The present invention relates to optical memories giving access to areas reserved for storing data wherein a disk's reference surface has been subject to arrangement. Data is stored by means of a read/record apparatus which comprises essentially motor means for setting a disk in rotation and a radially mobile optical head projecting onto the reference surface a light spot finely focussed by a lens. In order to produce regions on the reference surface intended to acquire data, the disk is pre-engraved. These regions are situated on a spiral track or on concentrically circular track elements. The essential tasks of the optical head are to read the pre-engraving, to write data, to read data and, if appropriate, to erase the latter. In order to carry out the various tasks, when data is very dense on the disk, it is necessary to provide focussing and track monitoring control. Track scanning also requires the provision of synchronisation measures, since each data element is assigned to occupy elementary sites arranged in series along the track, which are referred to by means of synchronisation patterns located on specific radii, with uniform angular distribution.

In the knowledge that the disk comprises a structure which is optically recordable by irreversibly or reversibly modifying its optical characteristics, it is prudent for the writing of data not to be possible in certain parts of the reference surface, the periodic scanning of which completely ensures synchronisation, track monitoring and focussing functions. The areas reserved for writing data are then clear of all pre-engraving or, if need be, provided with a pre-engraved groove which has no role in piloting the beam of radiation projected by the optical head. A disk pre-formatted according to this principle is generally read by a record/read apparatus which takes samples of the electric reading signal each time the light spot interacts with the pre-engraved patterns interpolated between the blocks of data.

In order to manage the radial positioning of the optical head, that is, get the scanning spot to follow a given track element in a set of several tens of thousands of elements, each element is given an identity in the form of a digital address.

This arrangement, which is exploited at the end of access to check the accuracy of positioning, cannot be sufficient in itself, since it consumes a lot of time. Another arrangement is generally provided, which consists of checking the forward motion of the head by measuring its radial displacement from the start position until one is in a position to read the addresses close to the destination point.

In order to measure displacement, it is known that a device can be used to displace the optical head such as a screw whose continuous or step-wise rotation makes it possible to know the amplitude and sign of displacement. It is also known that a displacement motor can be associated with a measuring system such as an optical rule that determines the actual displacement of the optical head. The disadvantages of these devices are their slowness and/or complexity, but they are in any case defective since they do not supply a measurement for the displacement of the reading spot relative to the pre-engraving. It is known indeed that pre-engraving can feature eccentricity relative to the disk's axis of rotation, hence it comes about that even when the reading spot is fixed in space, it periodically crosses several tens of track elements.

To overcome these disadvantages, it is also known that a technique can be used for counting track crossings, but this technique presupposes that the track is continuous and that the signals used for counting come from photodetector means suitable for producing signals detected by square-law. Counting the crossings of a continuous track involves the presence of a pre-engraved groove in the areas where data is stored and leads to the adoption for other areas of a variant of pre-engraving which is relatively difficult to implement.

Experience shows that the sampling technique ensures correct track monitoring even though the track may only be materialised by a few pre-engraved patterns grouped between the blocks of data. Such a disk using this technique is described in particular in application EP-A-89263. Thus, a disk is scanned in the

same way, whether or not it comprises written data, which considerably facilitates the choice of layers suitable for data storage since the writing contrast has no effect on that of the pre-engraved patterns.

Experience shows that the sampling technique makes it possible to tackle the counting of track crossings even when these take place between two batches of detected signals. Moreover, the counting of track crossings, which consists of deducing one address from another address by the indications on a counter, can be replaced by address indications read in fly mode which locate the scanning spot all the better in the memory plane as track crossings become less frequent relative to the frequency of picking up samples marking the trajectory. The capacity to use precise knowledge of the position of the scanning spot relative to the pre-engraved structure results in particular from the fact that the crossing speed evolves slowly enough to allow good analysis of radial access. This is particularly true at the beginning and end of access, when speeds are low.

The subject-matter of the present invention is a data carrier in the form of a disk comprising on a reference surface an assembly of adjacent track elements the respective curved axes of which are produced by pre-engraved patterns which alternate along said axes with areas reserved for storing said data; said curved axes having a common centre of rotation from which radii carrying said patterns are derived; a first family of N equi-angularly distributed radii defining, with each of said axes, intersection sites occupied by synchronisation patterns, characterised in that it comprises at least one other family of radii obtained by a predetermined angular displacement of P radii belonging to said first family and provided along its P radii with graduation; said graduation being composed of a radial arrangement of specific patterns wherein the repeated optical interactions with a focussed reading spot scanning said reference surface make it possible, during track crossings, to detect the amplitude and sign of a radial displacement of said spot within the range of said assembly; said radial arrangement, when it is encountered by

the reading spot, producing a defined marking of its instantaneous position relative to said graduation. Preferably, the radii of the second family derived from the first family are equiangular.

The invention also has as its subject-matter an optical scanning apparatus of the sampled-access type intended for implementing a data carrier according to Claim 1, said apparatus comprising an optical head projecting onto the reference surface a focussed scanning spot which can move along a trajectory crossing said track elements under the control of an access motor; said optical head being associated with photodetector means receiving a fraction of the radiation emerging from the portion of surface illuminated by said spot; said apparatus comprising means for controlling said access motor and receiving the destination address of the access to be performed and the electric signals delivered by said photodetector means, characterised in that said control means comprise sampling means picking up at least one digital value each time said spot encounters the radii provided with said graduation, which serves to locate said spot radially when its movement successively straddles several track elements; said digital value representing at least the remainder of the division of an absolute magnitude characteristic of the radial position of said spot by a number characteristic of said graduation.

The invention also has as its subject-matter a process for access in sampled mode to one track of a data carrier as described above, characterised by the following stages:

- scanning, by a focussed light reading spot, of the reference surface in a direction transverse to the tracks;
- determination of the amplitude and sign of the radial displacement of the spot within an assembly of adjacent track elements when the spot interacts optically and repeatedly with the graduation scale; and
- determination of the instantaneous position of the spot relative to the graduation scale when the spot scans the radial

arrangement, said determination being used to calculate the position of the spot in order to gain access to a given track.

It will be easier to understand the invention by means of the following description and the attached figures, in which:

Figure 1 is a partial isometric view of an optical scanning apparatus for a data carrier.

Figure 2 is an explanatory diagram.

Figure 3 shows an electric reading signal during scanning with track crossings.

Figure 4 illustrates a reversible counting technique based on the crossing of continuous track elements.

Figure 5 is a partial isometric view of a disk using pre-engraved patterns suitable for producing sampled access.

Figure 6 illustrates a first variant of pre-engraving in conformity with the invention.

Figure 7 is a diagram of an apparatus for the optical scanning of a disk, according to the invention.

Figure 8 shows the $\tilde{\phi}(t)$ function giving the absolute position of the spot as a function of time.

Figure 9 describes the operation of an optical scanning apparatus based on sampled access.

Figure 10 is a flow chart by which samples taken during access can be processed.

Figure 11 describes the operation of an optical scanning apparatus based on access by packets of track elements.

Figure 12 describes a method of absolute addressing and its use during sampled access.

Figure 13 shows the diagram of a decoding circuit.

Figure 14 describes a variant embodiment of the pre-engraved patterns according to the invention.

Figure 15 is an explanatory diagram relating to Figure 14.

Figure 16 is a diagram allowing the retrieval of digital samples deriving from patterns encoded as to position or length.

Figure 17 is an embodiment example of pre-engraving carried out by groups of packets of track elements.

Figure 18 is a variant embodiment of the pre-engraving illustrated in Figure 17.

Figures 19 and 20 show other examples of pre-engraving according to the invention.

