

A method and device for use with helical scan data recording by implementing a Reed-Solomon product code, a unitary medium comprising such data, and a cassette comprising such medium.

FIELD OF THE INVENTION

The invention relates to method for error protective data encoding for use with rotary head helical scan tape-recording by providing a first wordwise Reed-Solomon code along each recording track as being defined in first code words, and a second Reed-Solomon code as being defined in second code words, said first and second Reed-Solomon codes collectively forming a product code format. Such a method has been considered in John Watkinson, The Art of Digital Video, Butterworth Scientific, Borough Green, Kent, UK, 1990, pp. 416-434. Although the helical scan technology has been specifically developed for video, it is also applicable to data recording as well as to audio recording.

Various common error patterns are the following:

- random errors, that have a limited average size that is not much larger than a symbol, so that a random error does not directly influence the error protection capability for a neighbouring random error
- across-tape or lateral burst errors (Figure 4.2) that may be caused by mechanical parts which extend across the tape, so that a kind of tape fold may occur
- helical burst errors (Figure 4.3) that are caused by the rotary head motion and therefore make a small deviation angle with respect to the tape motion
- longitudinal burst errors that may be caused by capstan deformations and the like, which may cause a series of errors at uniform lateral positions.

The width of a burst region is generally small with respect to its length. However, the width may be of the same order of magnitude or larger than the width of a single storage track. Now, the occurrence of a burst, once incorrectible or miscorrected, is very degrading to the overall performance of the system.

SUMMARY TO THE INVENTION

Accordingly, amongst other things, it is an object of the present invention to provide for a substantially uniform level of error protection for all types of burst errors, including lateral burst errors, against only a low overhead penalty, and independent of the location of the burst. Now, according to one of its aspects, the invention is characterized by

providing each second code word as a sequence of symbols across a plurality of tracks, while providing said symbols of a single second code word with substantially uniform displacements between contiguous symbols both in a first direction parallel to a length of said tape, and also in a second direction perpendicular to a length of said tape, each second code word extending substantially along a length of said tracks associated to said recording.

Herein, the term contiguous in a particular direction means the direct succession of the projections of those symbols on an axis along the direction in question. Substantially uniform displacements imply a restricted ratio between the maximum and minimum displacement values, respectively. In the embodiments, this ratio is about 2 (Figure 6a), or even quite close to 1 (Figure 6), the choice depending on other storage requirements. Due to the fact that in most cases only two layers of error correction codes need to be provided, the error protectivity is sufficient at only a reasonable amount of overhead. In particular, because the spacing between symbols of the second code word is uniform in each of the two cited directions, the load of both lateral and longitudinal error bursts is distributed substantially uniformly over the pertaining second code words, which provides near-optimum protectivity. One solution is through appropriate cross-track shift of symbols within a relevant product code block. This will provide for good distribution of the error protectivity, so that overloading of this protectivity will occur only rarely.

In practice, the expression with "substantially uniform displacement between contiguous symbols in a direction perpendicular to a length of said tape" means that such displacement has a single uniform value when the position of the next symbol is on the next following track, or the next preceding track. When the final track pertaining to the code word in question has then been reached, the next symbol jumps back to the track at the other side of the bundle. According to the invention, such jump will not cause a forward jump that is much larger than in the former case. Such much larger jump could have led indeed to an uneven distribution of the error load. On the other hand the jump could be smaller or even be a jump backward in the direction of the tape. The solutions of the invention will lead to the excessively uneven distribution of the error load, supra. In the methodology as recited, bursts or scratches in various directions are coped with in an efficient manner by one and the same protection system. The plurality of tracks may be physically contiguous or not, depending on further requirements. Generally, if spaced, the spacing would be uniform.

Advantageously, the method provides along a single track respective symbols of a single second code word with substantially uniform displacements between contiguous symbols. This is a further trick for load equalizing in the same sense as referred

to above. Clearly, such single track has only a fraction of all symbols of such second code word.

Advantageously, each first code word pertains to a contiguous succession of symbols on an associated single track. This allows for a low-complexity decoding with
5 low storage requirements for the first code encoding/decoding. On the other hand, the words of the first code may be interleaved on their associated single track.

Advantageously, said first and second Reed-Solomon codes are the exclusive error protection codes on a storage system level. Due to the uncomplicated error protection format, only low overhead is required for good error protection. Of course, apart
10 from the storage system level, certain critical information may be protected on an application layer level, but this latter protection would be transparent for the encoding and decoding according to the present invention.

Advantageously, the method foresees for encoding auxiliary information pertaining to said plurality of tracks using similar formatting parameters as for said data, but
15 for shortening an area preserved for said auxiliary information through a uniform self-interleaving among the second code words pertaining thereto. The reliable quality used for the main data recording can now be used as well for audio or other information in parallel to the video. Herein, similar formatting means adhering to the advantageous spacing of the code words relative to the various types of error bursts (see the A,B bands in Figures 4, 6). Of
20 course, the lengths of the code words, as well as their numbers could be adapted to the size of the available storage area.

The invention also relates to an encoding device, a decoding device, a digital video recorder comprising an encoder or decoder according to the invention, to a unitary storage medium loaded with the error protection format according to the invention, in
25 particular, but not exclusively, a magnetic tape, and to a digital video cassette loaded with such unitary storage medium. Further advantageous aspects are recited in dependent Claims.

BRIEF DESCRIPTION OF THE DRAWING

Now, these and other aspects and advantages of the invention will be
30 discussed hereinafter in detail with reference to the preferred embodiments, and in particular with reference to the appended drawing, wherein:

Figure 1 schematically indicates the tape track disposition;

Figure 2 shows an exemplary track format sector arrangement;

Figure 3 shows a scanner example;

Figure 4 shows a first code format according to the invention;

Figure 5 is an enlarged detail of Figure 4;

Figure 6 shows another code format according to the invention;

Figure 6a shows still another code format according to the invention;

5 Figure 6b shows still another code format according to the invention;

Figure 7 shows a device for use with the invention;

Figure 8 shows a first variation on Figure 6;

Figure 9 shows a second variation on Figure 6.

