

"APPARATUS FOR REPRODUCING DIGITALLY CODED INFORMATION RECORDED ON
AN OPTICALLY READABLE DISC"

The invention relates to an apparatus for reproducing digitally coded information, which has been recorded on a disc-shaped record carrier in the form of optically detectable information areas arranged in a concentric ring or spiral track pattern, said areas being unit areas, which apparatus comprises a radiation source, an optical system for projecting a radiation beam onto the track pattern, a detector for detecting the presence of a unit area in said beam, a read circuit for reproducing the recorded digitally coded signal, and a clock-signal generation device for synchronizing the read circuit. A unit area is defined herein as an optically detectable area which when read by a read spot produces a pulse of a duration which is substantially constant for all parts of the record. A unit area may be formed by pulsing a laser beam which is focussed onto a radiation sensitive layer on a record carrier rotating at a constant-angular speed for a duration which is constant for all parts of the record.

The storage of, and apparatus for, the reproduction of digitally coded information on an optically readable disc-shaped record carrier is known from Patent Application No. 2,016,744A, which has been laid open to public inspection. It has been found advantageous, inter alia for reasons of recording technology, to record the information on such a record carrier in the form of unit areas, as disclosed in IEEE Spectrum, August 1979, pages 26-33.

When recording information on such a record carrier and especially during the reproduction of digitally coded information from such a record carrier synchronization is essential. The generation of a clock signal in synchronism with the information contained on the record carrier is not simple. Said Patent Application describes synchronization sectors formed between information sectors on the record carrier which, in addition to the address of the information sector following it, also contain synchronization information. Guaranteeing correct synchronism of a clock signal which is synchronized with the aid of said synchronization signal is intricate and not readily possible inter alia in the case of variations in the drive speed of the disc. In addition it is possible to synchronize a clock signal generator with the aid of the digitally coded signal

being read by recovering the bit frequency therefrom, for example by differentiation of said signal being read. Such methods are electronically complex and present problems such as a poor signal-to-noise ratio or susceptibility to amplitude variations.

5 It is an object of the invention to provide an apparatus of the type mentioned in the preamble in which during reproduction of the recorded digitally coded information a reliable clock signal can be generated in a very simple manner.

To this end the invention provides an apparatus for reproducing
10 digitally coded information, which has been recorded on a disc-shaped record carrier in the form of optically detectable information areas arranged in a concentric ring or spiral track pattern, said areas being unit areas as defined herein which have a centre-to-centre separation L along the track at a reading location, which apparatus
15 comprises a radiation source, an optical system for projecting a radiation beam onto the track pattern at the reading location, means for rotating the record carrier to produce a tangential speed V at the reading location, a detector for detecting the presence of a unit area in said beam, a read circuit for reproducing the recorded digitally
20 coded signal, and a clock-signal generation device for synchronizing the read circuit comprising a band-pass filter, having a centre frequency which is substantially equal to V/L for filtering the detector signal in order to obtain the clock signal, the digital code of the information on the record being chosen to have a zero in its
25 power spectrum at the frequency V/L .

The invention is based on the recognition that when the information is recorded in the form of unit areas the signal being read contains a comparatively strong component having a frequency equal to twice the bit frequency of the recorded digitally coded
30 signal, at which component frequency the average power spectrum of the digitally coded signal itself exhibits a zero point, so that this component frequency can be extracted in a very simple manner by filtering it out of the information signal and using it for the clock generation, for example by means of a phase-locked loop.

35 An embodiment of the invention will be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 schematically represents a plan view of a record carrier in conjunction with which the apparatus in accordance with the invention may be used,

Figure 2 is a cross-section through the record carrier of Figure 1 taken on the line II-II,

Figure 3 on an enlarged scale shows a part of a track of the record carrier of Figure 1,

Figure 4 is a plan view of the track portion shown in Figure 3,

Figure 5 schematically represents the signal obtained when reading a track portion in accordance with Figure 4,

Figure 6 represents the average power spectra of some binary signal codings,

Figure 7 shows the signal waveforms for which the spectra are given in Figure 6, and

Figure 8 schematically represents an apparatus in accordance with the invention.

Figure 1 is a plan view of a possible embodiment of a record carrier which may be used in an apparatus in accordance with the invention. The record carrier body 1 is provided with a spiral track 4. This track 4 is divided into a multitude of sectors 7, for example 128 per revolution. Each sector 7 comprises a data section 9, intended for recording data, and a synchronization section 8.

In order to ensure that the data is recorded in an accurately defined path the track 4 is employed as servo track. For this purpose the information sections 9 of the sectors 7 exhibit an amplitude structure, as is shown in Figure 2. This Figure 2 shows a small part of the cross-section taken on the line II-II' in Figure 1 and thus shows a number of adjacent track portions, specifically data sections, of the servo track 4. The direction of the servo tracks 4 is thus perpendicular to the plane of drawing. Said servo tracks 4, in particular the data sections 9, thus take the form of grooves in the substrate 5. In this way it is possible to make a radiation beam, which is directed at the record carrier in order to record data, accurately coincide with said servo track 4, in other words to control the position of the radiation beam in a radial

direction via a servo system which employs radiation reflected by the record carrier. The measurement of the radial position of the radiation spot on the record carrier may be in accordance with systems similar to those employed in optical record carriers provided with a video signal and as inter alia described in "I.E.E.E. Transactions on consumer electronics", Nov. 1976, page 307.