Figure 1 shows an optical disk 1 whose reference surface 2 has been subjected to double radial and angular subdivision. The radial subdivision is carried out by inscribing a track composed of concentrically circular elements or successive turns of a spiral curve. This first configuration of segmenting the annular area is illustrated in Figure 1 by portions of axes in dot-and-dash lines 3 traced on the reference surface 2. This first network of curved lines has a common centre 0 which, ideally, should be situated on the axis of rotation 4 of a rotary drive pin for the disk 1, which is not shown in Figure 1. The rotation of the disk takes place, for example, in the direction of the arrow 5 at a uniform speed. A second configuration for segmenting the annular area consists of a set of N equi-angular radii 6 shown in solid lines on the figure. Thus the disk 1 has the appearance of a memory plane compartmented into N sectors in each of which there is a great number of curved locations which serve to store data when they are scanned in a centred manner with a light spot 7. The light spot 7 is produced by an optical head 8 which is mobile, for example, parallel to the radius ρ. The optical head could also be displaced along an arc of a circle intersecting the track, but to simplify presentation, it has been assumed that the optical head 8 is displaced radially under the control of a linear access motor 9.

Each curved segment 3 of the disk is accessible by designating the angular sector that contains it and the serial number C that has been attributed to it in that sector. This serial number is the same for all the curved segments of a same turn and changes

by one unit when going from one turn to the next by crossing a particular radius. To get the scanning spot 7 to scan the address turn C, the motor 9 is controlled by a circuit 10 that manages this access. Access starts when the scanning spot 7 is somewhere on the disk and finishes in principle when the spot has reached the destination address C. In general the optical head ceases to move before the spot 7 is centred over the desired track element, since this spot is subject to micro-displacements obtained by means of a fine displacement motor which acts, inside the optical head 8 for example, on a beam deflector.

In this case, the radial movement of the optical head represents the coarse phase of access which it should be attempted to make as accurate as possible in order to reduce the operating time for the fine access intended to complete the positioning of the scanning spot 7.

Referring to Figure 2, this shows a curve 110 for the radial displacement D of the scanning spot 7 between the instants 0 and t_3. The part of this curve comprised between the instants t_2 and t_3 represents the fine approach which implements small stepwise displacements produced by the optical deflector contained in the optical head 8. The part of this curve that stretches from 0 to t_2 represents coarse access. It can also be seen in Figure 2 that to obtain the displacement distribution illustrated by the curve 110, it has been provided that the radial speed V of the optical head can be varied according to the reference 120, and that to obtain this reference a constant acceleration γ has been applied from 0 to t_1 by means of the motor 9, and this has simply changed sign from t_1 to t_2. The displacement D illustrated in Figure 2 is the absolute displacement of the scanning spot 7 obtained when the optical deflector contained in the optical head is immobilised.

The control circuit 10 cannot ensure accurate displacement by simply acting on acceleration and braking efforts, since ballistic operation would be at the mercy of friction and spurious causes of displacement. It is therefore advantageous to provide

an apparatus for measuring the displacement of the optical head which reacts to a command from the access motor. In Figure 1, this measurement is obtained by means of optical sensors 11 and 12 which detect the graduations 13 and 14 of an optical rule 15. The electrical signals furnished by the sensors 11 and 12 are exploited within the circuit 10, in order to produce a representative signal for the amplitude and sign of the displacement of the optical head 8. Such circuits are well known, but have two important disadvantages. The graduations 13 and 14 have a pitch p and are offset by a quarter of this pitch in order to demonstrate the sign of the displacement. Now, the track elements on the disk have a different separation which cannot remain in strict relation to the pitch of the rule. The other disadvantage is that the eccentricity of the disk creates a relative displacement between the rule and the network of track elements.

To overcome these disadvantages, it has been thought possible to use the interaction of the scanning spot with the continuous grooves carried by the disk 1 to define by reversible counting the number of times the grooves are crossed as a result of the radial displacement of the scanning spot.

More precisely, when the disk rotates, the radial access describes a trajectory 16 that intersects the axes 3 of the engraving carried on the reference surface 2. These intersections take place at the locations which have been given a round mark on Figure 1.

Assuming that the optical head analyses the radiation that emerges from the illuminated part 7 of the reference surface 2 with a photoelectric cell situated on the optical axis of the lens that focusses the spot 7 onto the disk, an electrical signal R(t) is obtained as represented in Figure 3. If the groove appears optically clearer than the inter-track area, the maximum values for the signal R(t) represent the instants while crossing the grooves that are closer together when the spot's displacement speed is high. However, the signal R(t) is not sufficient to

distinguish a track crossing near the periphery of the disk from another one taking place near the centre.

An apparatus for automatic access to the data stored along continuous grooves was described in a patent application filed in France on 1 July 1977 in the name of THOMSON-BRANDT under number 77 20 373, and published under number FR-A-2 396 379.

The essential feature of the operation of this apparatus is given in Figure 4 which shows in the upper part, connected to a system of axes (ρ, t) a portion of disk with four equidistant grooves 3 and a trajectory 16 of the scanning spot 7. The axis ρ represents the centrifugal radial direction and the axis t represents the tangential direction or elapsed time, because these two variables are linked together by the tangential scanning speed.

The diagram R(t) has the same significance as in Figure 3, but since it will be necessary also to define the direction of groove crossings, there is an extra electrical signal I(t). To produce the signal I(t), the optical head 8 comprises a second photodetector system with two continuous heads having their line of separation on the optical axis of the lens. These cells are connected to the supplementary inputs of a differential amplifier which furnishes the signal I(t). A threshold detector circuit transforms the signal R(t) into a rectangular waveform S(t) whereas another threshold detector circuit, switched when passing through zero, provides the rectangular waveform S'(t) from the signal I(t). A reversible counter circuit receives, at a clock input, pulses corresponding to each transition of the signal S(t), but the increment and decrement are determined by an auxiliary reversible counter signal whose logic states are those of an "EXCLUSIVE OR" logic gate which receives the signals S(t) and S'(t) at both its inputs. The indication N' of the reversible counter evolves as illustrated at the bottom of the page in Figure 4 and it can be seen that this faithfully reproduces the evolution defined by the trajectory 16. This apparatus further comprises means for updating the counter, at each rotation in the case of a spiral track. In this case, the form of the track is

taken into account by increasing the algebraic value of the contents of the reversible counter, at a frequency double the rotation frequency of the disk.

Returning to the compartmenting of the disk as illustrated in Figure 1, the technique of sampling and the pre-engraved pattern referred to may be introduced by imagining that the reference surface 2 is a smooth surface that reflects light uniformly, as described in application EP-A-89 263. It may then be imagined that the track is adequately materialised by the presence in the immediate vicinity of the radii 6 of groups of pre-engraved patterns which are the only ones to interact with the scanning spot 7.

Accepting that access is managed from the pre-engraving of the disk which is essentially present along the radii 6, the extent to which the trajectory 16 is known by the access apparatus will be limited to the points where the latter encounters the radii 6. These points of encounter which are marked in Figure 1 by squares mostly fall between the axes 3. Furthermore, between two of these successive points the spot may have crossed track elements without their presence being revealed. The concept of the sampled reading of a data carrier does not require the presence of a groove or the recognition of segments reserved for the writing of data. It is therefore perfectly conceivable that, before any writing, the blank disk has only pre-engraved patterns, but in all cases, it must be possible for the management of access by sampling to do without optical interactions with significant data to be stored and any continuous grooves which are subjacent to them.

The implementation of a sampled-access process according to the present invention assumes that synchronism between a clock signal and the periodic encountering of a first family of N equi-angular radii has been obtained with sufficient accuracy. This synchronism is obtained in a known manner by means of synchronisation flags pertaining to the pre-engraving of the disk.

Focussing of the optical radiation on the disk's reference surface is also achieved by known methods which it is superfluous to describe.

In view of the transient nature of the sampling along the P radii of a sub-family assigned to the management of sampled access, it is necessary for the electrical signals photodetected to be significant in whatever position the scanning spot encounters the radii of this sub-family. In practice, this condition implies that the specific patterns assigned to sampled access interact with the scanning spot in order to generate a detected signal whose value is defined, that is, distinct from that obtained when the scanning spot encounters an entirely smooth portion of the reference surface. It is clear that when the extent of a pattern exceeds that of the scanning spot, only the marginal interaction can establish this distinction, unless the contrast of the pattern in relation to its surroundings is due to a cause other than the alteration of the wave width of the radiation to be detected. An abnormally large inter-pattern space could provide an indefinite value for the instantaneous position of the scanning spot.

