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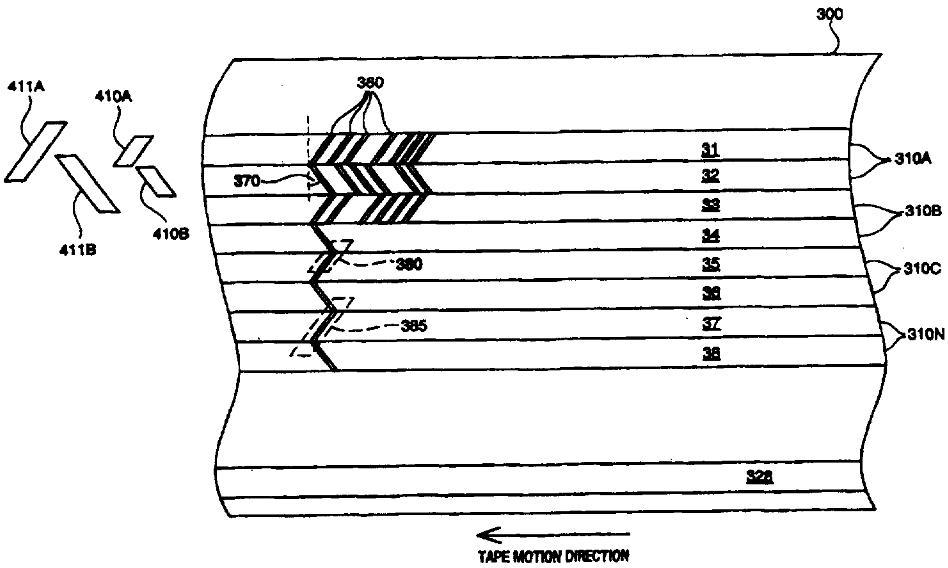

(57) Abstract

A system for storing data on and retrieving data from magnetic tape media (300) utilizing a linear format having data tracks (31-38) arranged on an azimuth (370) from the longitudinal axis of the magnetic tape media. The system receives a data stream from a host computer (1), segments the data into tracks, and writes the tracks in azimuthally oriented tracks on the magnetic tape media. A linear tape mechanism (400) is used to write and read data in the azimuthally oriented tracks such that a high data-density is achieved for a linear tape mechanism.

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LONGITUDINAL MAGNETIC RECORDING ARCHITECTURE USING AZIMUTHALLY ORIENTED TRACKS

FIELD OF THE INVENTION

The invention relates to magnetic recording architecture utilized for recording data on magnetic tape media for applications including video, audio, and computer system record and playback systems. More particularly, the present invention relates to a magnetic recording architecture which combines the high density recording advantages of azimuthally oriented tracks used in helical recording architecture with the lower cost and simpler tape tracking systems utilized with linear recording architecture.

PROBLEM

The design of read/write magnetic recording devices used in the storage of data presents a trade-off of cost and performance. It is desirable to record information using high density formats but in so doing the cost and complexity of the necessary equipment increases.

In standard tape formats, information is recorded in discrete sections of tape referred to as tracks. Tracks may be continuous and aligned with the longitudinal axis of the tape medium, vertically aligned perpendicular to the longitudinal axis of the tape medium, or helically positioned at an intermediate angle between the longitudinal axis and its perpendicular. The two most common approaches are to align the tracks with the longitudinal axis of the tape (linear drives) and the helical alignment of the tracks on the tape (helical drives). Helically positioned tracks allow a far greater density of tracks per inch (tpi) to be recorded on the tape. For example, a measure of 2500 tpi is a typical track density on tape used with helical drives. In comparison, a track density of 50 to 200 tpi is typical on tape used with linear-type drives. The greater density of tracks allows more data to be stored on a given length of tape.

The two primary types of read/write recording devices (tape drive mechanisms) are linear-type tape drives (linear drives) and helical-type tape drives (helical drives). Linear drives utilize relatively simple tape tracking mechanisms as well as relatively simple heads past which the magnetic tape moves. These devices are, as a result, relatively inexpensive. They suffer, however, from low performance in terms of the density of the data that can be stored on the magnetic tape and in the speed with which data can be read from or written to the magnetic tape. Helical drives store data on the tape in a way, and in a format, that allows for much greater density of data stored on the tape as well as significantly greater speed in reading data from and writing data to the tape. A drawback to helical drives is their complexity and resultant cost. Helical drives accomplish their increased performance, in part, through the utilization of very complex tape threading schemes and a rotating scanner containing read/write heads, all of which increase the complexity, cost, and reliability issues for helical drives.

In addition to data density, helical drives also offer an advantage in the speed with which data is read from and written to the magnetic tape. Helical drives can read data from and write data to tape significantly faster than linear drives. In linear drives, the read and write heads are stationary and the tape is moved past the heads. The read/write speed is therefore limited by the speed of the moving tape. The speed of the tape is limited by various physical constraints such as stretching of the tape, tape edge guiding, and tension control. The tape speed in linear drives typically is on the order of 10 meters/second. In helical drives, the tape moves very slowly, e.g. less than 1 m/s, but the scanner containing the read/write heads moves (spins) very quickly relative to the tape. The result is an effective tape speed of more than 20 m/s allowing for much faster read/write times.

The additional cost of helical drives is significant. Many users of linear drives desire the greater data storage density of helical drives but cannot justify the additional expense. As is evident from the above discussion, there is a need for a magnetic recording architecture that combines the advantages of relatively simple, low cost linear drives with the advantages of high density magnetic recording architecture utilized on tape for helical drives.

SOLUTION

The present invention solves the above identified problems and others, thereby advancing the state of the useful arts, by providing apparatus and methods for recording data on magnetic tape utilizing a format that increases the data storage capacity of the tape. This is accomplished by recording data using an architecture utilizing azimuthally oriented tracks aligned with the longitudinal axis of the tape. This invention uses standard linear tape drives to achieve an order of magnitude increase in the tracks per inch density on the magnetic tape. In addition to the increased data density, an increase in the read/write speed is also achieved.

In particular, the present invention records tracks on azimuth similar to helically recorded tracks. The difference is that, rather than the tracks being recorded helically on an angle from the longitudinal axis of the tape, the tracks are recorded in alignment with the longitudinal axis of the tape. The azimuthal nature of the recorded tracks, however, allows each track to be recorded so that it abuts the neighboring tracks, eliminating the need for guard bands as used in traditional linear type recording architecture. In the present invention, the result is a tracks per inch density, on ½" tape used with a low-cost linear drive, of 500 tpi to 2000 tpi as opposed to the prior art density of not more than 200 tpi.

Magnetic recording architecture typically used with linear drives requires guard bands between the various tracks. In linear architecture, each individual recorded bit on the magnetic tape is oriented orthogonally to the longitudinal axis of the tape. This bit orientation is the same for each bit in each track. The read and write heads of the linear drive are also aligned to be orthogonal to the longitudinal axis of the tape. When a read head senses a bit, it provides an appropriate output to associated circuitry. A problem arises when the alignment of the tape with the read/write heads is changed due to any one of a number of factors. For example, the read head might be directed by the tape drive controller to read a particular track, but due to a misalignment of the tape, a neighboring track may be passing the read head instead. To avoid this occurrence, guard bands are placed between the tracks to, in effect, separate one track from another. The result is that a significant portion of the tape goes unused for its intended purpose, that is storing data.

In helical drives, recorded tracks are recorded on an angle, called the track angle, from the longitudinal axis of the tape. These tracks are recorded, and read, by a rotating head which is oriented at an angle equal to the track angle. The angled orientation of the heads with respect to the longitudinal axis of the tape allows the head to spin with a high velocity thereby recording helical tracks relatively quickly on the slow moving tape. As the head spins, the tracks are recorded on the tape at the track angle. Each track is recorded on an azimuth which differs from the azimuth of neighboring tracks. Within a track, each bit is aligned on a similar azimuth angle. There are pairs of read and write heads, associated with each set of tracks having a similar azimuth. If a misalignment of the tape occurs, then a read head expecting to sense a track aligned at, a certain azimuth (ON azimuth) will instead sense a track aligned at a different azimuth (OFF azimuth). The signal generated in the read head by a bit out of alignment with the read head will be quite small. This high signal to noise ratio between ON azimuth readings and OFF azimuth readings allows the tracks on helically recorded magnetic tape to be placed so that one track abuts its neighboring tracks. Recording each track immediately next to its neighboring tracks eliminates the guard bands. Elimination of the guard bands used in linear recording architecture allows for significantly higher density in helically recorded tracks.

The present invention records pairs of tracks on azimuth, as just described in connection with helical type drives, but arranges the track pairs along the longitudinal axis of the tape. The high signal to noise ratio of ON azimuth versus OFF azimuth readings allows the elimination of guard bands in the recording architecture. The result is a tracks per inch density of 500 to 2000 tpi. This density is still less than that achieved in helical recording architecture but is significantly more than that currently possible with traditional linear architecture.

