector header code words in the sectors during the formatting of the disk;

D. encoding, in the same manner as steps A and B, the specified address of the sector to be located to produce the corresponding address code word or the corresponding sector header code word read from said disk sector;

E. comparing said corresponding address

code word and an address code word corresponding to a sector header code word read from a disk sector rotating under the head, or comparing said corresponding header code word to a header code word read from said disk sector;

F.

(1) If the comparison results in a number of symbols that differ which is less than or equal to said predetermined number, identifying the sector as the correct sector; or

(2) If the comparison results in a number of symbols that differ which is greater than said predetermined number, not identifying the sector as the correct sector and repeating steps E and F for a next sector;

the encoding in step B being such that the comparison in step F will always be as is defined in step F(2) if a mis-synchronisation of the head has occurred while reading the sector header code word from the disk.

2. The method of claim 1 wherein said encoding step A includes encoding said sector addresses using a large distance, "D", Reed-Solomon code over Galois Field $GF(2^P)$ to produce redundancy symbols and appending said redundancy symbols to said sector addresses to produce sector address code words.

3. The method of claim 1 wherein said encoding step B includes encoding said address code words by adding to the code words, using Galois Field addition, an element, "β", of a super-code of said Reed-Solomon code to produce sector header code words.

4. The method of claim 1 wherein said comparison step E further includes exclusive OR'ing said address code word and said corresponding address code word.

5. The method of claim 1 wherein said method further includes a step of determining the position of a read/write head relative to the sectors of a magnetic disk by:

i. decoding a sector header code word read from a sector rotating under the head to produce a sector address code word;

ii. encoding the address portion of said sector address code word to form a set of generated redundancy symbols;

iii. comparing said set of generated redundancy symbols with a set of redundancy symbols in said sector address code word; and

iv.

(a) if the result of the comparison is that the two sets of redundancy symbols differ



by less than or equal to a predetermined number of symbols, determining that the address portion of the sector header code word is error free; or

(b) if the result of the comparison is that the two sets of redundancy symbols differ by more than said predetermined number of symbols, encoding a next set of consecutive symbols in said sector address code word to generate a next set of redundancy symbols in the same manner and comparing the set of generated redundancy symbols with a set of corresponding symbols in said sector address code word, if the result of the comparison is that the two sets of symbols differ by fewer than a predetermined number of symbols, using as the error-free sector address the symbols in the set of generated redundancy symbols which correspond to the sector address symbols in the sector address codeword; (c) repeating step iv (b) for each set of consecutive symbols in the sector address code word until the error-free sector address is determined, or if an error-free sector address cannot be so determined, repeating steps iv (a)-(b) and, if necessary, step iv (c) using the sector header code words from successive sectors until an error-free sector address can be determined.

6. An apparatus for locating data sectors on a magnetic disk during sector seeking operations, the apparatus including a read/write head and a sector address encoder (10,12) for encoding the addresses of the sectors to produce sector address code words, the apparatus including:

A. a sector address code word encoder (14) for encoding said sector address code words to produce sector header code words such that sector address code words containing a number of errors not exceeding a predetermined number can be identified as the correct sector address;

B. recording means (16) for recording said sector header code words in the sectors during the formatting of the disk;

C. means (22) for encoding, in the same manner as the sector address encoder (10,12) and the sector address code word encoder (14), the specified address of the sector to be located to produce a corresponding address code word or a corresponding sector header code word;

D. comparison means (22,24) for comparing said corresponding address code word with an address code word corresponding to a sec-

tor header code word read from a disk sector, or for comparing said corresponding sector header code word with a header code word read from a disk sector; and

E. means (26,28) for identifying the sector as the correct sector if the comparison results in a number of symbols that differ which is less than or equal to said predetermined number, said comparison means refraining from identifying the sector as the correct sector if the comparison results in a number of symbols that differ which is greater than said predetermined number;

the sector address code word encoder being adapted to produce sector header code words in such a manner that the comparison according to feature E will always result in a number of symbols that differ which is greater than said predetermined number if a mis-synchronisation of the head has occurred while reading the sector header code word from the disk.