In the context of sampled access, it is appropriate to provide on the disk's reference surface means of radial graduation in relation to the arrangement of axes 3, and their elements can occupy a group of radii sampled successively. This constitutes an advantage of the method, since in the case of the continuous-groove solution the only basis that can be used is a single, very rudimentary graduation distribution.

As concerns the notion of graduation, two levels of integration can be envisaged. The most elementary level consists of reproducing a periodic distribution along a radius of the disk and adding to it, along a radius in the close vicinity, a periodic distribution of the same type, but offset by square-law to give an indication of the direction of displacement along this double graduation. A single distribution can suffice if the second distribution is derived by photodetector means which interpret in a differential manner the radiation to be detected. The fact of

choosing neighbouring radii to sample the functions by square-law comes from the fact that when the trajectory does not intersect these radii at right angles a slight radial offset is introduced which tends to distort the square-law relationship.

A more highly developed level of graduation consists of providing a non-periodic distribution assigning an absolute value to each position along the radius. In this case, this distribution is expressed by an encoded address which takes up more space but can be read less frequently during the scanning of a turn. These two levels of integration can coexist as will be seen in the rest of the description.

In Figure 5, an isometric view is shown of a fragment of the reference surface 2 of the disk in Figure 1 in relation to a system of axes x, y, ρ. The radius ρ and the axis x define the reference surface whilst the axis y is parallel to the disk's axis of rotation 4. Areas of data 17 are drawn with a dotted outline, centred on the axes 3 of several adjacent track elements. These areas 17 which extend from the radius ρ in the scanning direction x are preceded by pre-engraved patterns 18 which form two radial alignments following the sampling radii ρ_a and ρ_b. The radial arrangement of patterns 18 centred on the radius ρ_a is such that analysing it by the scanning spot 7 generates an electrical reading signal, having the course of the cosine curve 19 traced in the plane (y,ρ). The similar radial arrangement, offset by square-law, of the patterns 18 centred on the radius ρ_b is such that analysing it by the scanning spot 7 generates an electrical reading signal, having the course of the cosine curve 20 traced in the plane (x,ρ). These two circular functions 19 and 20 can represent components of a vector having for projection OM in the plane (x,y). This vector represents in an exhaustive manner the progress of the scanning spot along the radius ρ and describes with its extremity a spiral 21 which symbolises a graduation comparable to that given by the rotation of a screw. This illustration of the possibilities offered by the patterns 18 for transcribing the displacement of the spot by rotations of the vector OM clearly demonstrates the fact that

knowing the angle φ of the vector OM defined over the interval 0 - 360^0 does not provide an absolute indication of the position Φ of which φ is merely the fractional part. The patterns 18 in Figure 5 definitely allow the reversible counting of the tracks on condition that signal sampling is carried out at intervals of time sufficient close together to restore the continuity of the forward movement. The advantage of the configuration illustrated in Figure 5 is that it occupies little space along the track elements since it is sufficient to carry out two samples step by step in order to acquire the information relating to the track crossings. The disadvantage of this solution is setting up a process for resolving ambiguities, since between two successive samplings, the speed of radial translation can be such that the variation in Φ corresponds to more than one turn of the representative vector OM.

A particular advantage of the solution illustrated in Figure 5 is that the patterns 18 can be used to carry out sampled access, but also to monitor a track element. As shown in Figure 5, the patterns 18 centred on the radius ρ_a have a positive offset relative to the axes 3, whilst the patterns 18 centred on the radius ρ_b have a negative offset of the same amplitude. It can be seen that if this arrangement is adopted with its offset equal to one-eighth of the pitch p of the track elements, the samples taken along the radii ρ_a and ρ_b are precisely those that make it possible to determine the deviation between the centre of the scanning spot 7 and the axis 3 of the track element during scanning.

A configuration of pre-engraved patterns suited to this double use of the patterns 18 is illustrated in Figure 6.

Here are shown the axes 3 of two track elements as well as the data storage areas 17. The pre-engraving is hatched in Figure 6 between the boundaries 24 that surround the patterns used to carry out, by sampling, synchronisation, track monitoring and access by reversible counting.

As in Figure 5, the patterns 18 are shown with a length measured in the scanning direction equal to one and a half times the length L chosen as a transcription unit. The centred pattern 23 has the same length as the patterns 18 and, in association with the terminal patterns 22, serves to coordinate the track scanning rate. For this purpose, two particular distances 2.5 L and 6.5 L are adopted, so that the transitions that characterise the scanning of the patterns 22 and 23 are identified relative to all the other transitions that the reading signal can contain. Sampling along the radii ρ_a and ρ_b is linked to a clock signal whose coordination depends on the suitable scanning of the patterns 22 and 23 both during the access phase and during the following phase where the spot is once again constrained to follow the track element to which there is access.

The general diagram of a scanning apparatus with sampled access is illustrated in Figure 7. The electrical signal 5 resulting from scanning the disk 1 with the light spot 7 is furnished by the optical head 30 with an identification circuit 28 that recognises the arrangement of the patterns 22 and 23 and emits a clock synchronising signal 29. The signal S is also applied to a sampling circuit 25 which, controlled by the clock 29, isolates the data D inscribed in the data areas 17 as well as a specific address A for the track element currently being scanned.

The signal S also feeds another sampling circuit 26, also controlled by the clock 29, in order to take samples a and b which correspond to encounters with the radii ρ_a and ρ_b. These samples are in digital form at the input to a calculation circuit 32 which manages access and in analogue form at the input to a comparator circuit with memory 31 which, in a known manner, determines the radial offset of the scanning spot 7 relative to the track element 3. An apparatus for deflecting the scanning spot 27 is integrated into the optical head 30 to complete access by track hopping as illustrated in Figure 2. This track hopping is controlled by a circuit 33 which receives from the calculator 32 the track-hopping orders necessary for the final approach to the reference value C applied to the calculator 32. When the

scanning spot comes to read the track element designated by the reference C, the calculator emits a signal ST indicating the state of completion of the access procedure. Outside the access periods, the radial offset signal produced by the circuit 31 is transmitted by two switching units K_1 and K_2 to the deflector circuit 27 such that the reading spot 7 is constrained to follow the track. The temporary opening of the switching unit K_2 takes place each time that track-hopping is commanded by the circuit 33, hence the dotted connection 36 linking these two units. During the coarse access phase, the switching unit K_1 connects the deflector 27 to a control value 0 which fixes it in neutral position. This neutralisation is illustrated in Figure 7 by the dotted connection 37. The coarse access phase is managed by the calculator circuit 32 which receives the digitised samples a, b and which, according to the starting address A and the arrival reference C, will define the commands to be applied to the access motor 34. Through the connection 35 in a dot-and-dash line, the latter carries out the displacement of the optical head, in order to cross the track elements separating the starting point from the arrival point. For the purposes of information, it could be considered that a disk 300 mm in diameter carrying a spiral track having 30,000 turns at a pitch of 1.6 m and rotation at 1,200 rpm will be sampled at the frequency of 50 kHz, which represents 2,500 pairs of patterns 18 per disk rotation. Therefore with the arrangement of pre-engraved patterns illustrated in Figure 6 and taking a mean value of L equal to one micrometre, the space taken up on one rotation by the pre-engraving does not exceed 23.75 millimetres, which is little in view of the length of the turn.

Now that an overall view has been given concerning a first embodiment of the invention, further details should be given of the operation of the calculator 32 as concerns the processing of samples a and b.

The illustration in Figure 5 demonstrates that in general, during access, there is a function $\Phi(t)$ that represents the absolute position of a mobile as a function of time. This function is synthesised more or less perfectly by a limited number of pre-

engraved patterns and it represents an evolution subject to the laws of mechanics as illustrated in Figure 2.

In the diagram in Figure 8, it can be seen that the distribution $\Phi(t)$ represented by a solid line curve is sampled at instants t_2, t_1 and t_0, it being possible to choose without disadvantage the period τ as a unit of time. This distribution gives the measurement of an angle when the interpretation of Figure 5 is adopted, wherein the rotation of the vector OM has been associated with the radial displacement of the reading head. If Φ_2 and Φ_1 are the absolute values for the rotation of the vector at the sampling instants t_2 and t_1 and if knowledge of these values has been acquired from the initial access conditions and by step-by-step digital processing, it may be seen that the speed V of displacement between these instants is quite simply expressed by the difference between Φ_1 and Φ_2.