Another advantage in the use of azimuthally oriented tracks is the reduced need to utilize servos, or motors, to adjust the position of the read/write heads. In typical linear type drives, a servo is used to adjust the position of the read heads to compensate for changes in alignment between the read heads and the tape. Because of the high signal to noise ratio between ON azimuth and OFF azimuth readings with the use of azimuthally oriented tracks, the read heads may be made significantly larger than the width of a single track. As a result, changes in alignment between the tape and the read head can occur, within limits, without affecting the ability of the read head to accurately read data from the tape. For example, if the tape alignment shifts slightly so that the read head is reading from the intended track but is also overlapping slightly on the neighboring track, the signal strength of the neighboring, OFF azimuth, track will be so low as to not affect the accuracy of the data read by the read head.

The individual features of the present invention including the longitudinal recording of azimuthally oriented tracks serve to increase the density of data stored on magnetic tape for use with linear drives. The above and other features and advantages of the present invention will become apparent from the following description and the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts a segment of prior art magnetic tape with data recorded in a longitudinal format of the prior art;

Figure 2 depicts a segment of prior art magnetic tape with data recorded in a helical format of the prior art;

Figure 3 depicts a segment of magnetic tape recorded with data in the format of the present invention;

Figure 4 depicts a schematic representation of a tape drive mechanism of the present invention;

Figure 5 illustrates the physical format of the magnetic tape media; Figure 6 illustrates in block diagram form the architecture of the write data path in the tape drive control unit;

Figures 7-9 illustrate various data formats;

Figures 10 - 12 illustrate in flow diagram form the operational steps taken by the control unit to perform a number of operations on the magnetic tape;.

DETAILED DESCRIPTION

The prior art linear recording architecture and prior art helical recording architecture are first described. The recording architecture of the present invention, beginning with the tape drive system design, is then described.

Prior Art Linear Recording Architecture

Figure 1 depicts a representative segment of magnetic tape 100 which has been recorded in a longitudinal, or linear, format by a linear tape drive mechanism of the prior art. There are 5 separate tracks recorded on tape 100, four data tracks, tracks 110A , 110B, 110C, 110N, and one control track 120. Data tracks 110A-N are used for the storage of data as described below. Control track 120 has information encoded on it, dependent on the application, which is utilized by a tape drive mechanism (not shown) to control the process by which data is read from, and written to, tape 100. Depending on the type of tape, the type of tape drive, and the application, the number of tracks recorded in this format can vary. Therefore, track 110N represents any number of additional data tracks that could be recorded on a single tape in this format. Likewise, more than one control track 120 could be recorded on the tape depending on the particular application.

Each of tracks 110A-N are continuous tracks aligned with the longitudinal axis of tape 100. A data segment 130 of track 110A is representative of the magnetically encoded data on tracks 110A-N. Data segment 130 is comprised of a plurality of bits 160. Read head 140 of a tape drive mechanism (not shown) reads bits 160 as tape 100 moves past read head 140. The tape drive mechanism processes information from read/write heads 140 and 150 in a known way to either read data from tape 100 or record data to tape 100. Likewise, write head 150 of the tape drive mechanism will encode bits 160 on to one of tracks 110A-N as tape 100 moves past write head 150. In order to read or write data to each of the data and control tracks on tape 100, read/write heads (not shown) must be positioned adjacent each of the data and control tracks on tape 100. As tape 100 moves through a tape guide (not shown) of the tape drive mechanism, the alignment of data track 110A, for example, with respect to read/write heads 140 and 150 can change. These changes in alignment can occur for a variety of reasons. Tape 100 may become stretched in the tape guide and variations in speed of operation the tape guide can occur. These reasons are exemplary of the type of factors impacting the alignment of data track 110A with respect to read/write heads 140 and 150. Servos (not shown) are often used to move read/write heads 140 and 150 in order to compensate for differences in the alignment of magnetic tape 100 and read/write heads 140 and 150. In this way read/write heads 140 and 150 can track the movement of magnetic tape 100 with respect to the read/write heads 140 and 150. Even when servos are used, however, further steps must be taken to minimize errors that might be induced by a misalignment of tape 100 with respect to read/write heads 140 and 150. It is obvious to one skilled in the art that if data track 110A and data track 110B were immediately adjacent to one another, even tiny changes in the position of tape 100 with respect to read head 140 would result in read track 140 sensing bits 160 from both data tracks 110A and 110B at the same time. The result is erroneous signals from read head 140. The problem is the same with respect to write head 150.

Guard bands 180 are located between each of tracks 110A-N and control track 120 to ensure that read head 140 is reading data from the intended track and that write head 150 is writing data to the intended track. If the alignment between tape 100 and read head 140 should shift, read head 140 will attempt to read data from a guard band 180. In that event, a control system (not shown) associated with the tape drive mechanism will take steps, in a way know to those skilled in the art, to bring tape 100 and read write heads 140 and 150 back into alignment. It is obvious to one skilled in the art that guard bands 180, although useful and effective, require the commitment of space on tape 100 to a task different than the storage of data.

<u>Prior Art Helical Recording Format</u>

Figure 2 depicts a representative segment of magnetic tape 200 which has been recorded in a helical format by a helical tape drive of the prior art. There are 4 separate data track pairs recorded on tape 200, 210A-N, and one linear track 220 having data bits 225. Data track pairs 210A-N are used for the storage of data as described below and are each comprised of two separate tracks. For example, data track pair 210A is comprised of tracks 21 and 22. Linear track 220 has information encoded on it, dependent on the application, which is utilized by a tape drive mechanism (not shown) to control the process by which data is read from and written to tape 100. As in the linear format described with respect to Figure 1, depending on the type of tape, the type of tape drive, and the application, the number of tracks recorded in this format can vary. Therefore, track 210N represents any number of additional data tracks that could be recorded on a single tape in this format. Likewise, more than one linear track 120 could be recorded on the tape depending on the particular application. For example, in a common video application, three linear tracks 220 are used. One linear track 220 is provided for audio cue, one for time code and one for control.

Each track pair 210A-N is of a discrete length as opposed to the continuous tracks of the linear format described with respect to Figure 1. Angle 280 is commonly called the "track-angle" as it represents the angle between the axis of data tracks 210A-N and the longitudinal axis of tape 200. Although each discrete data track pair 210A-N appears simply angled, their orientation is referred to as "helical" because of the manner used to record the tracks. The helical orientation is the result of the relative orientation between tape 200 and write heads 250 and 252 and read heads 255 and 257. Write heads 250 and 252 and read heads 255 and 257 are mounted on a spinning drum, or scanner, (not shown) which is a component of the tape drive mechanism. The scanner is mounted at an angle to the longitudinal axis of tape 200 equal to angle 280. As the scanner spins, the read/write heads move in alignment with track pairs 210A-N and read or write data in data track pairs 210A-N.

Data segment 240 on data track pair 210A is exemplary of the manner in which data is recorded in a helical architecture. Data segment 240 is comprised of a plurality of data bits 260. Each data bit 260 is recorded at an angle 230 from the longitudinal axis of data track pair 210A. This angular displacement of data bits 260 from the longitudinal axis of track pair 210A is referred to as the azimuth of the tracks. Within each data track pair 210A-N, the data bits in one data track, 21 for example, have an azimuth angle opposite to the data bits in the other data track of the pair, 22 for example. Referring to Figure 2, data tracks 21, 23, and 25 share one azimuth while data tracks 22, 24, and 26 share a different azimuth. A typical azimuth angle 230 is 20 degrees.

Since data bits 260 in data tracks 21, 23, and 25 are oriented at one azimuth and data bits 260 in data tracks 22, 23, and 25 are oriented at a second azimuth, a read head and a write head for each azimuth are necessary to read and write data to the data tracks. As can be seen in Figure 2, write head 252 and read head 257 are aligned with the azimuth of data tracks 21, 23, and 25. Likewise, write head 250 and read head 255 are aligned with the azimuth of data tracks 22, 24, and 26.

Tape Drive System Architecture of the Present Invention

Figure 4 depicts the primary components of a linear tape drive 400 of the present invention. The operation of tape drive 400 is described in general terms with respect to Figure 4. A stream of data records is supplied by host computer 1 over line 2 to control unit 401. Host computer 1 may be any type of data generating device. Control unit 401 segments and organizes the data records into tracks as described below. Tape 300, a representative segment of which is depicted in Figure 3, discussed below, is wound around reel 403 and stored on removable cartridge 402. In order to read data from, or write data to, tape 300, removable cartridge 402 is inserted into tape drive mechanism 400. Tape 300 is automatically threaded along tape guide 406 and around machine reel 408. Machine reel 408 spins around spindle 409. Read heads 410 and write heads 411, as described below with respect to Figure 3, are arranged on guide 406 and are adjacent to tape media 300 as tape 300 is moved along guide 406. The write heads 411 simultaneously record two tracks of data at a time on magnetic tape 300. Similarly, the read heads 410 simultaneously play back two tracks of data at a time from magnetic tape 300. Each read heads 410 and write heads 411 may be comprised of more than one head, or even an array of heads. There is a fixed full-width erase head 405. There is also a fixed longitudinal erase head 412 and read/write head 413 to read and write data on each corresponding longitudinal control track contained on tape 300. In response to signals from host computer 1, control unit 401 controls the operation of tape drive 400 to record data tracks on tape 300. Tape 300 is pulled from reel 403 in removable cartridge 402 along guide 406 by the rotation of machine reel 408 about spindle 409. The rotation of machine reel 408 controlled, in a known way, by control unit 401.