7. The apparatus of claim 6 wherein said sector address encoder (10,12) includes means for encoding said sector addresses using a large distance, "D", Reed-Solomon code over Galois Field $GF(2^p)$ to produce redundancy symbols and appending said redundancy symbols to said sector addresses to produce said address code words.
8. The apparatus of claim 6 wherein said sector address code word encoder (14) includes means for encoding said sector address code words by adding, using Galois Field addition, an element, " β ", of a sub-code of said Reed-Solomon code.
9. The apparatus of claim 6 wherein said comparison means (22,24) includes means for exclusive OR'ing said code words.
10. The apparatus of claim 6 further including means for determining the position of a read/write head relative to the sectors of a magnetic disk, said means comprising:
- a. means (32) for decoding a sector header code word read from the disk to produce a corresponding sector address code word;
 - b. means (34) for encoding the address portion of the sector address code word to form generated redundancy symbols;
 - c. means (36) for comparing the redundancy symbols in said sector address code word with said generated redundancy symbols;
 - d. comparison and encoding means (36-52) for
 - (1) determining the sector address is error free if the comparison results in a number of symbols which differ that is less than or



equal to a predetermined number, or
 (2) if the comparison results in a number of symbols which differ that is greater than said predetermined number, encoding the next set of consecutive symbols in the sector address code word and comparing the generated redundancy symbols with the corresponding symbols in the sector address word, and if the result is that the two sets of redundancy symbols differ by fewer than a predetermined number of symbols, using the symbols in the set of generated redundancy symbols corresponding to the sector address symbols as the error-free sector address, and
 (3) repeating the encoding and comparison operations for each set of consecutive symbols in the sector address code word until the error-free sector address is determined, or if an error-free sector address cannot be so determined, repeating the encoding and comparison operations using the sector header code words for successive sectors until an error-free sector address can be determined.

Patentansprüche

1. Verfahren zum Lokalisieren von Datensektoren auf einer Magnetplatte während Sektorsuchoperationen, umfassend die folgenden Schritte:

A. Codieren der Adressen der Sektoren, um Sektoradreßcodeworte zu erzeugen derart, daß Sektoradreßcodeworte, die eine Anzahl von Fehlern enthalten, die nicht eine vorbestimmte Anzahl übersteigt, als die richtige Sektoradresse identifiziert werden können,
 B. Codieren der Sektoradreßcodeworte, um Sektorvorsatzcodeworte zu erzeugen,
 C. Aufzeichnen der Sektorvorsatzcodeworte in den Sektoren während des Formatierens der Platte,
 D. Codieren in der gleichen Weise wie in den Schritten A und B der spezifischen Adresse des zu lokalisierenden Sektors, um das entsprechende Adreßcodewort zu erzeugen, oder des entsprechenden von dem Plattensektor gelesenen Sektorvorsatzcodewortes,
 E. Vergleichen des entsprechenden Adreßcodewortes und eines Sektorvorsatzcodewortes entsprechend einem Sektorvorsatzcodewort, das von einem unter dem Kopf rotierenden Plattensektor gelesen ist, oder Vergleichen des entsprechenden Vorsatzcodewortes mit einem von dem Plattensektor gelesenen Vorsatzcodewort,
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(1) wenn der Vergleich in einer Anzahl von Symbolen resultiert, die kleiner oder gleich der vorbestimmten Anzahl ist, Identifizieren des Sektors als der richtige Sektor, oder

(2) wenn der Vergleich in einer Anzahl von Symbolen resultiert, die um größer als die vorbestimmte Anzahl abweicht, kein Identifizieren des Sektors als der richtige Sektor und Wiederholen der Schritte E und F für den nächsten Sektor,

wobei das Codieren in Schritt B derart ist, daß der Vergleich in Schritt F immer so ist, wie dies in Schritt F(2) definiert ist, wenn eine Fehlsynchronisierung des Kopfes aufgetreten ist, während das Sektorvorsatzcodewort von der Platte gelesen wird.