At the instant $t - t_0$ of the last sampling the problem raised is to determine Φ_0 in the knowledge that what is available is $\varphi_0 = \text{MOD}[\Phi_0 . 2\pi]$. The symbol MOD represents the modulo function which supplies the remainder φ_0 from dividing Φ_0 by 2π. It may be seen in Figure 8 that the speed at the instant t_0 is still V if the linear extrapolation is valid, and thus if the mobile has not undergone acceleration γ, but since this acceleration is worth exactly $\gamma = \Delta V$, the value at the instant t_0 is indeed Φ_0 and not the value X linearly extrapolated.

The following relationships are therefore available:

$$V = \Phi_1 - \Phi_2 \; ; \; X = \Phi_1 + V; \; \Delta V = \Phi_0 - X$$

hence it can be inferred that $\Phi_0 = X + \Delta V$

Noting that $M_t(u) = \text{MOD}\,[u + \pi, 2\pi] - \pi$ and imposing the condition: $-\pi < \Delta V < +\pi$, it may be seen that:

$$\Delta V = M_t(\varphi_0 - X)$$

hence it follows that:

$$\Phi_0 = X + M_t(\varphi_0 - X)$$

This relationship shows that with the hypothesis formulated, that is, by validating a test and for accelerations encountered in practice, Φ_0 can easily be updated with the sample φ_0 and the linear extrapolation that gives the value X.

The preceding mathematical study shows that sampled access based on the synthesis of a periodic function can supply the absolute position of a mobile by removing the ambiguity of the modulo function thanks to a step-by-step exploitation of the remainders from dividing by 2π.

Although the invention is not limited to the exploitation of radial functions of a purely periodic nature and with regular sampling, a more concrete illustration has been given in Figure 9 of this type of functioning, with an attempt to come as close as possible to the presentation in Figure 4.

It has been assumed, in accordance with Figure 5, that by using appropriate dimensioning and radial spacing, the patterns 18 in Figure 6 generate circular functions when they are scanned along the radii ρ_a and ρ_b by a reading spot with a diameter suited to the radial width of the patterns and the interstices between patterns. Such a variation is easy to obtain in practice with an accuracy of a few per cent. Trigonometrical calculation based on the arc tg function leads to a sampled distribution of the asymmetric saw-tooth type.

In Figure 9, an illustration has been given of a portion of surface Σ in a system of axes (ρ, t). This portion is divided up by radii ρ_1, ρ_2 and ρ_3 along which samplings are carried out of a saw-tooth function $F(\rho)$ the positive values φ_1, φ_2, φ_3 of which are samples.

The trajectory T_1 illustrates access at low speed. When it is followed towards the right, it can be seen that the scanning speed V_{12} is obtained by subtracting the preceding sample φ_1 from the sample φ_2 retrieved last. This subtraction is illustrated in the figure by a horizontal translation of the vector φ_2 over the

line of action of the vector φ_1. As long as the trajectory does not intersect any track axis, it is sufficient to apply the relationship $V_{ij} = \varphi_j = \varphi_i$. If the trajectory is followed in the inverse direction, the most recent sample is φ_i and the speed V_{21} is obtained by applying the relationship $V_{ji} = \varphi_i - \varphi_j$ which gives a negative result thus indicating that the movement is towards the left. In respecting the sequencing in time of the samples, these relationships are equivalent and would be applicable even in the case of track crossing if the function $F(\rho)$ were a simple oblique straight line in the axis system $\rho, F(\rho)$. The periodic nature of the function $F(\rho)$ makes it more arduous to calculate the speed.

To illustrate this fact, another trajectory T_2 has been shown in the figure which, when it is described from left to right, entails two track crossings and then a single crossing.

Once again, three sampled values φ_1, φ_2 and φ_3 have been considered, but this time they are no longer located on the same tooth of the function $F(\rho)$. The correct determination of the speeds V_{12} and V_{21} will be based on the extension by the dotted line AB of the slope that contains φ_1. By substituting for the sample φ_2 the value corresponding to the measurement of BC, the speeds V_{12} or V_{21} can be constructed diagrammatically from the straight line BD and the oblique CE. The problem raised is to determine BC, knowing φ_2. If the function $F(\rho)$ has as its range of variation the interval $(0, 2\pi)$, it can be seen that BC is equal to φ_2 increased by $2\,k\pi$ where $k = +2$ signifies that two track crossings have taken place between the sampling φ_1 and the sampling φ_2.

Continuing to examine Figure 9, it can be seen that determining the speeds V_{23} and V_{32} from the samples φ_2 and φ_3 implies another value for k since a single track crossing has taken place between these two samplings.

Since sampled access by definition ignores events which may have arisen between two samplings, a variable k has to be synthesised whose whole values -n, ... -2, -1, 0, 1, 2, ... +n, validated

according to an appropriate criterion, represent the track crossings in algebraic form. The sign of the variable k indicates the direction of crossing, such that a variable N' for the counting of track crossings can be updated each time a new sampling is made by means of the operation: $N' = N' + k$.

The validation criterion for the variable k is linked to the aptitude for a change in the speed of describing a trajectory on the disk. This aptitude has its extent limited in practice by the acceleration that the access motor is capable of communicating to the optical head. The eccentricity that characterises the rotation of the disk produces an oscillation in trajectory, but this is only a secondary effect which should not be taken into account when drawing the trajectory.

In Figure 9, the trajectory T_2 is a broken line illustrating a radial progression GC of duration τ, distinct from the radial progression CH of the same duration which precedes it or follows it. For displacement of the optical head from left to right, it can be said that the latter has undergone a deceleration $\gamma = HJ$, J being the position that would be reached on the radius ρ_3 if deceleration did not take place.

By way of a non-limitative embodiment example of the invention, it will be assumed that the trajectory T_2 is described from right to left and that the criterion for validating the variable k rests on comparing the estimates of speed carried out with the values φ_3 and φ_2 and then with the values φ_1 and φ_2. Figure 9 shows that determining the speed V_{32} is based on a knowledge of φ_3 and φ_2, as well as the value $k = -1$ which has been validated before. To place this determination in relationship with the one that supplies the speed V_{21}, the length GK that translates the previously calculated value V_{23}, that is, $\varphi_2 - \varphi_3 - 2\pi$, has been carried over to the vertical line carrying the vector V_{21}.

Around the point K, a framing interval for terminals L and M has been symbolised, such as $GL = V_{32} + \pi\tau$ and $GM = V_{32} - \pi\tau$, $\pi\tau$ being half the height of the saw-tooth $F(\rho)$. The extremity E of the

speed vector V_{21}, determined by assigning the value -2 to the variable k, falls within the interval LM, which constitutes its validation test. On the other hand, the values for V_{21} arising from φ_2, φ_1 and the choice of another value for k fall outside the interval LM. In Figure 9, the points R and S obtained by graphic construction offset by +- 2π are characteristic of speed calculations carried out respectively with the values k = -1 and k = -3. It can be seen therefore that the non-performance of the test indicates that the variable k has to be modified when moving from calculating V_{32} to calculating V_{21}. The magnitude and direction of the modification in the variable k are a function of the trajectory and direction of movement, but by starting from the previously validated value, it can be incremented unit by unit until the test is validated. Choosing the interval $\pm \pi$ means that a single value for k can be validated. This having been said, the hypothesis on which correct determination of k is based is the moderated variation of speed. This aspect is illustrated in Figure 9 by a dotted modification of the trajectory T_2 and by a graphic construction highlighting the re-centring of the interval LM relative to the point E. Thanks to this diagram, it can be seen that KE is the acceleration and that it must not exceed the value π in order for the value k validated by the test to correspond to reality.

In view of the above, the process of determining the variable k can be represented by the flow chart in Figure 10 in which the variables are:

- the indication N' of a track crossing counter,
- the speed V,
- the quantum of crossings: k,
- the deviation of speed Δv,
- the input values a_i, b_i,
- the angle φ,
- the angle φ_{-1} corresponding to the previous sampling.