10 DETAILED DISCLOSURE OF PREFERRED EMBODIMENTS

Figure 1 schematically indicates the tape track layout. Apart from the digital storage of the information, the layout format may correspond to the well-known VHS standard for analog video recording. During write and read operations, the tape moves horizontally with respect to the recorder head structure. Moreover, the rotary head rotates
15 which results in a component in the vertical direction with respect to the tape in the Figure. The two motions combine in that successive tracks, shown as slanting strips, are each scanned by an associated head during a sweep that is longitudinal with respect to the track. For convenience, many details and different solutions regarding the scanning are ignored here. The slanting angle may be about 6° . Each track contains a single series of contiguous
20 bits. With respect to a preferred embodiment for video recording, the digital storage format should be backwards compatible to the well-known VHS standard. According to this standard, successive tracks have their scanline synchronization pulses aligned in the cross-track direction, which dictates a longitudinal offset between scan-lines on contiguous tracks. This will avoid interference caused by a synchronization pulse of a track on the video signal
25 of an adjacent track: this interference would otherwise be caused by a less than infinite electrical signal separation between adjacent tracks. For digital video recording, this inter-track synchronizing preferably means that on adjacent tracks, respective MPEG data packages should be aligned as well.

Figure 2 shows an exemplary track format sector arrangement. Along the
30 scanning motion of the head, the sequence is margin, 2625 bits, preamble, 875 bits, auxiliary information, 24500 bits, postamble, 1750 bits, edit gap, 1750 bits, preamble, 875 bits, main information, 269500 bits, postamble, 1750 bits, and margin, 2625 bits. The total amount of information is 306250 bits per track. The lengths of the various parts as drawn along the track are not true to scale. The physical slant of a track is 5.93538° , the width of a

track is 0.029 mm, and the length of the part 'main' is 84.7 mm. Hereinafter, only the part main contains the video data. The part aux contains other data, such as audio. In the embodiment, the error protectivity of the video is based on a series of twelve contiguous tracks. The error protectivity for the audio is based on the same principles as that of the video, but with different parameter values. One particular property of the audio format may be that a single video channel is accompanied by two audio channels in parallel. This may mean that six contiguous tracks in the audio part would contain one audio block, that could be subject to separate editing from the other audio channel of the same video block as well as of the adjacent video block. For brevity, the audio format will not be considered in detail hereinafter. The other parts of the storage accommodate various operational delays of the hardware and often, do not need the high-level error protection according to the present invention.

Figure 3 shows a scanner example. In the recorder, the tape is wrapped over about 180° of the drum of 62 mm diameter. The lead angle gives the slanting orientation of the drum with respect to the tape. Due to the motion of the tape with respect to the drum, the effective slant angle of the tracks is a few percent different from the slanting orientation of the drum. As indicated, the drum carries four different heads that access two tape tracks at a time, four tracks per full rotation.

Figure 4 shows a first code format. The code is a product code based on shortened Reed-Solomon codes defined over the Galois Field GF(256). The Figure shows a series of twelve tracks, of which the information forms twelve respective product code blocks, of which only a single one has been highlighted by darkening. For clarity of the Figure, the slant angle of the tracks has been increased to nearly 90°, which however has no influence on the lateral coordinates of the various symbols with respect to the tape. Now, each word of the first or C1 code is disposed longitudinally along a single track: each dark block indicates the length of a single 205 byte error protected C1 code word which is separated from the next dark block by 11 further C1 code word positions shown in white. Each dark block furthermore contains five system bytes (sync/ident) not considered further for brevity. The number of C1 code words on a single track is 154. Now, the second or C2 code words pertaining to the dark C1 code words are disposed along the staggered positions of the dark blocks shown. In consequence, the array of dark blocks represents 205 C2 code words of 154 bytes each, that together form a single comprehensive product code block. The white code words in similar fashion are grouped into 11 further product code blocks. The total number of bytes on the tape section shown is therefore equal to $205 \times 154 \times 12$. The

minimum distance of the C1 code is 12, the minimum distance of the C2 code is 14. The error protection overhead for C1+C2 is about 15%, which was found acceptable, both for the object of attaining a favourable data rate, and for realizing a simple two-level decoding strategy. Indeed, according to the invention no further error protection was deemed necessary on the level of the storage system.

Figure 5 is an enlarged detail of a part of Figure 4, with the dark blocks of Figure 4 now shown as crossed blocks. On track 1 it is the first block, on track 2 the second, and so on, until the twelfth on track 12. The next block of this same product code format then is the 13th on track 1. So the cross-track shift of each next block, and also of each next symbol in a C2 code word, is one track, modulo the number of tracks in the block, 12. Therefore, the C2 code words extend virtually over the full track part that is used for the type of data considered here (video versus audio).

The error correction capability has been found sufficient for random errors, for longitudinal burst errors, as well as for in-track burst errors. This is shown in Figure 4 where band A symbolizes the region of a longitudinal burst error strip. Band A runs exactly parallel to the tape edge, and also parallel to the ends of the successive tracks. This means that the counterclockwise rotation of the tracks to regain their real orientation always keeps this band parallel to the edge of the tape. Moreover, shifting of this band across the tape will always cause a uniform intersection pattern with respect to the succession of dark blocks: regardless of the lateral position, always about four of the dark blocks will lie inside a band. Of course, this number is proportional to the width of the burst. The uniformity of the intersection pattern ensures the best spread of the errors over the protectivity that can be attained with the given amount of redundancy.

The error protection against lateral burst errors is non-uniform, however. This is shown in Figure 4 by band B, which is not fully parallel to the tape edge, but has a small inclination. In the Figure, the inclination angle appears to be a few degrees only (say 5°), but due to the clockwise rotation of the tracks, combined with the change of their lengths relative to the tape width, the real inclination of this error band B is nearly exactly orthogonal to the longitudinal direction of the tape. Therefore, this band corresponds to the position of a lateral error burst. Now, in the situation shown, error band B does not touch the C2 code words represented by the dark blocks, but only C2 words present in the white area. The same would apply for all bands that have a smaller width inside band B as shown. Such smaller width is quite common. The situation shown implies that the error performance of the various C2 code words is often taxed by lateral burst errors in a non-uniform manner:

either not at all, or quite heavily. Such concentrating the error pattern on a fraction of the code words gives less than the optimum protectivity, inasmuch as the burden is imperfectly shared among the C2 code words. Note that in the Figure, band B may be shifted parallel to itself, while still retaining its near orthogonality with respect to the 'real' tape length. Note also that the same problem will occur if the orientation of band B varies a little bit, so that the same problem could occur over a rather wide range of inclinations of the error burst with respect to the tape length.