2. Verfahren nach Anspruch 1, bei dem der Codierschritt A ein Codieren der Sektoradressen mittels eines Reed-Solomon-Codes großer Distanz "D" über ein Galois-Feld $GF(2^p)$ erfolgt, um Redundanzsymbole zu erzeugen, und bei dem die Redundanzsymbole den Sektoradressen beigelegt werden, um Sektoradreßcodeworte zu erzeugen.

3. Verfahren nach Anspruch 1, bei dem der Codierschritt B ein Codieren der Adreßcodeworte durch Addieren zu den Codeworten mittels einer Galoisfeld-Addition eines Elementes " β " eines Supercodes des Reed-Solomon-Codes umfaßt, um Sektorvorsatzcodeworte zu erzeugen.

4. Verfahren nach Anspruch 1, bei dem der Vergleichsschritt E weiterhin ein exklusives ODER-Verknüpfen des Adreßcodewortes und des entsprechenden Adreßcodewortes umfaßt.

5. Verfahren nach Anspruch 1, bei dem das Verfahren weiterhin einen Schritt eines Bestimmens der Position eines Lese/Schreibkopfes bezüglich der Sektoren einer Magnetplatte umfaßt, mit:

- i. Decodieren eines Sektorvorsatzcodewortes, das von einem unter dem Kopf rotierenden Sektor gelesen ist, um ein Sektoradreßcodewort zu erzeugen,
- ii. Codieren des Adreßteiles des Sektoradreßcodewortes, um einen Satz von erzeugten Redundanzsymbolen zu bilden;
- iii. Vergleichen des Satzes von erzeugten Redundanzsymbolen mit einem Satz von Redundanzsymbolen in dem Sektoradreßcodewort, und
- iv.

(a) wenn das Vergleichsergebnis darin besteht, daß die zwei Sätze von Redundanzsymbolen um weniger als oder gleich einer vorbestimmten Anzahl von Symbolen ab-



weichen, bestimmen, daß der Adreßteil des Sektorvorsatzcodewortes fehlerfrei ist, oder

(b) wenn das Vergleichsergebnis ist, daß die zwei Sätze von Redundanzsymbolen um mehr als die vorbestimmte Anzahl von Symbolen abweichen, Codieren eines nächsten Satzes von aufeinanderfolgenden Symbolen in dem Sektoradreßcodewort, um einen nächsten Satz von Redundanzsymbolen in der gleichen Weise zu erzeugen, und Vergleichen des Satzes von erzeugten Redundanzsymbolen mit einem Satz von entsprechenden Symbolen in dem Sektoradreßcodewort, wenn das Vergleichsergebnis darin besteht, daß die beiden Sätze von Symbolen um weniger als eine vorbestimmte Anzahl von Symbolen abweichen, wobei als die fehlerfreie Sektoradresse die Symbole in dem Satz von erzeugten Redundanzsymbolen verwendet werden, die den Sektoradreßsymbolen in dem Sektoradreßcodewort entsprechen,

(c) Wiederholen des Schrittes iv(b) für jeden Satz von aufeinanderfolgenden Symbolen in dem Sektoradreßcodewort, bis die fehlerfreie Sektoradresse bestimmt ist, oder wenn eine fehlerfreie Sektoradresse so nicht bestimmt werden kann, Wiederholen der Schritte iv(a) - (b) und, falls erforderlich, des Schrittes iv(c) mittels der Sektorvorsatzcodeworte von aufeinanderfolgenden Sektoren, bis eine fehlerfreie Sektoradresse bestimmt werden kann.