This flow chart is a module intended to be integrated into a more general, although conventional, flow chart which serves to manage access as from a reference C by controlling one or more motors intended to make the reading spot 7 coincide with a track element 3 covered by this reference. The variables have been reproduced at the bottom of Figure 10. The flow chart comprises the introduction of the digitised samples a_i and b_i which are taken at regular intervals τ. These values are assigned to the variables a and b used to update the variable φ thanks to a table of correspondence or trigonometrical calculation. The variables φ_{-1} and φ as well as the variable k validated during a previous calculation serve to determine the variation in speed V by which the first test $-\pi < \Delta V < +\pi$ can be carried out. In the case of validation, this test triggers the updating of the variables V, N' and φ_{-1}. Updating having been carried out, one returns to the general access flow chart. In the case of the test not being validated, it is accepted that the variable k must be incremented or decremented by one unit, the choice being determined by a second test $\Delta V > 0$ which leads to two loops which can operate recursively until validation of the first test. It goes without saying that this flow chart can be adapted to take into account a larger number of samples in order to guard against erroneous readings.

The test is characterised by fixed boundaries $+\pi$ and $-\pi$, but action could be taken to displace these boundaries as a function of the accelerations encountered during access. Updating the speed V is optional, although it is useful to know it, as concerns the stability of radial control or the determination of a radial deviation.

This flow chart does not mention initialisation operations, since they are managed by the general flow chart. They consist of assigning a zero value to the variables V and k when access is initiated. The variable N' can be assigned the value N_0 which defines the starting position on opening the track monitoring loop.

In the above explanation, it has been assumed that the distributions sampled along the radii of the disk are respectively sinusoidal and cosinusoidal. In this case, the values for the function F( ) are deducted from the pairs of samples (a_i, b_i) by the operation φ - arc tg b/a. It goes without saying that the radial arrangement of the patterns assigned to the radial identification of the scanning spot can generate periodic distributions distinct from a circular function, which does not prevent the obtaining of a saw-tooth function $F(\rho)$, if an appropriate correspondence rule, defined for example by means of a table, is adopted to determine the values.

Implementing a stepwise periodic function $F(\rho)$ also comes within the context of the present invention. Figure 11 gives, as a non-limitative example, an example of a reversible counting process based on the materialisation of a stepwise identification function.

This figure is related to Figure 9 and shows a portion of disk Σ with three radii ρ_1, ρ_2 and ρ_3 along which are arranged pre-engraved patterns.

A set of equidistant track elements is traced perpendicular to the radii ρ_1, ρ_2 and ρ_3. These track elements are grouped in packets of 16 which have been made more visible in Figure 11 by tracing the four end elements with a solid line and the eight central elements with a dotted line. Thus, it can be seen that a packet with pitch P is made up of four sets of four elements that are discernible one from the other by combinations of patterns that extend on either side of the radii ρ_1, ρ_2 and ρ_3. The patterns used are for example centred on the track elements and arranged along each radius ρ_1, ρ_2 and ρ_3 such that, starting from the left, four upper patterns identifying the first set of four elements are encountered, then a total absence of patterns indicating the second set of four elements, then four lower patterns identifying the third set of four elements and finally four upper patterns and four lower patterns for encoding the fourth set of four elements. A string of patterns must have dimensions

such that the corresponding reading signal has levels lower than the level achieved during the scanning of a smooth area.

By isolating this last level with a threshold circuit, scanning along the radius ρ_1 of the upper row of patterns produces the waveform $b(\rho)$ illustrated in the figure, whilst scanning the lower row of patterns produces the waveform $a(\rho)$. The waveform $F(\rho)$ takes on the appearance represented in Figure 11, when the waveforms $a(\rho)$ and $b(\rho)$ are deducted from it in accordance with the table below:

a	b	F
1	0	270^o
1	1	180^o
0	1	90^o
0	0	0^o

The values for F have been chosen to represent the notion of a quarter turn expressed in degrees as a set of four tracks is crossed.

In Figure 11, a trajectory T has been shown, travelled from right to left, which encounters in succession the radii ρ_3, ρ_2 and ρ_1 at the sampling instants t_3, t_2 and t_1. Samples φ_3 and φ_2 are therefore available in order to assign a value V_{32} to the speed of crossing packets of track elements.

The determination method does not differ in essence from the method described previously and, in particular, it will be noted that the boundary of a packet (dot-and-dash vertical line) has been crossed between the instants t_3 and t_2, this being linked to the value of the variable k which is +1 in this case. This is illustrated by the dotted extension of the stepwise function. With the aid of the samples φ_2 and φ_1, a further determination of speed V_{21} is made, to which the value k = 0 corresponds, which indicates that scanning between the instants t_2 and t_1 is internal to the packet without encountering a boundary.

Although Figure 11 does not show it, the patterns can have a length greater than the dimensions of the reading spot in the direction of the track elements.

When such an arrangement is adopted, there may be some difficulty in accurately recognising the pattern in its environment.

In this connection, it is appropriate to specify that the sampling of a pattern generally requires a sampling window wider or narrower than the portion of signal that represents the scanning of the pattern by the reading spot. When the window is narrow, it is assumed that the level sampled is distinct from the level representing the scanning of an area with no patterns.

If, on the other hand, the window is wide relative to the pattern, the signal sampled will in any case contain a pair of transitory variations in level which mark the spot's encounter with the leading and trailing edges of the pattern. In noting these two variations in the window, it may be concluded that a pattern is present, even if the level transmitted in the middle of the window was equal to that characterising a clear area of the disk. To recognise the presence of two successive patterns, it is appropriate to provide two staggered sampling windows which pick up the complete interaction with each pattern by framing it. When the two patterns follow one another without a sufficient interval between them, only the outer edges are recognised and the variations in level normally assigned to a pattern are not simultaneously present within any one window, which leads to the conclusion that the two patterns can coexist. It is therefore possible to separate the four cases that can occur in order to create radial graduation.

In the embodiment examples that have been described, two alignments of patterns encountered successively by the scanning spot 7 have been used with the aim of obtaining two periodic radial square-law distributions that define a graduation.

Since these distributions are exploited by sampling, one is led to use a recursive method to define access in an absolute manner. Updating a digital variable during the course of access is equivalent to an operation for counting track crossings.

It is possible to depart from this type of functioning by reducing the number of distributions to be provided around each radius which amounts, for instance, to reading a single distribution with a central-cell photodetector system and a photodetector system with two half-cells in the optical head. In this case, the patterns creating the periodic single distribution give rise to two square-law signals and they can be centred over the track axes 3.

In order to take up little room in the direction of scanning the track, it has been seen that radial graduation can bring into play the width of the patterns and their spacing in order to generate samples capable of taking numerous different values from one track axis to the next. If there are anomalies of form in the patterns, it is judicious to provide an algorithm for processing the samples which extends over three or four successive retrievals, so that extrapolation can take place while discarding the abnormal values picked up.

The example in Figure 11 shows that, without taking up more space, reversible counting in packets makes it possible to adopt two-element encoding of the levels of a stepwise periodic function. This solution is less vulnerable to pattern defects and would even mean that the strings of patterns could be replaced by radial bands of any width in the direction of track scanning.

By consenting to consume more space and therefore take more samples around each specific radius, it is possible to give more detail to the graduations and ultimately simplify the sampled-access process by adopting the concept of reading absolute addresses in fly mode.

Figure 12 shows a stepwise graduation function $F(\rho)$. The solid line curve 40 defines a fine graduation whereas the dotted curve 41 defines another graduation, four times less fine. It can be seen that the fine graduation 40 adds three levels to each step of the coarser graduation, which brings out a three-step periodic differential graduation which closely resembles that in Figure 11. It is noted that the curves 40 and 41 represent regularly increasing functions allowing the absolute reading of the radial position ρ on the disk.

In the lower part of Figure 12, a portion of the reference surface 2 of the disk 1 is shown. The vertical lines represent the axes of the inter-track areas. Two sampling radii ρ_1 and ρ_2 are traced horizontally at a distance equivalent in time to a sampling period τ.