Physical Format of Magnetic Tape

Figure 5 illustrates the physical format of tape 300. Tape 300 includes a leader block 501 that is attached at one end thereto and reel 403 around which tape 300 is wound into cartridge 402. A length of clear leader 502 is optionally interposed between the physical beginning (BOT) 521 of tape 300 and leader block 501 in order to protect tape 300 when it is wound in tape cartridge 402 around reel 403. A length 503 (typically 3m) of tape 300 exists between the physical beginning of tape 521 and a locale, known as the load point 522, at which point the density identification segment 504 of tape 300 begins. The density identification segment 504 represents data, for tape drive control unit 401 to access, indicative of the physical characteristics of tape 300. Internal leader header segment 505 is located at the end of density identification segment 504 of tape 300. The internal leader header 505 is followed by separator segment 506 of tape 300. The separator segment 506 isolates the logical beginning of tape (BOT) 523, which is the start of the data area 507 of tape 300, from the prepended header information described above. The data area 507 of tape 300 constitutes the majority of tape 300 and ends at the logical end of tape 524 which is a predetermined distance from tape to hub junction 526, wherein tape 300 is affixed to reel 403 of tape cartridge 402. A length of trailer tape 509 may be interposed between the physical end (EOT) of tape 525 and tape to hub junction 526. This serves as a method of attaching tape 300 to reel 403 in order to provide a secure method of attachment thereto.

The internal leader header 505 consists of administrative information typically including information about the location of data on tape 300 and information about when tape cartridge 402 was last mounted on tape drive 400. The internal leader header segment 505 of tape 300 is read on every load of tape cartridge 402 into a tape drive 400. The internal leader header segment 505 is updated by tape drive 400 prior to tape 300 being physically unloaded therefrom in order to update the header information concerning read and write information contained therein.

Write Data Path

Figure 6 illustrates in block diagram form the architecture of the write data path contained within tape drive control 401. The write data path includes a channel interface circuit 601 which interconnects tape drive control 401 with data channel 2 from host computer 1. Channel interface circuit 601 receives data from host computer 1 and stores the data in buffer 602 for processing by the hardware and software contained in tape drive control 401. Buffer 602 stores a predetermined amount of data that is received from host computer 1. A typical buffer size is 8Mb in order that host computer 1 can write a significant amount of data into tape drive control 401 without requiring interruption of the data transfer caused by the movement or delay in movement of tape 300 on tape drive 400.

Packetizer circuit 603 retrieves data from buffer 602 and packetizes the data 702 as shown in Figure 7 by adding a packet header 701 which is protected by a cyclic redundancy check (CRC) (not shown). Data records received from host computer 1 are followed by a packet trailer 703 and a CRC (not shown) which protects both data 702 and packet trailer 703. The packets 700 produced by packetizer 603 are transmitted to data block generator 604 which reformats the packetized data 700 into data blocks 800 as shown in Figure 8. If a block data field is incomplete, pad bytes are added to the block data field 801 as required to complete the block data field 801. A correctable block header 802 and a two byte CRC character 803 are then prepended to the block data field 801 and a CRC code 804 is also appended thereto. The data block groups 800 are transmitted to rewriteable block group header generator 605 which produces, as shown in Figure 9, a rewriteable block group header 901 and CRC code 902 which protects this rewriteable block group header 901, both of which are prepended to the data block groups 903. The resultant data 900 is then transmitted to the channel write circuits 606 for writing the data in the format of the present invention on to tape 300.

Data 900 is properly formatted for segmentation into tracks. The headers and trailers prepended and appended to data 900 allow multiple data blocks 900 appended one after the other in a single physical track to be differentiated by the operation of control unit 401. Tracks may be written one at a time on to tape 300 or may be written in pairs or in larger groupings.

Channel write circuit 606 receives data 900, encodes error correction codes (ECC) to enable the detection of errors, segments data 900 into tracks, and sends data 900 to read/write heads 410 and 411 for writing to magnetic tape 300. There are a variety of well known techniques for encoding ECC's. Typically multiple ECC's are employed to allow error checking on the byte, track, and data block levels.

Data Record Write to Magnetic Tape

Figures 10 - 12 illustrate in flow diagram form the operational steps taken by tape drive 400 to write data to tape 300. At step 1001, tape cartridge 402 is inserted into tape drive 400 and the tape drive mechanism illustrated in Figure 4 loads tape 300 by threading the leader block 501 and tape 300 through the tape threading path to the take up reel 408 which rotates around spindle 409. At step 1002, tape 300 is advanced forward in order to enable tape drive control 401 to read internal leader header 505 written on to tape 300 via read heads 410. If this tape is an unused tape, there is no internal leader header 505 on this tape 300. If the tape has been previously used, the internal leader header 505 contains the information described above and enables tape drive control 401 to determine where on tape 300 the last data record has been written. At step 1003, tape drive control unit 401 presents a ready signal to host computer 1 indicating that tape drive 400 is ready to receive data and commands from host computer 1 via data channel 2. At step 1004, host computer 1 transmits data over data channel 2 that interconnects it to tape drive 400 and the data is written into buffer 602. As the data is written into buffer 602, tape drive control unit 401 checks for errors to make sure there are no transmission errors in the data received from host computer 1. Since tape drive 400 can typically write data to tape 300 faster than host computer 1 can write the data into buffer 602, tape drive control unit 401 waits at step 1005 for host computer 1 to complete its data transmission and checks for errors. At step 1006 tape drive 400 presents the proper ending status to host computer 1 indicating that the data records have been written or, when buffer 602 is filled to a predetermined level, tape drive 400 begins writing the data to magnetic tape 300 in order to free up more buffer space for host computer 1 to continue writing data records therein. In either case, at step 1007 tape drive control unit 401 ensures that read/write heads 410 and 411, magnetic tape 300 and any servos (not shown) are all synchronized. At step 1008, tape drive control 401 positions magnetic tape 300 to the physical location on magnetic tape 300 that immediately follows the last written data record. At step 1009, control unit 401 retrieves the appropriate data block group 900 to be written. For the purpose of this description, assume that the data block groups written to magnetic tape 300 represent data records received from host computer 1 and stored in buffer 602. At step 1010, control unit 401 activates the read/write mechanism described above to write data block group 900 to tape 300 and at step 1011, the read after write process reads data block groups 900 as they are written on to tape 300 in order to ensure their integrity. If an error is detected in the written data block group, the data block group 900 is rewritten at step 1016 in order to maintain the logical sequence of data block groups on tape 300. At step 1012, control unit 401 checks the buffer status and at step 1013 determines whether further data is in buffer 602. If data is in buffer 602, steps 1009-1013 are repeated until, at step 1013, no more data is available from buffer 602. Control unit 401 determines at step 1014 whether more data is expected from host computer 1.

At this point (step 1017), control unit 401 writes a plurality (typically three) pad groups and an end group after the last written data block group in order to complete the writing of this stream of data records. At step 1018, tape 300 is rewound to its beginning and, at step 1019, internal leader header 505 is rewritten with updated information concerning the physical location and identity of the data records that have just been written on to magnetic tape 300. At step 1021, control unit 401 writes updated information into the administrative information section 501 of internal leader header 505. If, at step 1014, control unit 401 determines that further data is expected from host computer 1, control unit 401 at step 1017 writes a plurality of pad scan groups to the end of the last written data block group and rewinds magnetic tape 300 to the end of the first of these pad scan groups. Control unit 401 then returns to step 1003 and presents a ready status to host computer 1.