6. Gerät zum Lokalisieren von Datenfehlern auf einer Magnetplatte während Sektorsuchoperationen, wobei das Gerät einen Lese/Schreibkopf und einen Sektoradreßcodierer (10, 12) zum Codieren der Adressen der Sektoren enthält, um Sektoradreßcodeworte zu codieren, wobei das Gerät umfaßt:

A. einen Sektoradreßcodewortcodierer (14) zum Codieren der Sektoradreßcodeworte, um Sektorvorsatzcodeworte derart zu erzeugen, daß Sektoradreßcodeworte, die eine Anzahl von Fehlern enthalten, die nicht eine vorbestimmten Anzahl überschreitet, als die richtige Sektoradresse identifiziert werden können,

B. eine Aufzeichnungseinrichtung (16) zum Aufzeichnen der Sektorvorsatzcodeworte in den Sektoren während des Formatierens der Platte,

C. eine Einrichtung (22), um in der gleichen Weise wie der Sektoradreßcodierer (10, 12)

und der Sektoradreßcodewortcodierer (14) die spezifische Adresse des zu lokalisierenden Sektors zu codieren; um ein entsprechendes Adreßcodewort oder ein entsprechendes Vorsatzcodewort zu erzeugen,

D. eine Vergleichseinrichtung (22, 24) zum Vergleichen des entsprechenden Adreßcodewortes mit einem Adreßcodewort entsprechend einem von einem Plattensektor gelesenen Sektorvorsatzcodewort oder zum Vergleichen des entsprechenden Sektorvorsatzcodewortes mit einem Vorsatzcodewort, das von einem Plattensektor gelesen ist, und

E. eine Einrichtung (26, 28) zum Identifizieren des Sektors als der richtige Sektor, wenn der Vergleich in einer Anzahl von Symbolen resultiert, die um weniger als die vorbestimmte Anzahl oder gleich der vorbestimmten Anzahl abweicht, wobei die Vergleichseinrichtung den Sektor nicht als den richtigen Sektor identifiziert, wenn der Vergleich in einer Anzahl von Symbolen resultiert, die größer als die vorbestimmte Anzahl ist,

wobei der Sektoradreßcodewortcodierer gestaltet ist, um Sektorvorsatzcodeworte derart zu erzeugen, daß der Vergleich entsprechend Merkmal E immer in einer Anzahl von abweichenden Symbolen resultiert, die größer als die vorbestimmte Anzahl ist, falls eine Fehlsynchronisierung des Kopfes während eines Lesens des Sektorvorsatzcodewortes von der Platte aufgetreten ist.

7. Gerät nach Anspruch 6, bei dem der Sektoradreßcodierer (10, 12) eine Einrichtung zum Codieren der Sektoradressen mittels eines Reed-Solomon-Codes großer Entfernung "D" über ein Galois-Feld $GF(2^p)$, um Redundanzsymbole, und zum Befügen der Redundanzsymbole zu den Sektoradressen, um die Adreßcodeworte zu erzeugen, umfaßt.

8. Gerät nach Anspruch 6, bei dem der Sektoradreßcodewortcodierer (14) eine Einrichtung zum Codieren der Sektoradreßcodeworte umfaßt, indem mittels einer Galois-Feld-Addition ein Element "β" eines Untercode des Reed-Solomon-Codes addiert wird.

9. Gerät nach Anspruch 6, bei dem die Vergleichseinrichtung (22, 24) eine Einrichtung zum exklusiven ODER-Verknüpfen der Codeworte umfaßt.

10. Gerät nach Anspruch 6, weiterhin mit einer Einrichtung zum Bestimmen der Position eines Lese/Schreibkopfes bezüglich der Sektoren einer Magnetplatte, wobei die Einrichtung umfaßt:

a. eine Einrichtung (32) zum Decodieren ei-



nes von der Platte gelesenen Sektorvorsatzcodewortes, um ein entsprechendes Sektoradreßcodewort zu erzeugen,

b. eine Einrichtung (34) zum Codieren des Adreßteiles des Sektoradreßcodewortes, um erzeugte Redundanzsymbole zu bilden,

c. eine Einrichtung (36) zum Vergleichen der Redundanzsymbole in dem Sektoradreßcodewort mit den erzeugten Redundanzsymbolen,

d. eine Vergleichs- und Codiereinrichtung (36 bis 52), um

(1) zu bestimmen, daß Sektoradresse fehlerfrei ist, wenn der Vergleich in einer Anzahl von abweichenden Symbolen, die kleiner oder gleich eine vorbestimmte Anzahl ist, resultiert, oder