To materialise the radial graduation on the disk, pre-engraved patterns 42 are used, distributed over equi-distant radii grouped around the radii ρ_1 and ρ_2. In Figure 12, five of these radii are defined by the lines of patterns 42 parallel to the radii ρ_1 and ρ_2.

These lines are occupied by the patterns 42 through a particular code which has been shown in the middle part of Figure 12. In each column paired with a track, this code comprises a five-bit address. This address is materialised in the bottom of Figure 12 where an absent pattern 42 represents the binary value "0" and a present pattern 42, the binary value "1". Each complete five-bit address denotes a value of the stepwise function 40. The portion 43 framed with a dotted line contains the parts of address formed of the three most significant bits that define the values of the stepwise function 41. The two low-order bits form parts of address which represent the values of the periodic function by which the curve 41 can be converted into the curve 40.

The encoding illustrated in Figure 12 is specially chosen so that the addresses contained in two contiguous columns differ from one another only by one bit inversion. More specifically, this is a

reflected binary code that can be constructed by inscribing in the upper row a "01" module which is repeated from left to right while being permuting on each repetition. In the next row, the same process is used starting from a "0011" module and so on. To determine the value of $F(\rho)$ starting from an address with n + 1 bits respectively marked a_n, a_{n-1}, ..., a_j, a_2, a_1, a_0, it is appropriate to use the relationship:

$$F(\ ) = \sum_{k=n}^{k=0} 2^k \cdot \sum_{j=n}^{j=k} a_j$$

This relationship is illustrated in Figure 13 in the case of a five-bit address. The binary adders 44 each receive a bit value contained in the address 46 and add it to the sum of the values of the most significant bits. The results that appear at the various outputs of the adders 44 are assigned the weights indicated in the Figure and are added by the circuit 45 that furnishes the appropriate value of $F(\rho)$.

One of the advantages of the solution illustrated in Figure 12 lies in the fact that passing from one track element to the next modifies only one bit in the complete address. By referring to the trajectory T illustrated in Figure 12, it can be seen that the scanning spot 7 encounters the sampling radius ρ_1 straddling two track elements 17. The address reading resulting from this scanning phase is represented by the box 46 on the diagram $F(\rho),\rho$, but low-order bits are not legible in a stable manner, since a slight offset in trajectory is sufficient for one of the bits to be interpreted differently. This sampling could just as well denote the box 47 or the box 48 which has only a slight effect on the value of $F(\rho)$. Now, precisely, it has been seen that low-order bits generate a fine periodic graduation for which it has been seen that by processing of the samples an absolute indication can be given as to access. It may also be noted in Figure 12 that the part of the address comprising high-order bits is stable for small shifts in trajectory. For this part of the address, the notion of displacement is acquired in a coarser man-

ner since it represents a monotonic stepwise function. Similar conclusions may be reached by considering the encounter of the trajectory T with the sampling radius ρ_2.

The above explanation shows that by assigning to each track element an address encoded in reflected binary, absolute stepwise graduations are made which are all the finer when fewer low-order bits in these addresses have been neglected. With the aid of the same addresses, it may also be considered that periodic graduations are available which are all the more detailed over a greater period when fewer high-order bits have been neglected. These two approaches can be used in all proportions according to the evolution of the access characteristics. The use of pre-engraved patterns defining absolute addressing of the track elements uses up more space on the disk.

A first option consists of providing over a complete revolution of the disk a limited number of sampling radii, each comprising a complete 15-bit address sampled 250 times per revolution. Complete reading of this address is possible when the access speed is moderate, that is, at the beginning and end of access. Partial reading of the address during access can serve to determine the operating conditions of the access motor.

A second option consists of arranging, on the track element, part of the complete address, at intervals that are closer than the remaining part of the address, which leads to the provision of at least two sampling rates. It is for example possible to adopt a denser arrangement of the partial addresses formed of low-order bits and thus manage one graduation per periodic function applicable throughout access; the partial addresses formed of high-order bits are arranged less densely in order to finalise access through full knowledge of the address.

The inverse solution can also be envisaged when it is a question of piloting access with stable, frequent reading of the high-order bits of the full address, a final reading becoming asympto-

tically complete as a consequence of the reduction in crossing speed.

In the last analysis, there is no fundamental difference between graduation based on square-law periodic functions and graduation based on the presence of absolute addresses in reflected binary code.

In the above description, it has been seen that synthesising a radial graduation could be based on the radial dimensions of the specific patterns of access without attaching any particular importance to their extension along the track elements. An absolute address can be put into a sequence of bit cells whose content is retrieved more or less completely by the scanning carried out by the reading spot.

One advantage - and a not insignificant one - of the sampling technique is the possibility of differentiating patterns by their length along the track element. A radial graduation can therefore be based on this parameter, which is not possible in the case of disks with continuous grooves. This technique has already found application in implementing synchronisation patterns as illustrated in Figure 6 where non-whole distances 2.5 L and 6.5 L have been defined.

The adoption of encoding by duration of the access patterns also comes within the context of the present invention.

In Figure 14, a system of axes ρ,t has been shown where t represents the elapsed time or - which comes to the same thing - the distance travelled along the track axes 3. In this system of axes, adjacent track elements have been represented in a region containing pre-engraved patterns 18. On the left, a line F_G forms the envelope of the leading edges of the patterns 18 and, on the right, another line F_D forms the envelope of the trailing edges of the patterns 18. The radius ρ represents a time reference for patterns to be scanned by the reading spot 7; the lines F_G and F_D can be considered representative of functions serving

to establish a radial graduation. The interval T_G does not vary from one track element to the next, since the line F_G is a radius. On the other hand, the interval T_D varies linearly, since the line F_D forms a constant angle with the disk radius.

When the scanning spot 7 takes the trajectory T, the optical interaction gives rise to a photodetected signal S(t) illustrated by the curve 50 which has a depressed zone corresponding to the encounter with the patterns 18.

The level of the signal S(t) outside this zone is maximum since the scanning spot illuminates a smooth part of the reference surface 2 of the disk 1. The base of the depression 50 is located sufficiently far down beneath this level to fall below the detection threshold materialised by the line 51. It is therefore possible to detect the instant t_G when the signal S(t) falls below the threshold 51 and the instant t_D when it rises back above the threshold. By triggering a counter at the reference instant defined by the radius ρ, a stepwise distribution 52 is materialised which represents an indication C by the counter as a function of time. It is therefore possible to take indications from the counter at the instants t_G and t_D, that is, samples C_G and C_D are therefore available, corresponding to the encounters of the spot 7 with the lines F_G and F_D. It may be seen that it is possible to play on the position and length of the patterns 18 in order to generate functions by which graduation of access can be ensured.

The precision with which the samples are obtained depends on the resolution of the counter and the slightly fluctuating encounter of the patterns 18.

This fluctuation is illustrated in Figure 15 which represents in a system of axes x,ρ the positions of the scanning spot 7 when the signal S(t) starts or finishes subsiding. The line 53 is the geometric location of the centre of the spot 7 and it can be seen that in the case of radially isolated patterns 18 it fluctuates slightly, which entails some inaccuracy in evaluating the times t_G and t_D. If the patterns 18 are merged into one as illustrated

on the right in Figure 15, the line 53 does not fluctuate. In this latter case, the signal S(t) in Figure 14 comprises two depressions illustrated by the dotted curve 55. In detecting these transitions, precise determination of the instants t_G and t_D is obtained. The edges of the plateau of the curve 55 correspond in Figure 15 to the line 54 which is the image of the line 53 relative to the edge 56 of the pattern 18.

As concerns the taking of samples C_G and C_D, reference can be made to the diagram in Figure 16 which uses certain elements from Figure 7. The optical head 30 furnishes the reading signal S(t) to the circuit 28 which identifies the synchronisation patterns and serves to reset the clock 29.

The clock 29 delivers a sampling pulse of sufficient duration to frame the band of time corresponding to the scanning of the access patterns 18 in Figure 14. This pulse defines a window and controls the sampling circuit 57 which isolates from the signal S(t) the portion containing the interaction with the access patterns. This portion is transmitted to the threshold circuit 59 which detects the instants t_C and t_D while emitting selection pulses applied to the sampling circuit 60.