Recording Format of the Present Invention

Referring now to Figure 3, a segment of tape 300 is shown with data recorded utilizing tape drive 400. The operation of tape drive 400, and in particular drive control 401, was described with respect to Figure 4 through 12. The data on tape 300 is arranged into 4 data track pairs 310A, 310B, 310C, and 310N where data track 310N represents any number of additional data track pairs depending on factors such as track size, tape size, and application. Control track 328 is used by tape drive 400 to control the process by which data is read from and written to tape 300 as described above. Control track 328 is exemplary and there may in fact be a plurality of control tracks used, depending on the particular application. As can be seen from a comparison of Figures 2 and 3, data track pairs 310A-N are similar in format to data track pairs 210A-N with the difference that data track pairs 310A-N are aligned with the longitudinal axis of tape 300. As a result, tape track pairs

310A-N are continuous tracks aligned with the longitudinal axis of tape 300 similar to the data tracks described with respect to Figure 1 depicting prior art linear drive architecture. In the preferred embodiment of the present invention, therefore, the tape drive mechanism of a linear drive is used, as described with respect to Figure 4. However, the read/write heads typically used in the linear type drive, and described with respect to Figure 1, are replaced with read/write heads similar to those used in helical-type drives. As is evident in Figure 3, there are no longer any guard bands necessary between data tracks 310A-N as were required between data tracks 110A-N , in Figure 1, of the linear architecture. Clearly, an advantage of the present invention is an ability to record more data on a given size tape while still utilizing the tape drive mechanism of the linear drive.

As with the helical architecture, multiple read and write heads are necessary because of the azimuthal nature of the tracks. Each track pair 310A-N is aligned with the longitudinal axis of tape 300, but data bits 360 are aligned at an azimuth angle 370. As in the helical architecture of Figure 2, data tracks 31, 33, and 35 share one azimuth aligned with write head 410A and read head 411A, and data tracks 32, 34, and 36 share a different azimuth, aligned with write head 410B and read head 411B. There is a write head pair at each location 410 on Figure 4 and a read head pair at each location 411 on Figure 4. One skilled in the art will recognize that the write and read head pairs could be positioned at other locations in tape drive assembly 400.

A particular advantage of the present invention, and the reason guard bands are unnecessary, is the reverse azimuth orientation of adjacent tracks. If a misalignment of the tape occurs, meaning read head 411B, for example, is not exactly aligned with the intended data track, track 32, then a portion of read head 411B will overlap the adjacent data track, track 31 or 33 Read head position 380 represents the position of a read head (not shown) intended to be aligned with track 35 but with a misalignment between tape 300 and the read head. The read head at position 380 reads data from data track 35 of data track pair 310C but, due to a misalignment as illustrated by read head position 380, overlaps data track 34. A typical azimuth angle 370 is 20 degrees, therefore the difference between an ON azimuth read and an OFF azimuth read is 140 degrees. Using this value as an example, the read head at position 380 is expecting to sense a track aligned at 20 degrees azimuth from the track angle (ON azimuth) but also reads a portion of a track aligned at 20 degrees in the opposite direction (OFF azimuth). The signal generated by the read head at read head position 380 by track 34, out of alignment with the read head at position 380 by 140 degrees, is quite small. The result is a very high signal to noise ratio between ON azimuth readings and OFF azimuth readings.

In an embodiment of the present invention, the high signal to noise ratio between ON azimuth readings and OFF azimuth readings is used to further advantage. Control of the alignment between tape 300 and read heads 411A and 411B can be relaxed to some extent since OFF azimuth signal strength is too low to be a factor in interfering with an ON azimuth read. In this embodiment, each data track is 20 micro-meters wide. Rather than using read heads that are also 20 micro-meters wide, read heads as large as 50 micro-meters are used as represented by read head 385. Read head 385 reads data track 37 and 36 overlaps into data tracks 36 and 38 but the OFF azimuth signals from data tracks 36 and 38 are too low to interfere with the ON azimuth signals from data track 37. If the misalignment between tape 300 and read head 385 can be controlled by the tape drive mechanism to less than 30 micro-meters, then there is no need to use a servo to control the position of read head 385. Controlling misalignment to less than 30 micro meters means that tape 300 will not change position with respect to read head 385 by more than 15 micro meters in both directions. This simplifies the tape drive mechanism necessary to utilize tape 300 and results in a tracks per inch density, for ½ inch tape, of about 1270 tpi.

In another embodiment, the data track width is doubled to 40 micro-meters and the read head size is doubled to 100 micro-meters. In this embodiment, misalignment between tape 300 and read head 385 need only be maintained to less than 60 micro-meters to avoid the need to servo read head 385. The data density of tape 300, as a result, is about 600 tpi for this embodiment.

It is to be expressly understood that the claimed invention is not to be limited to the description of the preferred embodiment but encompasses other modifications and alterations within the scope and spirit of the inventive concept.

I claim:

1. Apparatus (400) in a linear tape drive mechanism which reads and writes a stream of data records on a magnetic tape, comprising:

means for receiving (401) said stream of data records from a host computer (1),

means for segmenting (401) said received stream of data records into tracks predetermined length; and

CHARACTERIZED IN THAT:

means for writing (401, 406) a plurality of juxtaposed parallel oriented tracks (310) on said magnetic tape media (300) wherein each of said tracks comprises data bits (360) aligned on an azimuth with respect to a longitudinal axis of said magnetic tape.

2. The apparatus of claim 1 wherein said data bits comprising a first track (31) are aligned at a first azimuth (370) and the data bits comprising a second track (32) are aligned at a second azimuth said second track being adjacent said first track.

3. The apparatus of claim 2 wherein said first azimuth and said second azimuth are substantially orthogonal to one another.

4. The apparatus of claim 1 wherein said means for segmenting said received stream of data records into tracks comprises:

means for storing a plurality of bytes of said received stream of data records,

means for packetizing said received stream of data records into data segments having a predetermined number of bytes; and

means for concatenating a plurality of said data segments to form one of said tracks.

5. The apparatus of claim 4 wherein said means for segmenting said received stream of data records into tracks further comprises:

means for generating a first error correction code specific to said stored plurality of bytes,

means for dividing said stored plurality of bytes and said first error correction codes into a series of data segments having a predetermined number of bytes; and

means for concatenating a plurality of said data segments and their associated second error correction codes to form one of said tracks.

6. The apparatus of claim 5 wherein said means for writing tracks comprises:

means (410A, 410B) for writing pairs of tracks each track pair having a first track and a second track; and

said first track is comprised of data bits aligned at a first azimuth and said second track is comprised of data bits aligned at a second azimuth.

7. The apparatus of claim 1 wherein said means for writing a plurality of juxtaposed parallel oriented tracks comprises:

means (410A) adjacent said magnetic tape as said magnetic tape moves through said linear tape drive mechanism for encoding said magnetic tape with a first track (31),

said first track having data bits arranged at a first azimuth in relation to said longitudinal axis of said magnetic tape,

means (410B) adjacent said magnetic tape as said magnetic tape moves through said linear tape drive mechanism for encoding said magnetic tape with a second track (32), said second track having data bits arranged at a second azimuth in relation to said longitudinal axis of said magnetic tape; and

said first and second tracks being juxtaposed in parallel orientation on said magnetic tape.

8. The apparatus of claim 7 wherein said encoding means comprises:

a first write head (401A) oriented adjacent said first track and aligned at said first azimuth; and a second write (410B) head oriented adjacent said second track and aligned at said second azimuth.

9. The apparatus of claim 4 wherein said means for segmenting saidreceived stream of data records comprises:

means for combining a predetermined number of sequentially generated ones of said tracks to form a data block group; and

means for writing each of said data block groups on to said magnetic tape in azimuthally oriented linear format.

10. The apparatus of claim 9 further comprising:

means for reading (411A, 411B) each of said data block groups immediately following its writing on to said magnetic tape; and

means, responsive to the detection of errors in a read data block group, for rewriting said read data block group on said magnetic tape immediately following an end of a presently writing data block group.

11. The apparatus of claim 1 further comprising:

means for generating administrative data specific to each of said data records received from said host computer and to said magnetic tape; and

means for writing said administrative data to said magnetic tape.

12. The apparatus of claim 11 wherein said administrative data writing means writes said generated administrative data as a header on said magnetic tape, prepended to said stream of data records written in azimuthally oriented linear form on said magnetic tape.

13. A method, in a linear tape drive mechanism which reads and writes a stream of data records on a magnetic tape, comprising the steps of:

receiving (601, 602) said stream of data records from a host computer,

segmenting (603) said received stream of data records into tracks predetermined length; and

CHARACTERIZED IN THAT:

writing (604, 606) a plurality of juxtaposed parallel oriented tracks on said magnetic tape media wherein each of said tracks comprises data bits aligned on an azimuth with respect to a longitudinal axis of said magnetic tape.

14. The method of claim 13 wherein the step of writing a plurality of juxtaposed parallel oriented tracks on said magnetic tape media further comprises the steps of:

writing a first track (31) on said magnetic tape having data bits aligned at a first azimuth; and

writing a second track (32) on said magnetic tape having data bits aligned at a second azimuth.

15. The method of claim 14 wherein said step of segmenting said received stream of data records into tracks further comprises the steps of:

storing (602) a plurality of bytes of said received stream of data records,

packetizing (603) said received stream of data records into data segments having a predetermined number of bytes; and

concatenating (604) a plurality of said data segments to form one of said tracks.