In this respect, Figure 6 shows another code format according to the invention. Now, the same dark blocks of Figure 4 have been randomized more over the area shown. One method to realize this is to rotate the even numbered tracks over half the track width of the overall block, therefore over 6 tracks. This corresponds to a cross-track shift of each next symbol of a code word by 7 (seven) tracks. In Figure 5, the first six blocks of this amended product code format have been shown hatched. Again the same two error bands A, B of Figure 4 have been shown in Figure 6, proving that for both these bands the errors are now distributed more uniformly over the various C2 code words. The reason is that the uniformly shifted positions of the dark blocks in Figure 4 had the effect of a series of theatrical side-wings or shutters that are transmissive in certain directions, but opaque in others, at least one of these directions representing an often occurring burst error pattern. In practice, the randomizing must be done in a systematic way as exemplified in Figure 6. The Figure realizes indeed a minimum symbol-to-symbol displacement in a direction perpendicular to the length of the tape. In the situation shown, this also realizes minimum codeword-to-codeword displacement in a direction perpendicular to the tape length of the C2 code.

According to the foregoing, the cross-track shift of the C2 code words has uniform values +1 in Figure 4, and +7 in Figure 6. The further Figures give other possibilities that are slightly worse than Figure 6, but better than Figure 4. Here, the cross-track shifts are respectively:

- a. 445445445445 (nonuniform): Figure 8 shows this first variation on Figure 6;
 - b. 555555555555 (uniform): Figure 9 shows this second variation on Figure 6.
- Many other combinations fall within the scope of the present invention. These and other shifts between successive code symbols can be expressed as well in other ways as rotations of the separate tracks along their respective lengths. Certain ones of these rotations, from their part, cannot be so easily expressed in the formalism according to the above, but would still fall within the scope and object of the present invention.

Figure 6a shows still another code format according to the invention. Here the number of tracks pertaining to a particular C2 code word is only six. This lowering of the number of tracks diminishes the storage requirements in the recorder, that would be necessary for encoding and decoding, respectively. Again, the cross-track shift has been
 5 chosen relatively prime to the number of tracks. A number of five was found as optimum. This causes an apparent "staircase" pattern in the opposite direction compared with Figure 4. In contradistinction to Figure 4, there is no B-type gap between successive staircases. Successive staircases do rather overlap, in that the first symbol of a next staircase lies between the last two stairs of the previous staircase. Even so, this provides for a more even
 10 sharing of the error burden from a cross-track burst among various C2 codewords.

Hereinafter, the code format is briefly explicated in formulae for better understanding. The so-called inner code is restricted to a single track, without interleaving as follows:

one inner code word is made of following symbols.

$$15 \quad \text{Codeword}(t,s) = \sum_{d=0}^{106} \text{Data}_{t,s,d} \times X^{(106-d)}$$

$$(t = 0..5, s=0..335)$$

where: $\text{Data}_{t,s,d}$ means a symbol which position is track number: t , sync block number: s , and data byte number: d .

Last 8 symbols ($d=99..106$) are parity.

20 This equation indicates the inner codeword which position is track number: t and sync block numbers: s .

Generator polynomial for inner error correcting code is as follows.

$$G(X) = \prod_{i=0}^7 (X + \alpha^i)$$

25 On the other hand, the outer code is interleaved among six tracks, as follows:

One outer codeword is made of following symbols

$$\text{Codeword}(t,s,d) = \sum_{i=0}^{111} \text{Data}_{T,S,D} \times X^{(111-i)}$$

$$(t=0..5, s=0..2, d=0..98)$$

where: the variable i means the order of symbols in the codeword.

$$T = (t + 5 \times i) \bmod 6$$

$$S = s + 3 \times i$$

$$D = d$$

- 5 Data_{T,S,D} means a symbol which position is track number: T, sync block number: S, and data byte number: D.

Last 10 symbols ($i=102..111$) are parity.

This equation indicates the outer codeword which the first symbol position is track number: t , sync block number: s , and data byte number: d .

- 10 Generator polynomial for outer error correcting code is as follows.

$$G(X) = \prod_{i=0}^9 (X + \alpha^i)$$

- By way of variation, Figure 6a also shows a composite format. The code as discussed supra is present in block 52. The band at indication 54 shows the sequence of the one product code block that is highlighted as being projected perpendicularly to the track direction. The displacement between successive C1 code words has either single or double size.

- Furthermore, the block shown at indication 50 may be superposed on a part of block 52; in the embodiment, it could cover less than 10% thereof. In such case, the symbols of block 52 to be covered by block 50, are identically set to zero. This does not destroy the format of the original code. The additional information of block 50 can relate to non-video data. This format of block 50 has been shown enlarged in Figure 6b. As shown it could also pertain to the part AUX in Figure 2: this would obviate the need for the above superposing. Now, the number of tracks is again equal to six, whereas the scale of the Figure has been enlarged in both directions by a factor of three. The black rectangles have uniform sizes, which correspond to those of Figures 6, 6a. The seemingly greater width when touching the edges of the tape section is an artefact from the drawing software. For the part AUX, the storage requirements are about a factor of ten smaller than those for the part MAIN. In consequence, a shorter C2 codeword was chosen at a length of 46 symbols and the distance between successive dark blocks on a single track equal to only two such blocks.
- 30 Therefore, the width of the white areas is equal to twice the width of the black areas. The format has been realized by providing the same displacements as in Figure 6a, accompanied by interleaving the format amongst itself. Thus, the format of Figure 6b is attained by

putting further "staircases" between the "staircases" of Figure 6a, for collectively bringing the number of symbols of a single C2 word to the intended level. Just as was the case with Figure 6a, the load distribution for cross-track error burst will be shared evenly among the various C2 code words.

- 5 In correspondence to the video part in Figure 6a, the additional code format can be given as follows, for the inner code that is restricted to one single track: One inner codeword is made of following symbols.

$$\text{Codeword}(t,s) = \sum_{d=0}^{106} \text{Data}_{t,s,d} X^{(106-d)}$$

$$(t=0..55, s=0..22)$$

- 10 where: $\text{Data}_{t,s,d}$ means a symbol which position is track number: t, sync block number: s, and data byte number: d.

Last 8 symbols ($d=99..106$) are parity.

This equation indicates the inner codeword which position is track number: t and sync block number: s.

- 15 Generator polynomial for inner error correcting code is as follows.

$$G(X) = \prod_{i=0}^7 (X + \alpha^i)$$

On the other hand, the outer code is interleaved among six tracks, as follows:

One outer codeword is made of following symbols.

20
$$\text{Codeword}(t,d) = \sum_{i=0}^{45} \text{Data}_{T,S,D} \times X^{(45-i)}$$

$$(t=0..2, d=0..98)$$

where: the variable i means the order of symbols in the codeword.

$$T = (t + 3 \times (\text{imod}2) + 5 \times \text{int}(i/2)) \bmod 6$$

$$S = \text{int}(i/2)$$

25 $D=d$

$\text{Data}_{T,S,D}$ means a symbol which position is track number: T, sync block number: S, and data byte number D.

Last 10 symbols ($i=36..45$) are parity.