The circuit 60 samples the indications C from a counter 58 which receives from the circuit 29 clock pulses and a reset pulse which coincides with the scanning by the light spot 7 of the reference radius ρ in Figure 14.

The exploitation of the samples C_G and C_D does not differ from what has been envisaged above. It may be imagined that C_G and C_D are samples belonging to two square-law periodic functions. It may also be considered that C_G is a sample arising from a stepwise function and C_D a sample arising from a saw-tooth function so as to enumerate a group G of packets P of track elements by repeated addressing in which C_G and C_D are partial addresses.

Figure 17 gives an example of pre-engraving ensuring radial graduation for access by means of specific patterns 18 with non-uniform positions and lengths.

In Figure 17, two successive radii ρ_1 and ρ_2 are shown but their real spacing is not respected since the zone illustrated has been interrupted while admitting that the interruption contains data areas. Radially, the disk is compartmented into groups G of 16 track elements with axes 3. Within a group G, the track elements are grouped in packets P′ of four. It may be seen in Figure 17 that the patterns 18 specific to access are arranged in areas 61 with a trapezoidal outline. The left edge of each trapezoidal outline is oriented along a radius of the disk so as to assign to each packet P′ of four track elements a value T_G representing the offset of the left edge relative to the reference radius 62. The right edge of each trapezoidal outline is inclined relative to the radii of the disk, so as to assign to each track element of a packet a value T_D representing an offset of the right edge relative to the radius 63. This arrangement of patterns creates a graduation by two stepwise functions, one with a period 4μ, the other with a period 16μ where μ represents the pitch of the track elements. It may be seen in Figure 17 that the patterns 18 specific to access are associated with synchronisation patterns 66 and 67 which define intervals T_A and T_B which ensure their identification in the stream of patterns present on the axes 3. The edges of the pattern 66 are aligned over the reference radii 62 and 63, so as to define precisely the instants of encounter with the scanning spot even when it follows the trajectory T that is inclined relative to the axes 3. Figure 17 also shows that pre-engraving can comprise patterns 68 and 69 offset relative to the axes 3 of the track elements, in order to ensure the track monitoring function by sampling the area comprised between the radii 64 and 65.

In the example in Figure 17, the left edge of the trapezoidal outlines 61 serves as a coarse graduation whereas the right edge serves as fine graduation. These two graduations are not necessarily to be united in one and the same trapezoidal outline since

they can be provided alternately when patterns 18, framed by differentiated trapezoidal patterns, are arranged along the track elements.

Figure 18 illustrates another variant embodiment of the pre-engraved patterns according to the invention. In Figure 18 a packet P' of track elements 17 has been shown, comprising for example eight elements whose axes 3 are p away from one another. The last element of the previous packet has also been shown at the top of the figure, and the first element of the next packet at the bottom. The packets P' form, for example, groups of eight such that the configuration of pre-engraved patterns has, radially, a period equal to sixty-four pitches p. Areas of data have been shown in dotted lines, framing the central region of Figure 18 where the pre-engraved patterns 18 and 66 appear. The patterns 66 centred on a radius ρ and on the axes 3 have a constant length, such that their edges are aligned along radii. The expression "length" is connected here to the notion of angular cover, since it should not be lost from sight that the axes 3 are in reality curved.

In consideration of this remark, it will be seen that each pattern 66 has been framed by two patterns 18 whose inner edges centred over the axes 3 are aligned over radii 62 and 63. It will be seen in Figure 18 that the leading edge of the central pattern 66 is 2.5 U away from the leading edge of the pattern 18 situated to its right. Similarly the trailing edge of the pattern 66 is 2.5 U away from trailing edge of the pattern 18 placed to its left.

The symbol U denotes a reference length which serves to locate the specific patterns for data storage along the track. It is therefore admitted that scanning the track only provides the inter-distances 2.5 U between homologous edges of patterns for the combination 18-66-18 illustrated in Figure 18. Thus, this combination forms a synchronisation apparatus which has the same properties as that illustrated in Figure 17 by the succession of patterns 66 and 67.

In accordance with the invention, the patterns 18 serve to establish a radial graduation obtained in Figure 18 by modulating the positions of the outer edges of these patterns. This modulation generates envelope lines F_G and F_D as in Figure 14, but in Figure 18 the edges of patterns 18 used for this purpose have a radial offset relative to the track axes 3. This difference, which does not prevent the materialisation of the periodic graduation necessary to the access function, offers the advantage of also fulfilling the track monitoring function and the synchronisation function. To obtain this standard function taken to the extreme, the invention provides for the use of patterns 18 comprising at least one centred portion and one offset portion which, as in the case of Figure 6, comes down to achieving access and track monitoring functions with the same patterns.

In the same line of thought, these functions can be brought together by means of pre-engraved patterns having an offset along their whole length.

Figure 19 illustrates a variant embodiment offering space-saving by distributing the patterns over two areas separated by a data area 17. To demonstrate better the periodic location of the zones occupied by the pre-engraved patterns, the axis 3 of the track element has been folded over twice in a meander. The odd-numbered part-row illustrated at the top of Figure 19 starts with two synchronisation patterns 66 and 67 which, relative to the graduation 101, have two specific semi-whole distances 2.5 U. The patterns 66 and 67 are followed at a suitable distance by an offset pattern 18. The leading and trailing edges of this pattern can occupy four positions represented by four half-circles in dotted lines to the left, and four half-circles in dotted lines to the right. The pattern 18 is therefore an addressing means by which sixteen track elements forming a packet can be distinguished from one another. The even-numbered part-row illustrated at the bottom of Figure 19 also comprises a pattern 18 that can serve for addressing sixteen packets of elements forming a group of 256 track elements. Such a group is repeated periodically within the usable area of the disk. It can be seen in Figure 19

that the patterns 18 have alternately an offset ε_G and an offset ε_D making it possible to determine the eccentricity of the reading spot relative to the axis 3.

The sampling frequency of the pair of patterns assigned to the evaluation of eccentricity is therefore reduced by half relative to that of the synchronisation patterns 66 and 67.

The arrangement illustrated in Figure 20 ensures twice as frequent sampling of the eccentricity of the scanning spot since the two patterns 18 of Figure 19 are united in the interval separating two blocks of data 17. This last configuration is slightly less compact that the previous one, but it allows greater frequency for sampling access monitoring and graduation.

Disks provided with pre-engraved patterns specific to radial graduation of absolute or periodic type can have very varied configurations and more or less frequent sampling as described above. The fact of abandoning the concept of continuity of the track contributes great facility since access to a track becomes a process of the same type as the processes already implemented to provide monitoring, focussing and synchronisation for scanning a disk with a reading spot. Using sufficiently frequent sampling, it has been seen that movements may be determined without the slightest ambiguity and with a perfectly adequate accuracy in practice. The choice of pre-engraved patterns having simple forms does not prevent them being given a great data capacity and it has been seen that this capacity can be acquired while taking up little space on the disk. The creation of pre-engraved patterns specific to access can be both a stage preceding any optical recording on the disk and a subsequent stage implementing their writing. In this case, they differ from user data only by their location on the disk and by the data source that has conditioned them. In these conditions, everything that has preceded the writing on a disk of user data is pre-engraving in the sense of the present invention. Similarly, patterns are specific to access when they are arranged specially with a view to this

result, even when they were assigned to other tasks which did not up to now suggest the appropriate arrangement.

In the above description, reference has been made to a technique for identifying synchronisation patterns based on the implementation of semi-whole distances; however the invention is not in any way limited to this particular case.

Similarly, it has been seen that it can happen that the scanning spot gives the same optical interaction with the pattern when it is totally inside its outline or when it is completely outside the latter. In this case, full sampling of the pattern is substituted by marginal sampling which is easily demarcated from the non-encounter of the pattern by the scanning spot.