16. The method of claim 15 wherein said step of segmenting (603) said received stream of data records into tracks further comprises the steps of:

generating a first error correction code specific to said stored plurality of bytes,

dividing said stored plurality of bytes and said first error correction codes into a series of data segments having a predetermined number of bytes; and

concatenating a plurality of said data segments and their associated second error correction codes to form one of said tracks.

17. The method of claim 15 wherein said step of writing tracks (606) further comprises the steps of:

writing pairs of tracks each track pair having a first track and a second track; and

aligning said data bits of said first track at a first azimuth; and

aligning said data bits of said second track at a second azimuth.

18. The method of claim 13 wherein said step of writing (606) a plurality of juxtaposed parallel oriented tracks comprises:

encoding said magnetic tape with a first track (31), said first track having data bits arranged at a first azimuth in relation to said longitudinal axis of said magnetic tape,

encoding said magnetic tape with a second track (32) juxtaposed in parallel orientation with respect to said first track, said second track having data bits arranged at a second azimuth in relation to said longitudinal axis of said magnetic tape.

19. The method of claim 18 wherein said step of encoding further comprises the steps of:

locating a first write head (410A) oriented adjacent said first track and aligned at said first azimuth; and

locating a second write head (410B) oriented adjacent said second track and aligned at said second azimuth.

20. The method of claim 15 wherein said step of segmenting said received stream of data records further comprises the steps of:

combining (604) a predetermined number of sequentially generated ones of said tracks to form a data block group; and

writing (606) each of said data block groups on to said magnetic tape in azimuthally oriented linear format.

21. The method of claim 20 further comprising the steps of:

reading (1011) each of said data block groups immediately following its writing on to said magnetic tape; and rewriting (1016), responsive to the detection of errors in a read data block group, said read data block group on said magnetic tape immediately following an end of a presently writing data block group.

22. The method of claim 13 further comprising the steps of:

generating administrative data (505) specific to each of said data records received from said host computer and to said magnetic tape; and

writing said administrative data to said magnetic tape.

23. The method of claim 22 wherein said step of writing administrative data further comprises the steps of:

writing said generated administrative data as a header (505) on said magnetic tape, prepended to said stream of data records written in azimuthally oriented linear form on said magnetic tape.