(2) wenn der Vergleich in einer Anzahl von abweichenden Symbolen, die größer als die vorbestimmte Anzahl ist, resultiert, den nächsten Satz von aufeinanderfolgenden Symbolen in dem Sektoradreßcodewort zu codieren und die erzeugten Redundanzsymbole mit den entsprechenden Symbolen in dem Sektoradreßcodewort zu vergleichen, und wenn das Ergebnis darin besteht, daß die beiden Sätze von Redundanzsymbolen um weniger als eine vorbestimmte Anzahl von Symbolen abweichen, die Symbole in dem Satz der erzeugten Redundanzsymbole entsprechend den Sektoradreßsymbolen als die fehlerfreie Sektoradresse zu verwenden, und

(3) die Codier- und Vergleichsoperationen für jeden Satz von aufeinanderfolgenden Symbolen in dem Sektoradreßcodewort zu wiederholen, bis die fehlerfreie Sektoradresse bestimmt ist, oder wenn eine fehlerfreie Sektoradresse so nicht bestimmt werden kann, die Codier- und Vergleichsoperationen mittels der Sektorvorsatzcodeworte für aufeinanderfolgende Sektoren zu wiederholen, bis eine fehlerfreie Sektoradresse bestimmt werden kann.

Revendications

1. Méthode pour localiser des secteurs de données sur un disque magnétique pendant des opérations de recherche de secteurs comprenant les étapes de :

A. codage des adresses des secteurs pour produire des mots de code d'adresse de secteur tels que des mots de code d'adresse de secteur contenant un nombre d'erreurs ne dépassant pas un nombre prédéterminé puis-

sent être identifiés comme adresse de secteur correcte ;

B. codage desdits mots de code d'adresse de secteur pour produire des mots de code d'en-tête de secteur ;

C. enregistrement desdits mots de code d'en-tête de secteur dans les secteurs pendant le formatage du disque ;

D. codage, de la même manière que dans les étapes A et B, de l'adresse spécifiée du secteur à localiser pour produire le mot de code d'adresse correspondant ou le mot de code d'en-tête de secteur correspondant lu dans ledit secteur du disque ;

E. comparaison dudit mot de code d'adresse correspondant et d'un mot de code d'adresse correspondant à un mot de code d'en-tête de secteur lu dans un secteur du disque tournant sous la tête, ou comparaison dudit mot de code d'en-tête correspondant à un mot de code d'en-tête lu dans ledit secteur du disque ;

F.

(1) si la comparaison donne un nombre de symboles qui diffèrent qui est inférieur ou égal audit nombre prédéterminé, identification du secteur comme secteur correct ;

ou
(2) si la comparaison donne un nombre de symboles qui diffèrent qui est supérieur audit nombre prédéterminé, non identification du secteur comme secteur correct et répétition des étapes E et F pour un secteur suivant ;

le codage dans l'étape B étant tel que la comparaison dans l'étape F sera toujours telle que définie dans l'étape F (2) si un défaut de synchronisation de la tête s'est produit pendant la lecture du mot de code d'en-tête de secteur sur le disque.

2. Méthode selon la revendication 1, dans laquelle ladite étape de codage A comprend le codage desdites adresses des secteurs en utilisant un code de Reed-Solomon de grande distance "D" dans le Corps de Galois $GF(2^p)$ pour produire des symboles de redondance et l'addition desdits symboles de redondance auxdites adresses des secteurs pour produire des mots de code d'adresse de secteur.