This equation indicates the outer codeword which the first symbol position is track number: t , sync block number: 0, and data byte number: d .

Generator polynomial for outer error correcting code is as follows.

$$G(X) = \prod_{i=0}^7 (X + \alpha^i)$$

5 Figure 7 shows a device for use with the invention. In this first embodiment, the device would cope with decoding the format of Figures 4 or 6. The format of Figure 6a could do with less required storage, and would also be able to decode the AUX format of Figure 6b as well.

Various electromechanical subsystems have been omitted for clarity. Upon
 10 accessing of tape 20 either for reading or for writing, the latter is driven by a motor not shown. Drum 22 is rotated around its axis 24, and provided with a detection mechanism 26 that provides a synchronizing signal at full turn intervals. First, the read operations will be described. Interconnection 28 carries the data signals from the four heads. Multiplexer block 30 under synchronization by the pulses on line 26 interconnects the proper head output to the
 15 C1 word decoder 32. The C1 decoder first comprises an analog part that synchronizes to preamble pr2 in Figure 2, in this way effecting the extracting of the encoded bit stream from the raw tape signal. Next, for each C1 code word the syndrome symbols are calculated by means of conventional matrix multiplications. When non-zero syndrome symbols indicate an error pattern, decoder 32 undertakes an error correction. To this effect, decoder 32
 20 comprises a sufficient amount of intermediate storage capacity not shown. Almost universally, this will allow to calculate random errors. If burst errors occur, this will generally lead to the detecting and flagging of an incorrectible error pattern. Subsequently, demultiplexer 34 by way of interconnection pattern 36 assigns the symbols of each C1 code word to one of the 12 RAM sectors in RAM 38, that is assigned to the associated a single
 25 product code block. The RAM sector may in consequence come to contain all dark blocks shown in Figure 4. Multiplexer 42 thereupon forwards the contents of each respective C2 code word to decoder 44 that may output the information after correction via output 46. RAM 38 should accommodate the content of twelve full storage tracks to allow for the fullest flexibility in the error correction. During execution of the error correction, the RAM should
 30 already start inputting of the next twelve tracks, and also continue outputting of the preceding twelve tracks. In practice, the inventors have found that a capacity for about 17 tracks would be sufficient, if combined with a raised access frequency for the error correction as

compared with the access frequency for the write-in from the tape or the read-out to the user. In an enhanced decoder, various higher level strategies may be implemented, such as rerouting after the undertakings in decoder 44 the not yet fully decoded information back to the decoder part of block 32. However, this would not necessitate a higher storage capacity.

- 5 The decoding of the parts 'main' and 'aux' in Figure 2 may be effected in substantially the same way, be it that the format of the product code blocks is different. For encoding, the process is effected substantially the other way round. Therefore, block 44 corresponds to an encoder, block 42 to a demultiplexer, block 34 to a multiplexer, block 32 to an encoder, and block 30 to a demultiplexer.

CLAIMS:

1. A method for error protective data encoding for use with rotary head helical scan tape-recording by providing a first wordwise Reed-Solomon code along each recording track as being defined in first code words, and a second Reed-Solomon code as being defined in second code words, said first and second Reed-Solomon codes collectively
5 forming a product code format, characterized by providing each second code word as a sequence of symbols across a plurality of tracks, while providing said symbols of a single second code word with substantially uniform displacements between contiguous symbols both in a first direction parallel to a length of said tape, and also in a second direction perpendicular to a length of said tape, each second code word extending substantially along a
10 length of said tracks associated to said recording.
2. A method as claimed in Claim 1, wherein said plurality of tracks are contiguous tracks.
3. A method as claimed in Claims 1 or 2, while providing along a single track respective symbols of a single second code word with substantially uniform
15 displacements between contiguous symbols.
4. A method as claimed in Claim 1, 2 or 3, whilst providing said symbols along said sequence with a uniform symbol-to-symbol cross-track shift that is relatively prime to a value of said plurality.
5. A method as claimed in any of Claims 1 to 4, for recording video
20 information, wherein said uniform cross-track shift is uniform among all second code words.
6. A method as claimed in Claim 4, wherein said cross-track shift is greater than one and calculated modulo the value of said plurality.
7. A method as claimed in Claim 6, wherein said cross-track shift is one lower than the value of said plurality.
- 25 8. A method as claimed in any Claim 1 to 6, wherein each first code word pertains to a contiguous succession of symbols on an associated single track.
9. A method as claimed in Claim 7, wherein within a single track successive first code words are cyclically assigned to respective product code blocks with a cycle length that is equal to the value of said plurality.



10. A method as claimed in any of Claims 1 to 8, wherein said first and second Reed-Solomon codes are the exclusive error protection codes on a storage system level.

11. A method as claimed in any of Claims 1 to 10, whilst for encoding
5 auxiliary information pertaining to said plurality of tracks using similar formatting parameters as for said data, but for shortening an area preserved for said auxiliary information through a uniform self-interleaving among the second code words pertaining thereto.

12. A device for error protective encoding according to a method as claimed
10 in any of Claims 1 to 11, having an output for feeding a rotary head for helical scan track-wise recording by providing a first wordwise Reed-Solomon code along a recording track defined in first code words and a second Reed-Solomon code defined in second code words, said first and second Reed-Solomon codes collectively forming a product code format, characterized in that said device has encoder means for encoding each said second code word
15 as a sequence of symbols across a plurality of tracks, and having disposing means for disposing in said sequence said symbols with a substantially uniform symbol-to-symbol displacement both in a first direction parallel to a length of said tape, and in a second direction perpendicular to a length of said tape, and having extending means for extending each second code word to a size substantially equal to a length of said tracks associated to
20 said recording.

13. A device as claimed in Claim 12, wherein said disposing means are arranged for disposing along a single track the symbols of a single second code word with substantially uniform displacements between contiguous symbols thereof.

14. A device as claimed in Claim 12 or 13, for use in recording video
25 information, wherein said disposing means are arranged for disposing said symbols along said sequence with a uniform cross-track shift that is relatively prime to a value of said plurality.

15. A device as claimed in Claim 14, wherein said uniform cross-track shift is greater than one and calculated modulo the value of said plurality.

30 16. A device as claimed in any of Claims 12 to 15, wherein said encoder within a single track assigns symbols cyclically to respective product code blocks with a cycle length that is equal to the number in said plurality.

17. A device as claimed in any of Claims 12 to 16, and having secondary encoding means for encoding auxiliary information pertaining to said plurality of tracks using



similar formatting parameters as for said data, but for shortening an area preserved for said auxiliary information through a uniform self-interleaving among the second code words, pertaining thereto.