FIG. 1
PRIOR ART

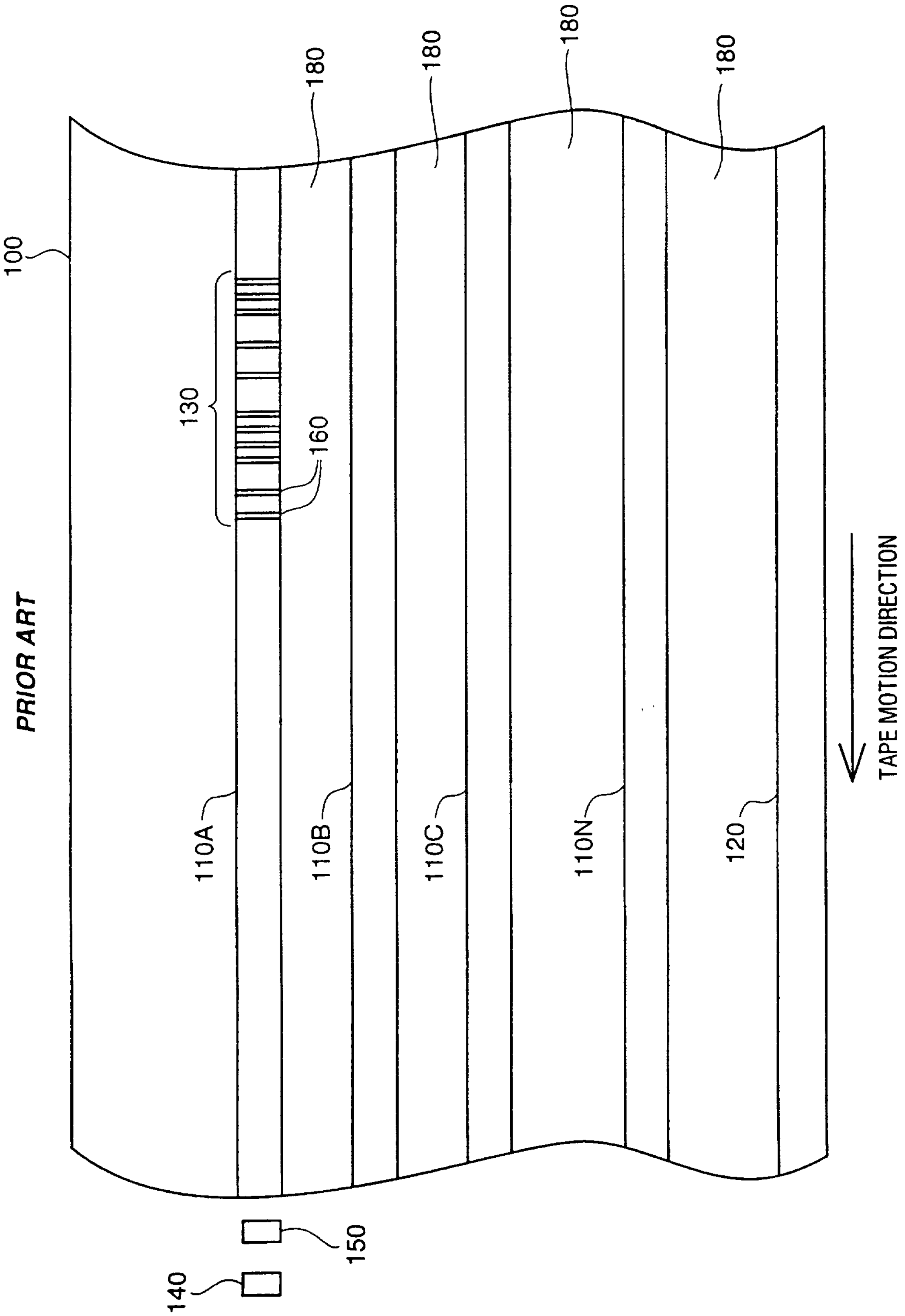


FIG. 2

PRIOR ART

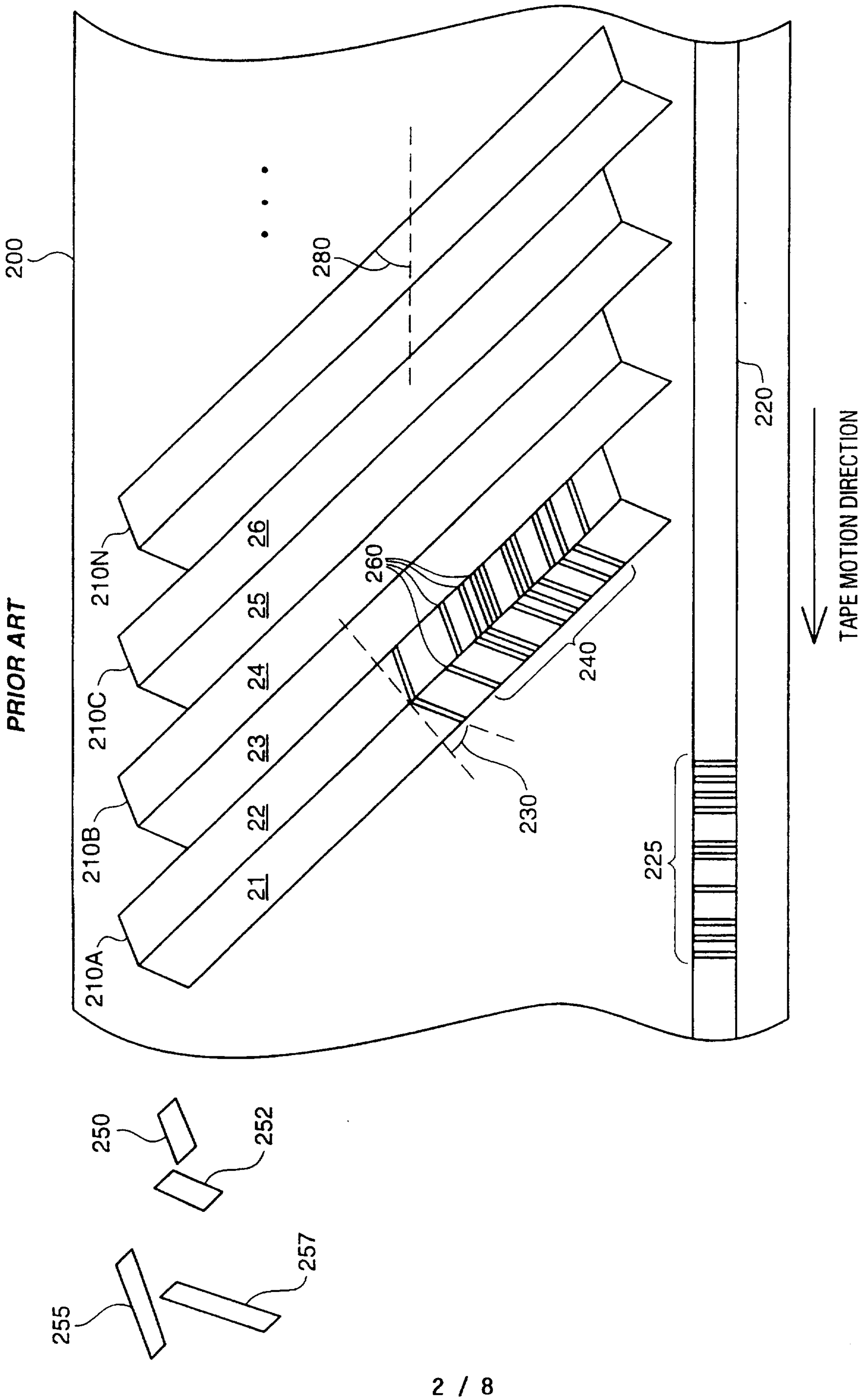


FIG. 3

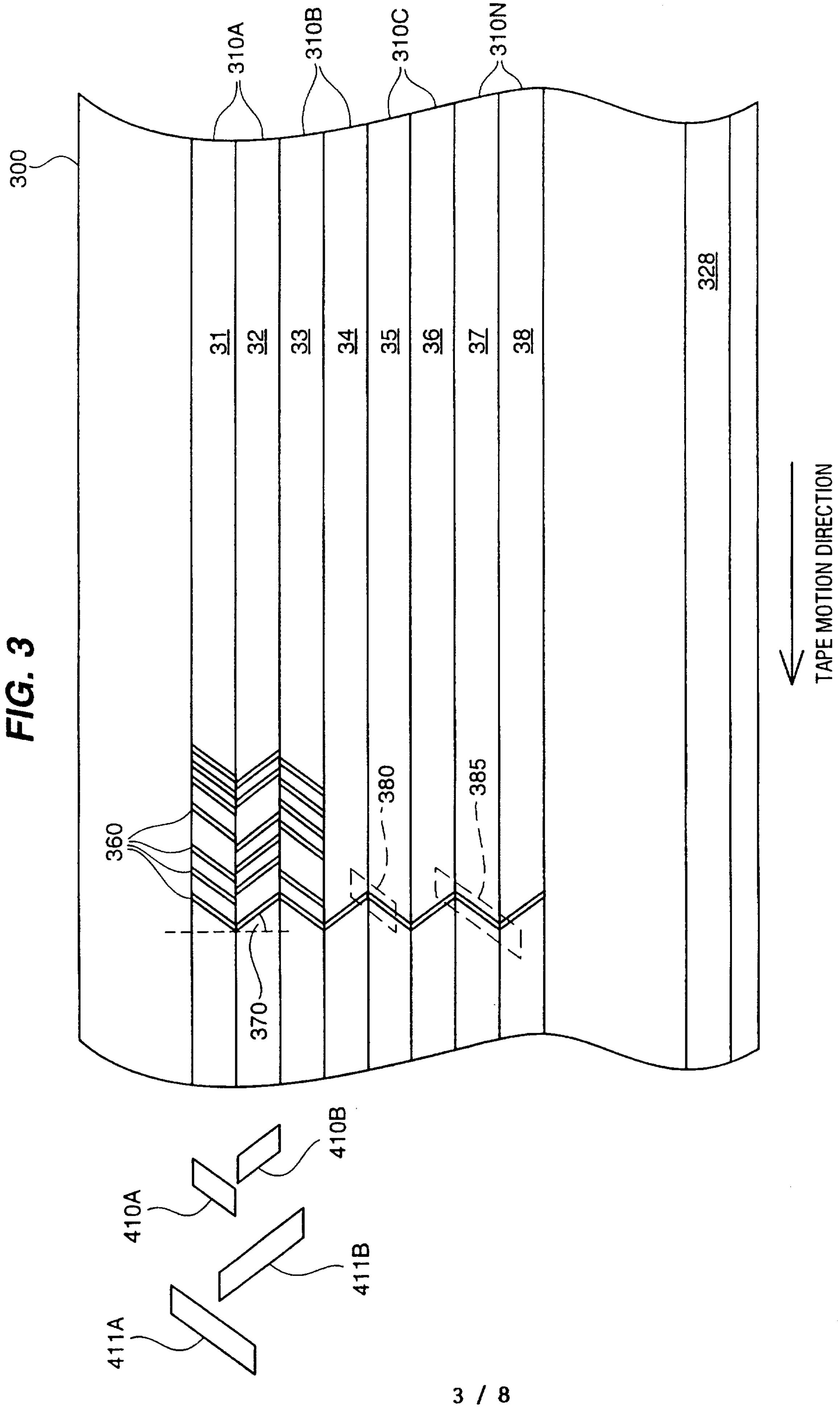

300
310A
310B
310C
310N
31
32
33
34
35
36
37
38
328
TAPE MOTION DIRECTION
360
370
380
385
410A
410B
411A
411B

FIG. 4

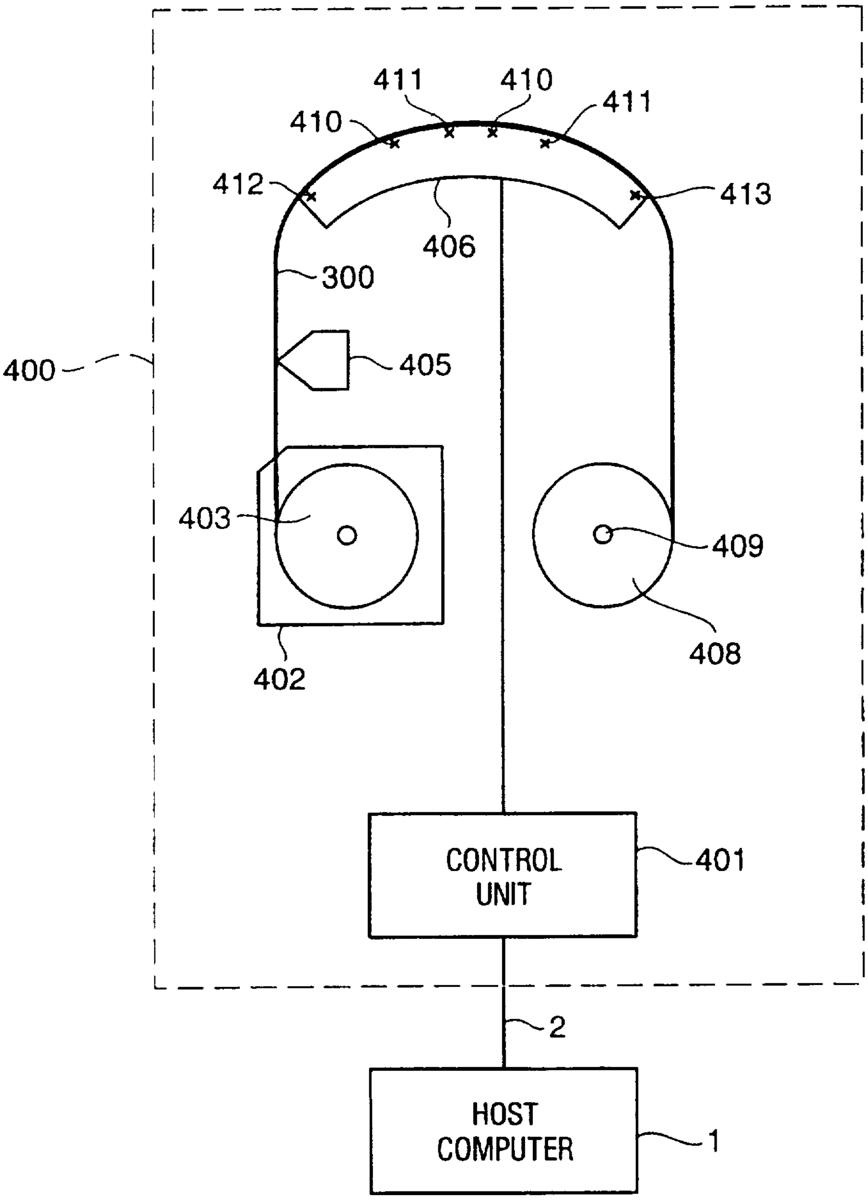

411
410
410
411
412
413
406
300
400
405
403
409
402
408
CONTROL UNIT
401
2
HOST COMPUTER
1

FIG. 5

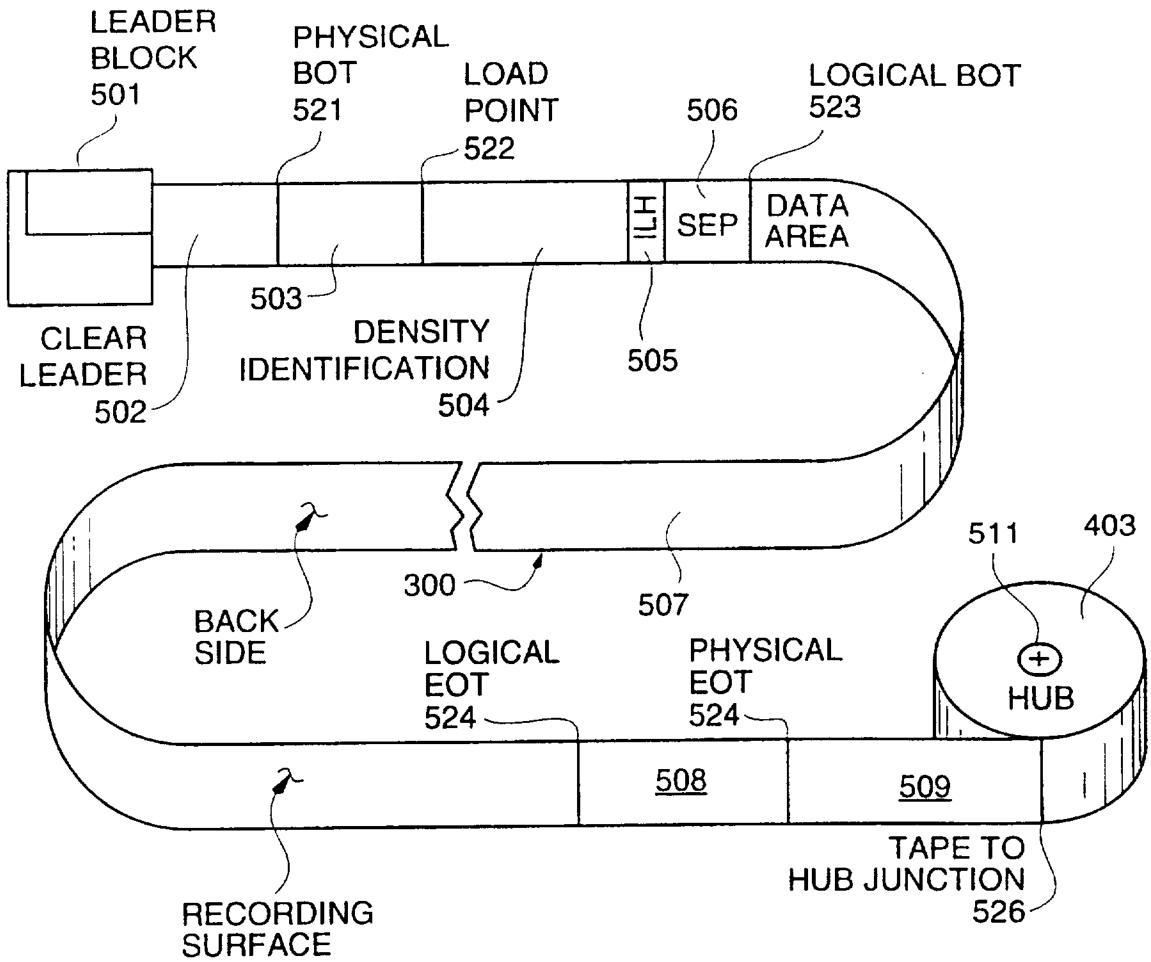

LEADER
BLOCK
501
PHYSICAL
BOT
521
LOAD
POINT
522
506
LOGICAL BOT
523
ILH
SEP
DATA
AREA
503
CLEAR
LEADER
502
DENSITY
IDENTIFICATION