* C L M S *

CLAIMS

1. A data carrier in the form of a disk (1) comprising on a reference surface (2) an assembly of adjacent track elements the respective curved axes (3) of which are produced by pre-engraved patterns (18) which alternate along said axes with areas (17) reserved for storing said data; said curved axes having a common centre of rotation (0) from which radii carrying said patterns are derived; a first family of N equi-angularly distributed radii defining, with each of said axes, intersection sites occupied by synchronisation patterns, characterised in that it comprises at least one other family of radii obtained by a predetermined angular displacement of P radii belonging to said first family and provided along its P radii with graduation (21, 40, 41); said graduation being composed of a radial arrangement of specific patterns (18) wherein the repeated optical interactions with a focussed reading spot scanning said reference surface make it possible, during track crossings, to detect the amplitude and sign of a radial displacement of said spot within the range of said assembly; said radial arrangement, when it is encountered by the reading spot, producing a defined marking (φ) of its instantaneous position relative to said graduation.

2. A data carrier according to Claim 1, characterised in that said graduation generates, by radially scanning said arrangement, two periodic functions of the same periodicity but being distinguished by a significant phase shift.

3. A data carrier according to Claim 2, characterised in that said functions are each produced by the radial scanning of a row of said specific patterns.

4. A data carrier according to Claim 2, characterised in that said functions are produced by radially scanning two rows (ρ_a, ρ_b) of said specific patterns (18).

* C L M S *

5. A data carrier according to Claim 4, characterised in that the specific patterns (18) of the first (ρ_a) of said rows have a predetermined offset relative to each of said curved axes (3); the specific patterns (18) of the second (ρ_b) of said rows having an offset equal and of opposite sign to that of the patterns of the first row.

6. A data carrier according to Claim 1, characterised in that said radial arrangement of patterns (42) defines, at the intersection with said axes (3), digital addresses (43) expressing the absolute positions of the latter in reflected binary code.

7. A data carrier according to Claim 6, characterised in that said digital addresses are distinct and equal in number to said axes (3).

8. A data carrier according to Claim 1, characterised in that said track elements are grouped in packets; digital addresses defined by said radial arrangement of patterns (18) at the intersection with said axes (3) being the same within a packet and distinct from one packet to the adjacent packet.

9. A data carrier according to Claim 8, characterised in that the packets (P') form a group (G) and in that several of said groups are arranged radially within the annular area containing said track elements.

10. A data carrier according to Claim 1, characterised in that said radial arrangement of patterns represents a stepwise function (F_G) wherein the successive values are associated with the relative position of the edges of said patterns (18) relative to a reference radius (ρ); said position being measured in the direction of said axes (3).

11. A data carrier according to Claim 10, characterised in that said stepwise function is periodic.

* C L M S *

12. A data carrier according to Claim 10, characterised in that at least one of said edges can occupy several predetermined positions relative to said reference radius.

13. A data carrier according to Claim 10, characterised in that several patterns (18) encountered successively on one of said axes (3) are necessary to define the value of said stepwise function (F_G, F_D) assigned to said axis (3).

14. A data carrier according to any one of Claims 1 to 13, characterised in that said patterns (18) comprise a centred part and an offset part relative to said axes (3).

15. A data carrier according to Claim 6, characterised in that said digital addresses comprise at least two parts (F_G, F_D) expressed respectively by arrangements of patterns (18) which succeed each other along said axes (3).

16. A data carrier according to any one of the previous claims, characterised in that the radii of the second family derived from the first family are equi-angular.

17. A data carrier according to Claim 16, characterised in that said families have the same number of radii.

18. An optical scanning apparatus of the sampled-access type intended for implementing a data carrier (1) according to Claim 1, said apparatus comprising an optical head (8) projecting onto the reference surface (2) a focussed scanning spot (7) which can move along a trajectory (16) crossing said track elements (17, 18) under the control of an access motor (9); said optical head being associated with photodetector means (30) receiving a fraction of the radiation emerging from the portion of surface (2) illuminated by said spot; said apparatus comprising means (10) for controlling said access motor and receiving the destination address of the access to be performed and the electric signals delivered by said photodetector means, characterised in that said control

means comprise sampling means (26) picking up at least one digital value (φ) each time said spot encounters the radii provided with said graduation, which serves to locate said spot radially when its movement successively straddles several track elements; said digital value representing at least the remainder of the division of an absolute magnitude (Φ) characteristic of the radial position of said spot by a number characteristic of said graduation.

19. An optical scanning apparatus according to Claim 18, characterised in that said digital value (φ) merges with said absolute magnitude (Φ); said characteristic number being unity.

20. An optical scanning apparatus according to Claim 18, characterised in that said characteristic number not being unity represents one pitch of said graduation.

21. An optical scanning apparatus according to Claim 20, characterised in that said pitch is that of said track elements.

22. An optical scanning apparatus according to Claim 20, characterised in that said pitch is extended to several adjacent track elements (17).

23. An optical scanning apparatus according to Claim 18, characterised in that said sampling means comprise means for taking one pair of samples (a, b) arising from said electric signals, said sampling control means (29) synchronised from the scanning of said synchronisation patterns, means for digitising the samples of said pair, and means (32) for determining said digital value starting from said pair of samples.

24. An optical scanning apparatus according to Claim 23, characterised in that said digital value is the angle of a vector having for components said pair of samples.

25. An optical scanning apparatus according to Claim 18, characterised in that said sampling means comprise means for picking

up a portion of said electric signals containing transitions which correspond to the encountering of the edges of said specific patterns (18) by said scanning spot (3), sampling control means synchronised from the scanning of said synchronisation patterns, counting means initialised by said control means, and means performing the retrieval of said digital value in coincidence with at least one of said transitions and from the indication given by said counting means.

26. An optical scanning apparatus according to Claim 18, characterised in that several of said transitions supply digital values characteristic of the encounter with the leading and trailing edges of said specific patterns (18).

27. An optical scanning apparatus according to Claim 18, characterised in that said sampling means comprise means (44, 45, 46) for taking samples intended to express said digital value from a pick-up control address, in reflected binary code, synchronised from the scanning of said synchronisation patterns (22, 23).

28. An optical scanning apparatus according to Claim 27, characterised in that said digital value results from the interpretation of at least one part (43) of said address.

29. An optical scanning apparatus according to Claim 27, characterised in that parts of said address are sampled at non-contiguous locations along said axes.

30. An optical scanning apparatus according to Claim 29, characterised in that certain parts are sampled more frequently than others.

31. An optical scanning apparatus according to Claim 18, characterised in that said sampling means comprise means for picking up said digital value based on the scanning spot encountering the edges of said specific patterns; said encounter being likely to take place at sampling instants with predetermined

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offsets relative to the synchronisation pulse produced in response to the scanning of said synchronisation patterns.

32. A scanning apparatus according to any one of Claims 18 to 31, characterised in that it comprises means (32) for processing said digital value (φ) by which, by linear extrapolation and considering at least one digital value previously sampled, a new value for said absolute magnitude (Φ) can be validated, its previous value being known.

33. A scanning apparatus according to any one of Claims 18 to 32, characterised in that said sampling means provide samples useful for track control (31).

34. A scanning apparatus according to any one of Claims 18 to 33, characterised in that said sampling means provide transitions (T_G) useful for identifying the synchronisation patterns.

35. A process for access in sampled mode to one track of a data carrier (1) according to Claim 1, characterised by the following stages:

- scanning by a focussed light reading spot of the reference surface (2) in a direction transverse to the tracks;
- determination of the amplitude and sign of the radial displacement of the spot within an assembly of adjacent track elements when the spot interacts optically and repeatedly with the graduation scale; and
- determination of the instantaneous position of the spot relative to the graduation scale when the spot scans the radial arrangement, said determinations being used to calculate the position of the spot in order to gain access to a given track.

36. A process according to Claim 35, characterised in that the graduation scale is suitable for generating, during the radial scanning of said arrangement, two periodic functions

with the same period but being distinguished by a significant phase shift.

37. A process according to Claim 36, characterised in that determination of the absolute position of the spot along a radius is obtained by using two known positions in order to determine the speed of displacement of the spot and to extrapolate said absolute position linearly.

38. A process according to Claim 35, characterised in that the graduation scale is a scale giving an absolute address during scanning by the reading head.

39. A process according to Claim 38, characterised in that the complete absolute address is obtained by reading several sites where there are partial addresses.