3. Méthode selon la revendication 1, dans laquelle ladite étape de codage B comprend le codage desdits mots de code d'adresse en ajoutant aux mots de code, par utilisation d'une addition dans le Corps de Galois, un élément " β " d'un supercode dudit code de Reed-Solomon pour produire des mots de code d'en-tête de secteur.



4. Méthode selon la revendication 1, dans laquelle ladite étape de comparaison E comprend en outre une opération OU-exclusif sur ledit mot de code d'adresse et ledit mot de code d'adresse correspondant. 5
 5. Méthode selon la revendication 1, dans laquelle ladite méthode comprend en outre une étape de détermination de la position d'une tête de lecture/d'écriture par rapport aux secteurs d'un disque magnétique par : 10
 - i. le décodage d'un mot de code d'en-tête de secteur lu dans un secteur tournant sous la tête pour produire un mot de code d'adresse de secteur ; 15
 - ii. le codage de la partie d'adresse dudit mot de code d'adresse de secteur pour former un ensemble de symboles de redondance générés ;
 - iii. la comparaison dudit ensemble de symboles de redondance générés à un ensemble de symboles de redondance générés dans ledit mot de code d'adresse de secteur ; et, 20
 - iv.
 - (a) si le résultat de la comparaison est que les deux ensembles de symboles de redondance diffèrent d'un nombre inférieur ou égal à un nombre de symboles prédéterminé, la détermination que la partie d'adresse du mot de code d'en-tête de secteur est sans erreur ; ou 25
 - (b) si le résultat de la comparaison est que les deux ensembles de symboles de redondance diffèrent de plus dudit nombre prédéterminé de symboles, le codage d'un ensemble suivant de symboles consécutifs dans ledit mot de code d'adresse de secteur pour générer un ensemble suivant de symboles de redondance de la même manière et la comparaison de l'ensemble de symboles de redondance générés à un ensemble de symboles correspondants dans ledit mot de code d'adresse de secteur, si le résultat de la comparaison est que les deux ensembles de symboles diffèrent de moins qu'un nombre prédéterminé de symboles, en utilisant comme adresse de secteur sans erreur les symboles dans l'ensemble de symboles de redondance générés qui correspondent aux symboles d'adresse de secteur dans le mot de code d'adresse de secteur ; 30
 - (c) la répétition de l'étape iv (b) pour chaque ensemble de symboles consécutifs dans le mot de code d'adresse de secteur jusqu'à ce que l'adresse de secteur sans erreur soit déterminée, ou, si une adresse de secteur sans erreur ne peut pas être 35
 6. Appareil pour localiser des secteurs de données sur un disque magnétique pendant des opérations de recherche de secteurs, l'appareil incluant une tête de lecture/d'écriture et un codeur d'adresse de secteur (10, 12) pour coder les adresses des secteurs afin de produire des mots de code d'adresse de secteur, l'appareil incluant : 40
 - A. un codeur de mot de code d'adresse de secteur (14) pour coder lesdits mots de code d'adresse de secteur afin de produire des mots de code d'en-tête de secteur tels que les mots de code d'adresse de secteur contenant un nombre d'erreurs ne dépassant pas un nombre prédéterminé puissent être identifiés comme adresse de secteur correct ;
 - B. un moyen d'enregistrement (16) pour enregistrer lesdits mots de code d'en-tête de secteur dans les secteurs pendant le formatage du disque ;
 - C. un moyen (22) pour coder, de la même manière que le codeur d'adresse de secteur (10, 12) et le codeur de mot de code d'adresse de secteur (14), l'adresse spécifiée du secteur à localiser pour produire un mot de code d'adresse correspondant ou un mot de code d'en-tête de secteur correspondant ;
 - D. un moyen de comparaison (22, 24) pour comparer ledit mot de code d'adresse correspondant à un mot de code d'adresse correspondant à un mot de code d'en-tête de secteur lu dans un secteur du disque, ou pour comparer ledit mot de code d'en-tête de secteur correspondant à un mot de code d'en-tête lu dans un secteur du disque ; et,
 - E. un moyen (26, 28) pour identifier le secteur comme secteur correct si la comparaison donne un nombre de symboles qui diffèrent qui est inférieur ou égal audit nombre prédéterminé, ledit moyen de comparaison empêchant l'identification du secteur comme secteur correct si la comparaison donne un nombre de symboles qui diffèrent qui est supérieur audit nombre prédéterminé ; 45
- le codeur de mot de code d'adresse de secteur étant adapté pour produire des mots de code d'en-tête de secteur de telle manière que la comparaison selon la caractéristique E donnera toujours un nombre de symboles qui diffèrent qui est supérieur audit nombre prédéterminé si un défaut de synchronisation de la tête s'est produit pendant la lecture du mot de code d'en-tête de 50