504
505
511
403
300
507
BACK
SIDE
LOGICAL
EOT
524
PHYSICAL
EOT
524
HUB
508
509
TAPE TO
HUB JUNCTION
526
RECORDING
SURFACE

FIG. 6

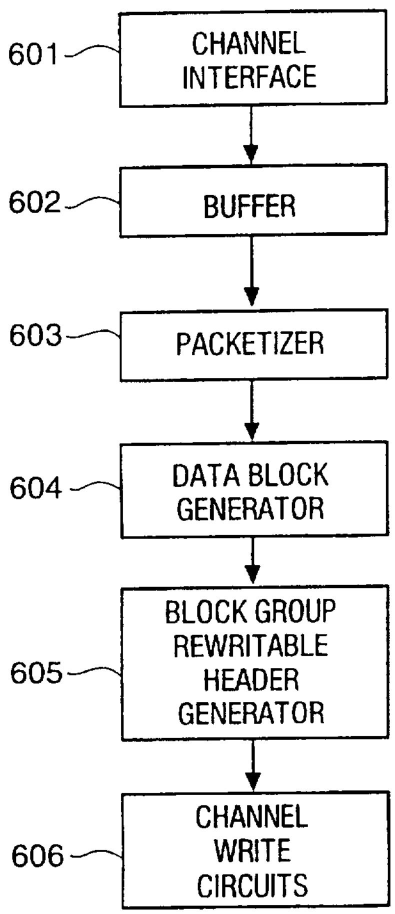

601 CHANNEL INTERFACE
602 BUFFER
603 PACKETIZER
604 DATA BLOCK GENERATOR
605 BLOCK GROUP REWRITABLE HEADER GENERATOR
606 CHANNEL WRITE CIRCUITS

FIG. 10

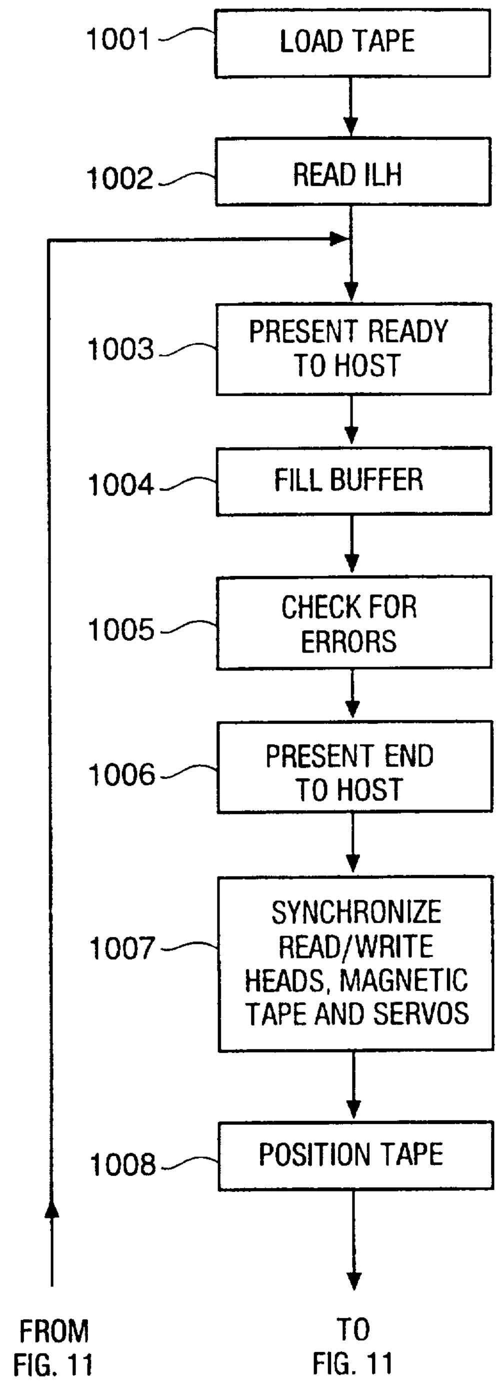

1001 LOAD TAPE
1002 READ ILH
1003 PRESENT READY TO HOST
1004 FILL BUFFER
1005 CHECK FOR ERRORS
1006 PRESENT END TO HOST
1007 SYNCHRONIZE READ/WRITE HEADS, MAGNETIC TAPE AND SERVOS
1008 POSITION TAPE
FROM FIG. 11
TO FIG. 11