18. A device for error protective decoding of digital video data having an
5 input for connecting to a rotary head for helical scan track-wise scanning tape information that is protected by a first wordwise Reed-Solomon code along a recording track defined in first code words and a second Reed-Solomon code defined in second code words, said first and second Reed-Solomon codes collectively forming a product code format, characterized in that said device has decoder means for decoding each said second code word as a sequence
10 of symbols disposed across a plurality of tracks, whilst reading said symbols of a single second code word with a uniform symbol-to-symbol displacements between contiguous symbols both in a first direction parallel to a length of said tape, and also in a second direction perpendicular to a length of said tape, and reading each second code word along an extension substantially equal to a length of said tracks associated to said digital video data.
- 15 19. A digital video recorder comprising a device as claimed in any of Claims 12 to 18.
20. A unitary storage medium having data stored thereon that has been encoded according to a method as claimed in any of Claims 1 to 10.
21. A digital video cassette comprising a medium as claimed in Claim 20.

1/7

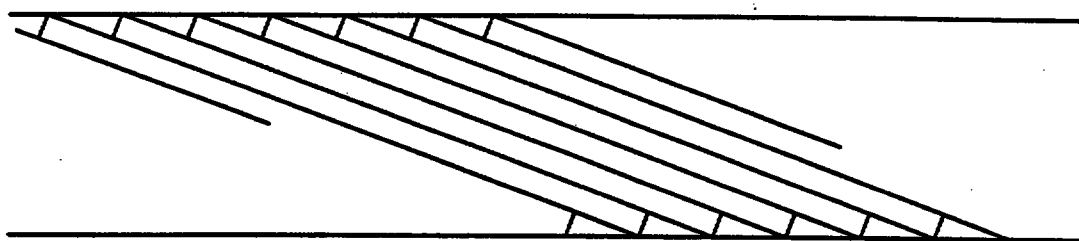


FIG. 1

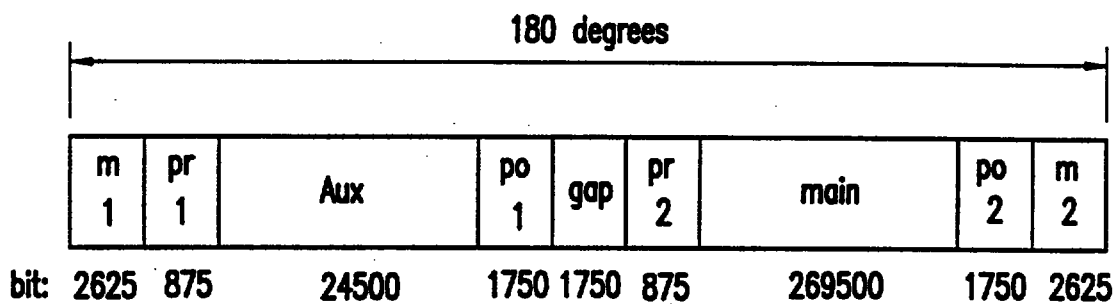


FIG. 2

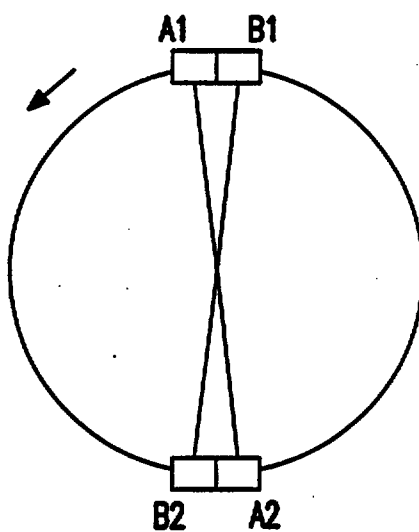


FIG. 3

2/7

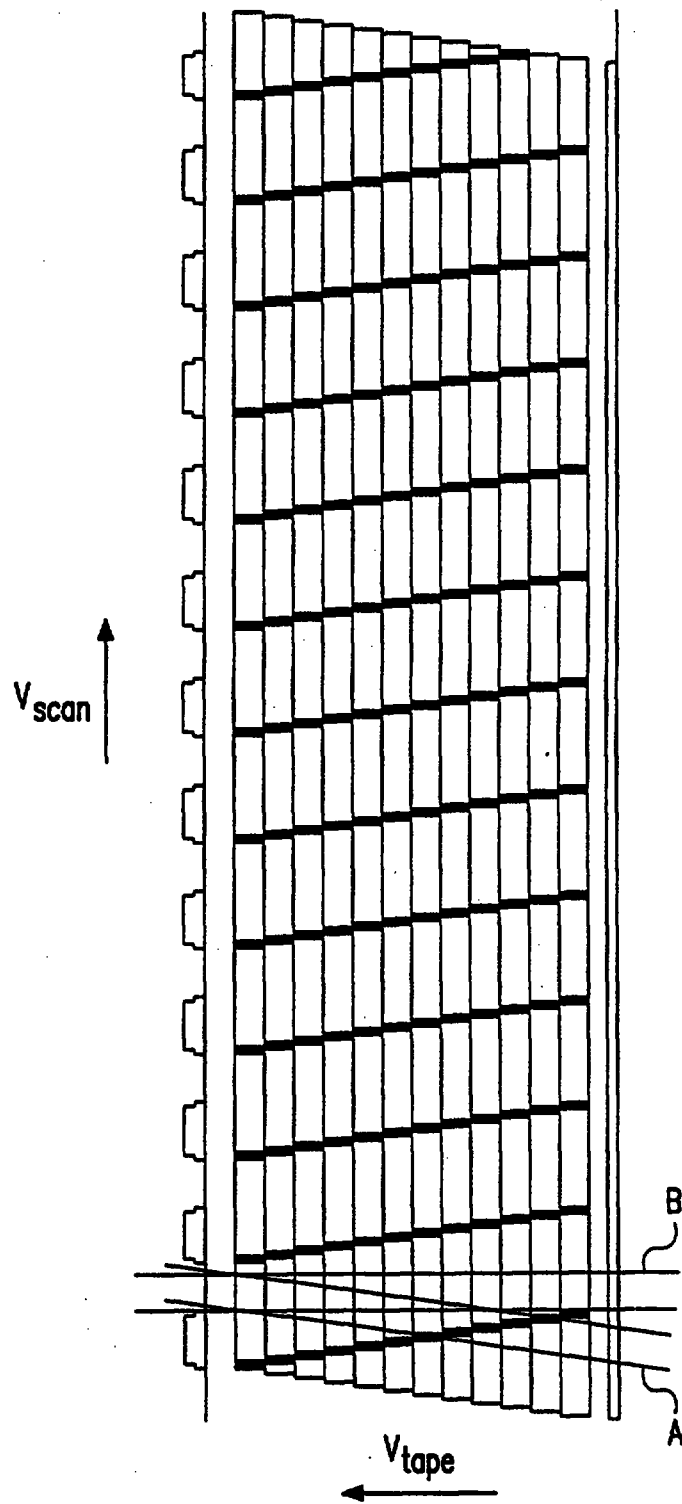


FIG. 4

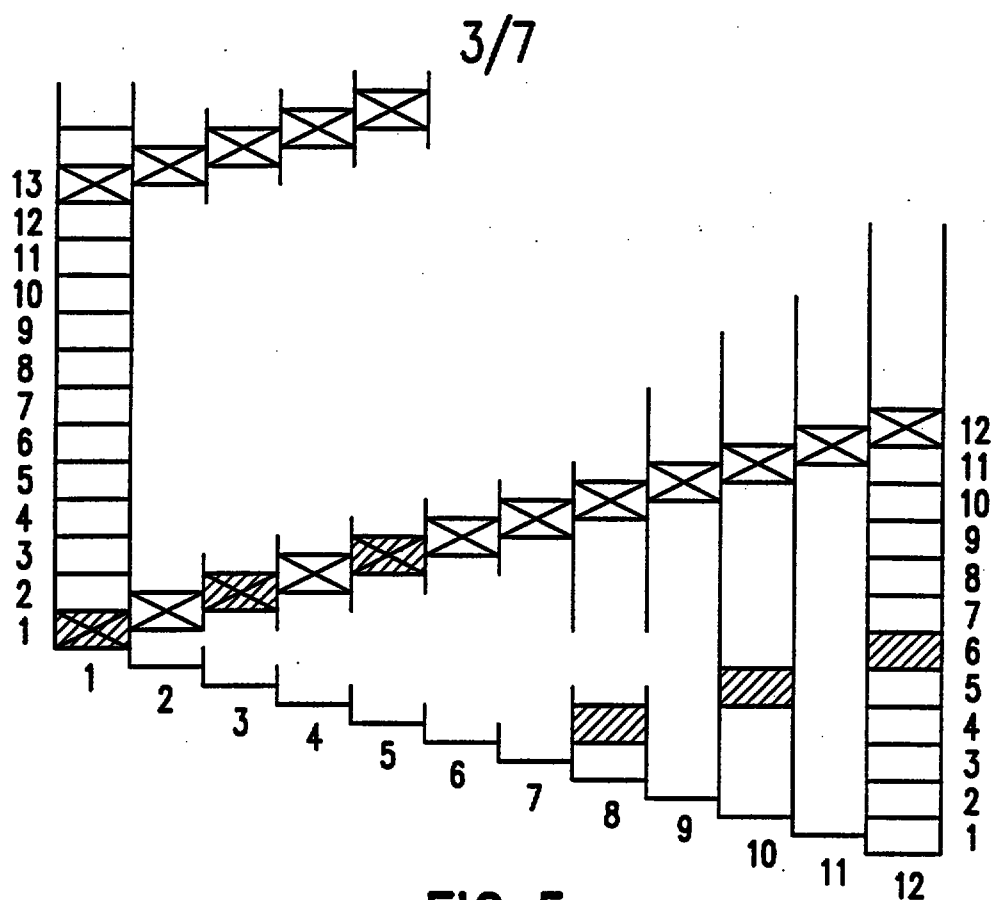


FIG. 5

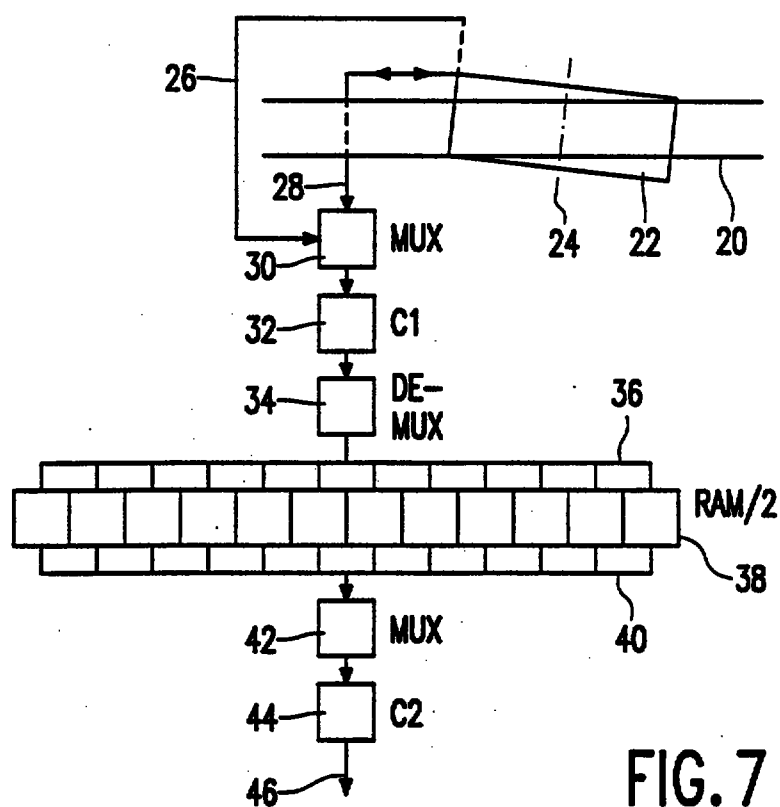


FIG. 7

4/7

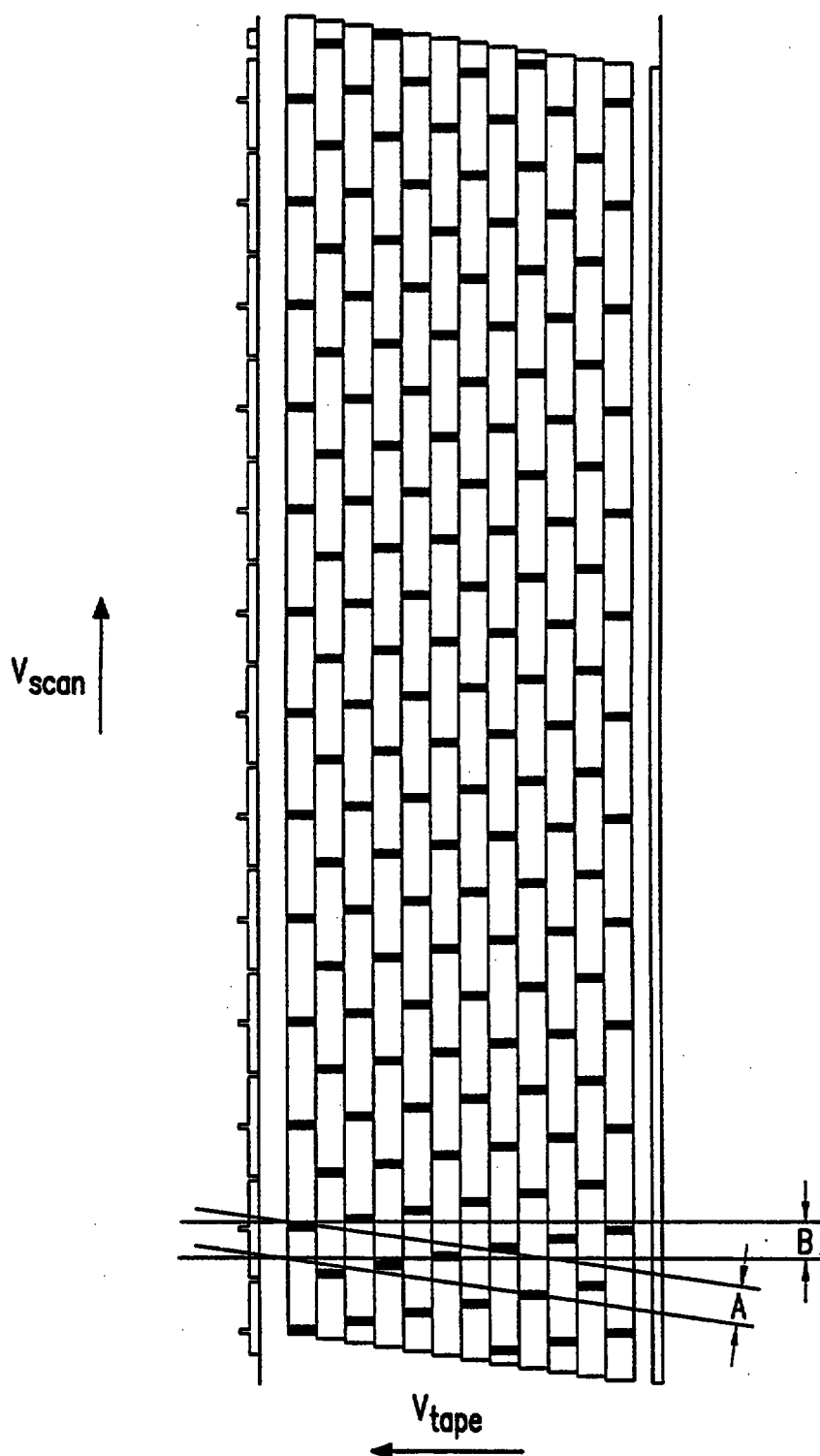


FIG. 6

5/7

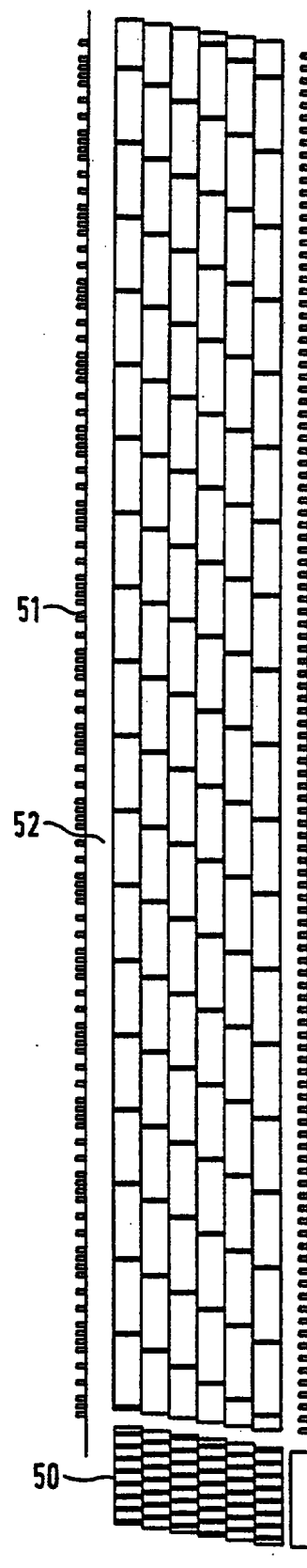


FIG. 6a

6/7

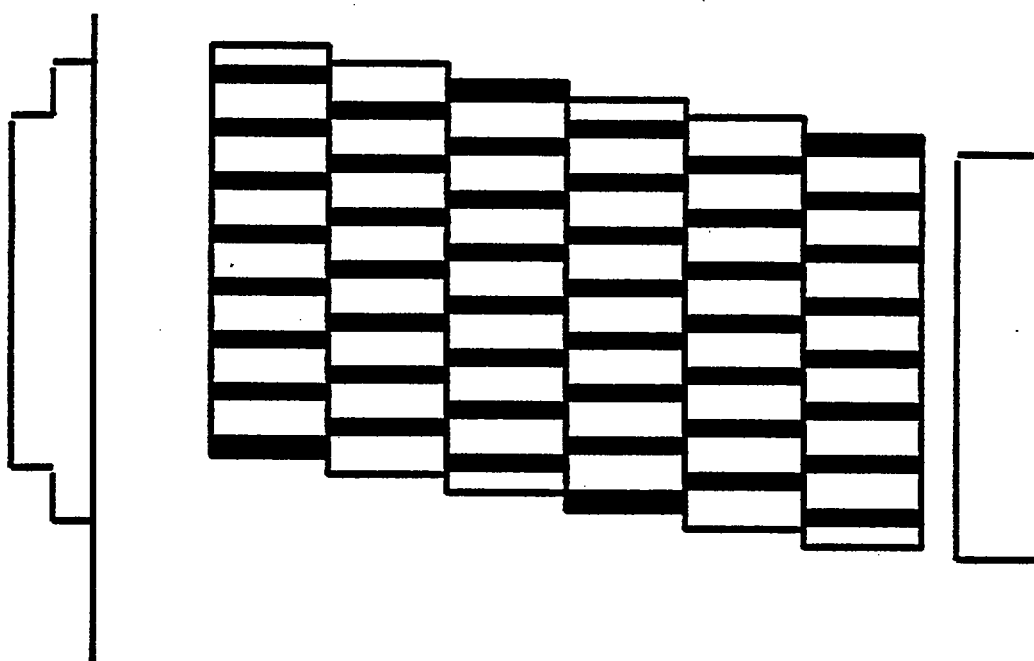


FIG. 6b

7/7

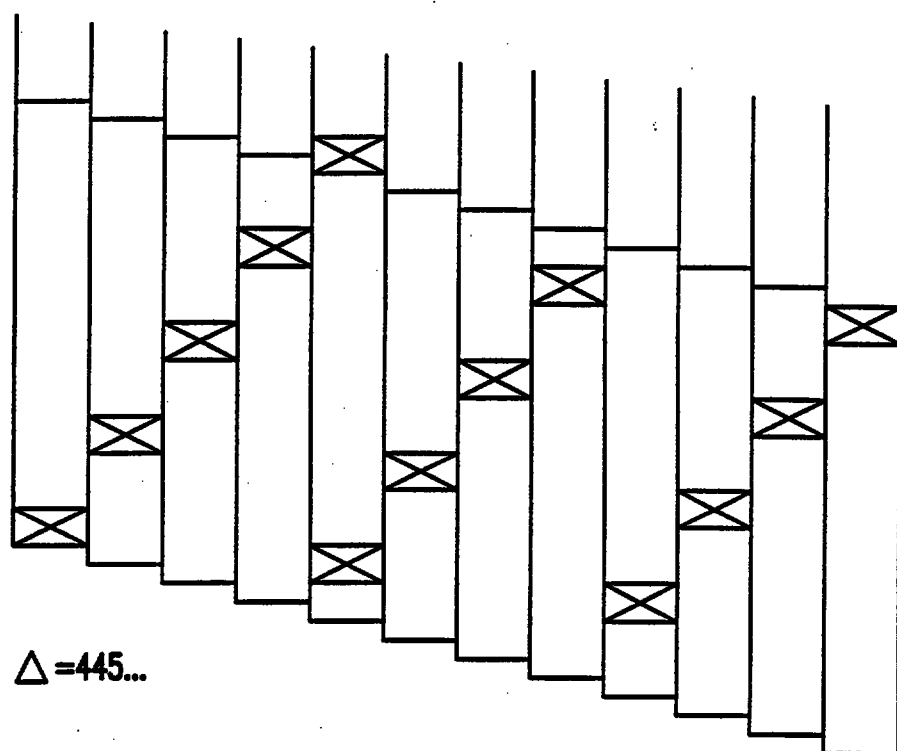


FIG. 8

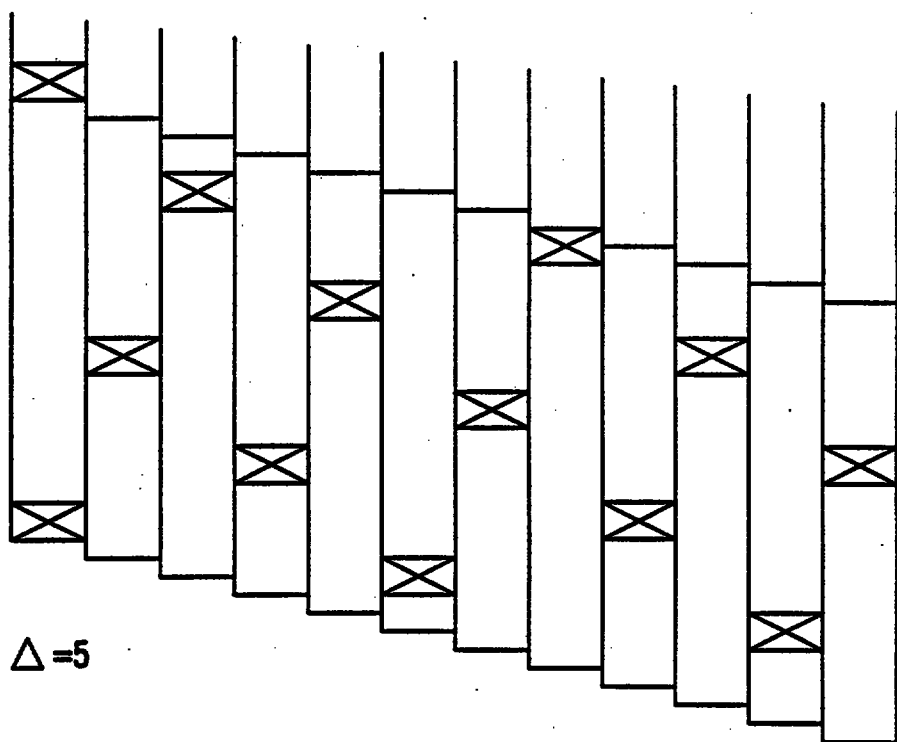


FIG. 9



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶: G11B 20/18, H03M 13/22	A2	(11) International Publication Number: WO 96/20474 (43) International Publication Date: 4 July 1996 (04.07.96)