secteur sur le disque.

7. Appareil selon la revendication 6, dans lequel le-
dit codeur d'adresse de secteur (10, 12)
comprend un moyen pour coder lesdites adres- 5
ses des secteurs en utilisant un code de Reed-
Solomon de grande distance "D" dans le Corps
de Galois $GF(2^P)$ pour produire des symboles de
redondance et ajouter lesdits symboles de redon- 10
dance auxdites adresses des secteurs pour pro-
duire lesdits mots de code d'adresse.
8. Appareil selon la revendication 6, dans lequel le-
dit codeur de mot de code d'adresse de secteur 15
(14) comprend un moyen pour coder lesdits mots
de code d'adresse de secteur en ajoutant, par uti-
lisation d'une addition dans le Corps de Galois,
un élément "β" d'un sous-code dudit code de
Reed-Solomon. 20
9. Appareil selon la revendication 6, dans lequel le-
dit moyen de comparaison (22, 24) comprend un
moyen pour exécuter une opération OU-exclusif
sur lesdits mots de code. 25
10. Appareil selon la revendication 6, comprenant en
outre un moyen pour déterminer la position d'une
tête de lecture/d'écriture par rapport aux sec-
teurs d'un disque magnétique, ledit moyen
comprenant : 30
 - a. un moyen (32) pour décoder un mot de
code d'en-tête de secteur lu sur le disque afin
de produire un mot de code d'adresse de sec-
teur correspondant ;
 - b. un moyen (34) pour coder la partie d'adres- 35
se du mot de code d'adresse de secteur afin
de former des symboles de redondance géné-
rés ;
 - c. un moyen (36) pour comparer les symboles
de redondance dans ledit mot de code 40
d'adresse de secteur auxdits symboles de re-
dondance générés ;
 - d. des moyens de comparaison et de codage
(36-52) pour
 - (1) déterminer que l'adresse de secteur 45
est sans erreur si la comparaison donne
un nombre de symboles qui diffèrent qui
est inférieur ou égal à un nombre prédéter-
miné, ou
 - (2) si la comparaison donne un nombre de 50
symboles qui diffèrent qui est supérieur
audit nombre prédéterminé, coder l'en-
semble suivant de symboles consécutifs
dans le mot de code d'adresse de secteur
et comparer les symboles de redondance 55
générés aux symboles correspondants
dans le mot d'adresse de secteur et, si le
résultat est que les deux ensembles de

symboles de redondance différent de
moins qu'un nombre prédéterminé de
symboles, utiliser les symboles dans l'en-
semble des symboles de redondance gé-
nérés correspondant aux symboles
d'adresse de secteur comme adresse de
secteur sans erreur, et

(3) répéter les opérations de codage et de
comparaison pour chaque ensemble de
symboles consécutifs dans le mot de code
d'adresse de secteur jusqu'à ce que
l'adresse de secteur sans erreur soit dé-
terminée, ou, si une adresse de secteur
sans erreur ne peut pas être ainsi détermi-
née, répéter les opérations de codage et
de comparaison en utilisant les mots de
code d'en-tête de secteur pour les sec-
teurs successifs jusqu'à ce qu'une adres-
se de secteur sans erreur puisse être dé-
terminée.