FIG. 7

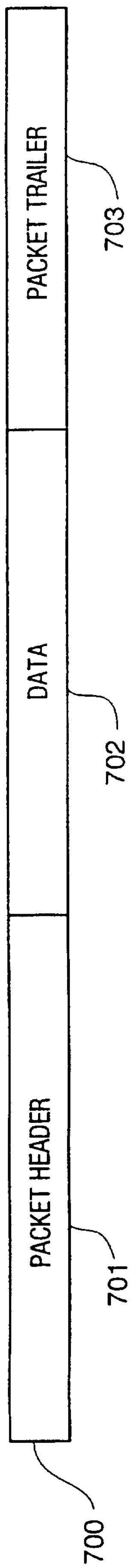


FIG. 8

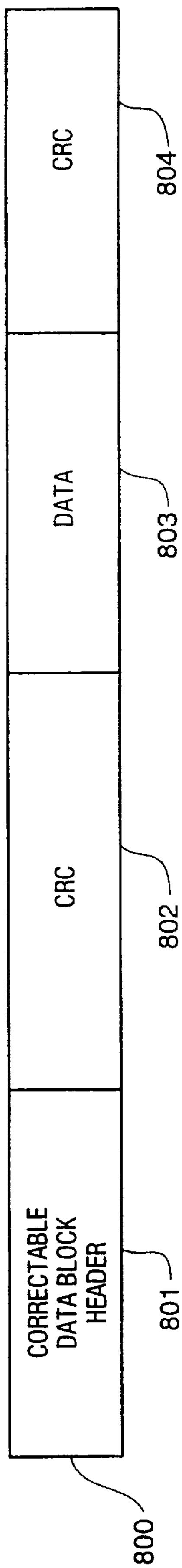


FIG. 9

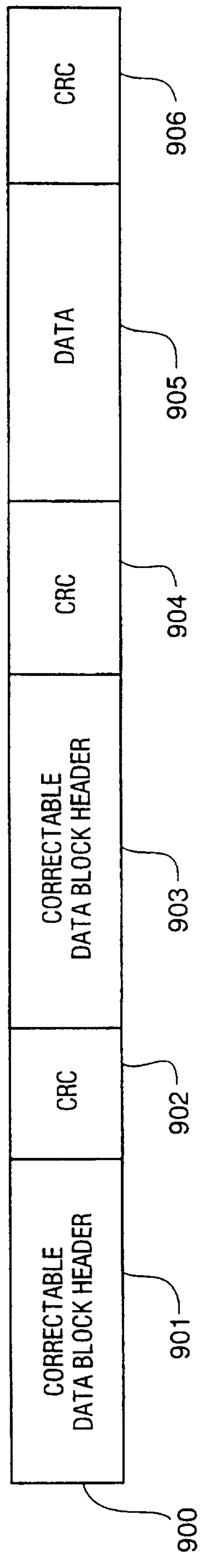


FIG. 11

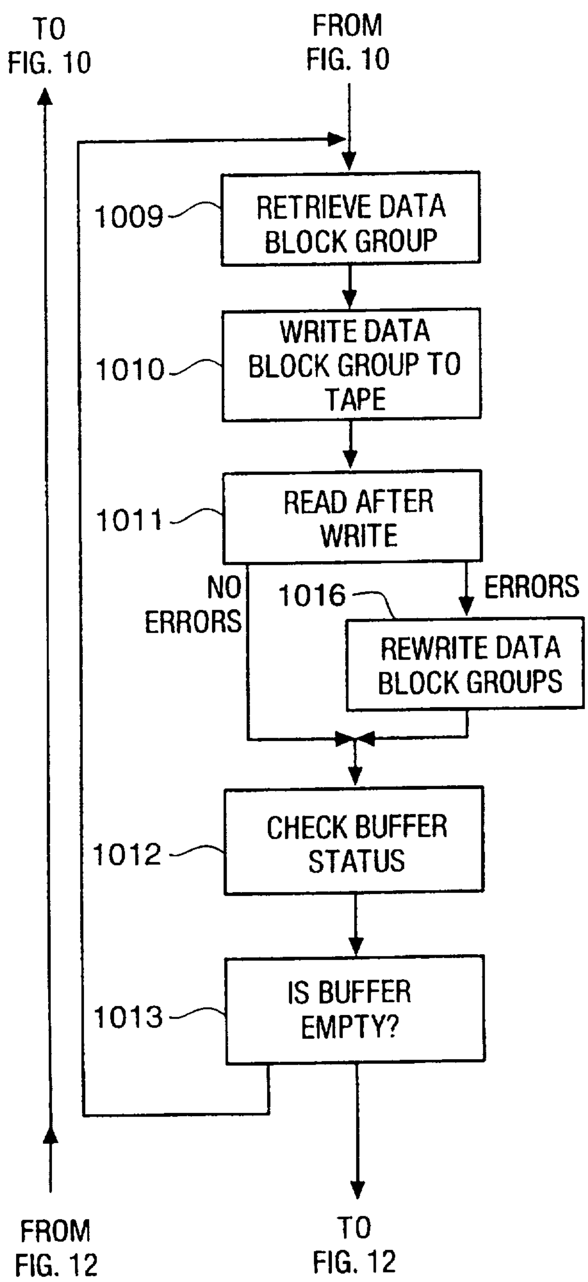
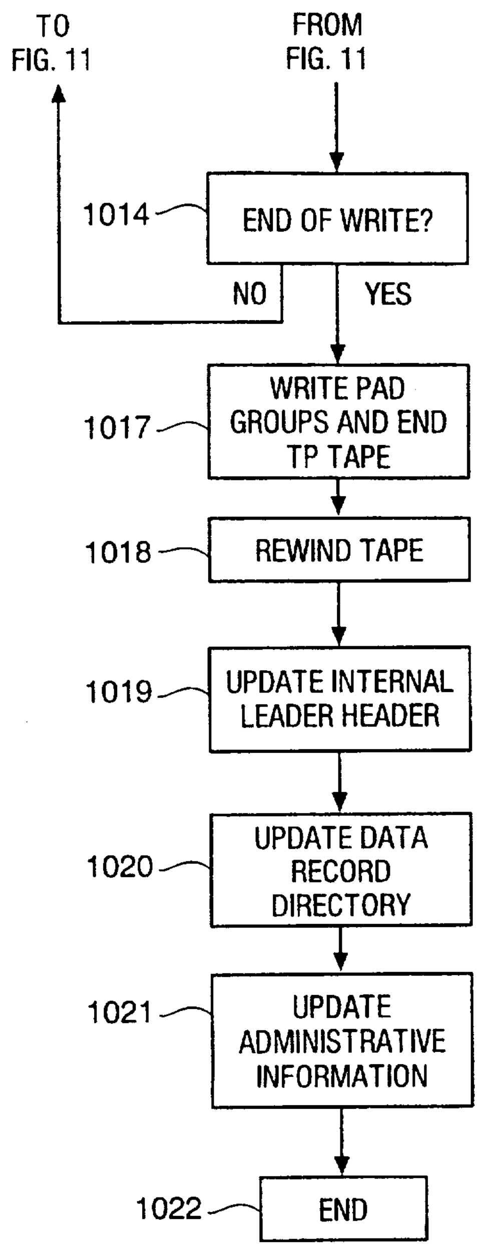

TO
FIG. 10
FROM
FIG. 10
1009
RETRIEVE DATA BLOCK GROUP
1010
WRITE DATA BLOCK GROUP TO TAPE
1011
READ AFTER WRITE
NO ERRORS
1016
ERRORS
REWRITE DATA BLOCK GROUPS
1012
CHECK BUFFER STATUS
1013
IS BUFFER EMPTY?
FROM
FIG. 12
TO
FIG. 12

FIG. 12


TO
FIG. 11
FROM
FIG. 11
1014
END OF WRITE?
NO
YES
1017
WRITE PAD GROUPS AND END TP TAPE
1018
REWIND TAPE
1019
UPDATE INTERNAL LEADER HEADER
1020
UPDATE DATA RECORD DIRECTORY
1021
UPDATE ADMINISTRATIVE INFORMATION
1022
END

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/12886

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G11B5/008 G11B5/48

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G11B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X A	US 5 307 217 A (SALIBA GEORGE A) 26 April 1994 see figures 3,5,11,12 see column 2, line 19 - column 3, line 33 see column 4, line 42 - column 5, line 57 see column 8, line 33 - column 9, line 19 ---	1-4,9, 13-15,20 7,10-12
X	EP 0 067 601 A (REYNOLDS TOBACCO CO R) 22 December 1982 see abstract see page 11, line 21 - page 19, line 3 see figures 5-9 --- -/--	1-4,8,9, 13-15,17

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 1997	04.11.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Schiwy-Rausch, G

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/12886

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 092 (P-1009) [4035] , 20 February 1990 & JP 01 298512 A (SANKYO SEIKI MFG CO LTD), 1 December 1989, see the whole document ---	1-4,7-9, 13-15, 17-21
A	GB 2 070 843 A (VICTOR COMPANY OF JAPAN) 9 September 1981 see page 1, line 83 - page 2, line 12 see figures 3-5 ---	1-3,7,8, 13,14, 18-21
A	US 4 456 930 A (HASHIMOTO YOSHITAKA) 26 June 1984 see figures 2,3 see column 7, line 53 - column 10, line 20 see claims 1,2 ---	1-10, 13-21
A	US 5 452 152 A (RUDI GUTTORM) 19 September 1995 ---	
A	DE 28 03 524 A (BLAUPUNKT WERKE GMBH) 2 August 1979 -----	

1

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

Intern: al Application No
PCT/US 97/12886

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		JP 3052274 B	09-08-91
		JP 57125588 A	04-08-82
		AT 391578 B	25-10-90
		AU 546864 B	26-09-85
		AU 7974582 A	05-08-82
		CA 1181170 A	15-01-85
		DE 3202664 A	19-08-82
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