(21) International Application Number: PCT/IB95/01136 (22) International Filing Date: 18 December 1995 (18.12.95) (30) Priority Data: 94203759.9 23 December 1994 (23.12.94) EP (34) Countries for which the regional or international application was filed: NL et al. 95200928.0 12 April 1995 (12.04.95) EP (34) Countries for which the regional or international application was filed: NL et al. (71) Applicant: PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). (71) Applicant (for SE only): PHILIPS NORDEN AB [SE/SE]; Kottbygatan 5, Kista, S-164 85 Stockholm (SE). (72) Inventors: DENISSEN, Adrianus, Johannes, Maria; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). RIJCKAERT, Albert, Maria, Arnold; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). (74) Agent: STRIJLAND, Wilfred; Internationaal Octrooibureau B.V., P.O. Box 220, NL-5600 AE Eindhoven (NL).		(81) Designated States: BR, CN, JP, KR, SG , VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>Without international search report and to be republished upon receipt of that report.</i>
(54) Title: A METHOD AND DEVICE FOR USE WITH HELICAL SCAN DATA RECORDING BY IMPLEMENTING A REED-SOLOMON PRODUCT CODE, A UNITARY MEDIUM COMPRISING SUCH DATA, AND A CASSETTE COMPRISING SUCH MEDIUM (57) Abstract Error protective data encoding for use with rotary head helical scan tape-recording is done by providing a first wordwise Reed-Solomon code along each recording track defined in first code words, and a second Reed-Solomon code defined in second code words. The first and second Reed-Solomon codes together form a product code format. Each second code word has a sequence of symbols across a plurality of contiguous tracks. The symbols of a single second code word have substantially uniform displacements between contiguous symbols both in a direction parallel to a length of the tape, and also in a direction perpendicular to a length of said tape. Each second code word extends substantially along a length of said tracks associated to the recording.		