For the recording of data the record carrier body is provided with a layer of a material 6 which, if exposed to suitable radiation, is subject to an optically detectable change. In principle only the data sections 9 of the sectors need be provided with such a layer. However, for reasons of manufacturing technology it is simpler to provide the entire record carrier surface with such a layer. This layer 6 may for example comprise a thin layer of a metal, such as tellurium. This metal layer can be melted locally by laser radiation of sufficiently high intensity, so that locally this information layer 6 is given a different reflection coefficient, as a result of which the reflected radiation beam is amplitude-modulated in accordance with the recorded information when an information track thus inscribed is scanned by a read beam.

Alternatively, the layer 6 may take the form of a double layer of materials, for example aluminium on iron, which react chemically to incident radiation. At the location where a high-power radiation beam is incident on the disc FeAl_6 is formed, which is a poor reflector. A similar effect is obtained in the case of a double layer of bismuth on tellurium, Bi_2Te_3 being formed.

Since the write radiation spot is made to coincide accurately with said grooved servo track, in particular when a data section is being scanned, the data modulating the write beam is exactly recorded in the data section coinciding with said servo track.

As is apparent from the foregoing, record carriers intended for the user, in which the data sections do not yet contain data, have a groove structure in said data sections within the sectors. Moreover, within each sector such a record carrier has a synchronization section 8 in the form of an optically detectable relief structure, which in this case is constituted by a sequence of recesses alternating

with intermediate areas. The depth of the recesses in this structure of the synchronization section is greater than the depth of the servo track in the data section 9. This depth of the recesses is selected in accordance with general optical rules and, depending on the shape of said recesses in the selected read system, in such way that an optimum read-out of the information represented by the structure is obtained. In the case of a read system in which the radiation beam reflected by the record carrier is detected by a single photo-detector, $1/4 \lambda$ may be selected as depth for the synchronisation section recesses, λ being the wavelength of the radiation used. If, for the depth of the servo track in the data section 9, the value $1/8 \lambda$ or less is selected, this servo track will hardly affect the amount of light detected by the detector.

Figure 3 schematically represents in a cross-section in the longitudinal direction of the servo tracks 4, showing a part of such a servo track 4 with a part of the synchronization section 8 and a part of the data section 9, and

Figure 4 shows a plan view of said part of the track 4.

The prepared disc is provided with a servo track 4, formed in a substrate 5, for example by means of a laser beam. By modulating the intensity of the laser beam it is then possible to form a relief structure of "pits" 13 containing information in the synchronization section 8. Subsequently, the entire disc, including for the sake of simplicity, the portion of the record carrier 1 outside the grooves 4, may then be coated with the reflecting information recording layer 6. In the record carrier thus prepared information can be recorded in the information section 9 by forming holes 14 in the layer 6, for example by means of a laser beam.

Instead of a reflecting layer 6 it is alternatively possible to provide a non-reflecting layer on a reflecting substrate, which non-reflecting layer is locally removed in order to obtain the information areas. Instead of read-out based on a different reflectivity of a record carrier, read-out may also be based on a different transmissivity of a record carrier.

The digitally coded information can be modulated in different manners before being recorded. For this purpose Figure 7 represents three modulation methods, the associated spectra being shown in Figure 6.

5 The reference a in Figure 7 designates a modulation known by the name of "biphase" modulation. The applied digital signal is then converted into a binary signal which for a logic "one" of the applied digital signal is positive during the time interval $T/2$ and negative during the next time interval $T/2$, T being the bit length
10 of the applied digital signal. A logic "zero" yields exactly the opposite binary signal, i.e. negative for the time interval $T/2$ and positive for the next time interval $T/2$. This modulation technique yields a binary signal which has a power spectrum represented by curve a in Figure 6. The frequency f_0 then corresponds to $\frac{1}{T}$.

15 The reference b in Figure 7 represents the modulation known by the name of "Miller" modulation. The binary signal generated by means of this modulation has a transition from "0" to "1" or vice-versa in the middle of a logic "one" of the applied digital signal and a similar transition at the junction between two consecutive
20 logic "zeros". The frequency spectrum of the binary signal obtained by means of this modulation technique is given by curve b in Figure 6.

Finally, the reference c in Figure 7 represents a modulation known by the name of "quadphase" modulation, the applied bit series of the digital signal first of all being divided into consecutive
25 groups of two bits. From each two-bit group having a duration of $2T$ a binary signal is derived which in a first time interval T has the same variation as the original two bits and in the next time interval T an inverse variation. The bit combinations 11, 00, 01 and 10 which are possible are thus converted into the bit combinations 1100, 0011,
30 0110 and 1001 respectively. The binary signal obtained by means of this modulation technique has a frequency spectrum as is represented by curve c in Figure 6.

It is evident from Figure 6 that these modulation techniques
35 have the common property that the resulting binary signal exhibits no strong frequency components at comparatively low frequencies,

for example frequencies below $0.2 f_0$. This is very useful when an optical record carrier is used with the associated write and read systems. As stated previously, such systems employ both a servo control in order to keep the scanning spot accurately focussed on the record carrier and a servo control which controls the radial position of the scanning spot and ensures that said scanning spot accurately coincides with the information track. As the control signals required for these servo controls are derived from the radiation beam which is reflected by the record carrier, which is also modulated by the relief structure of the synchronization section, it is essential that the frequency spectrum of the binary signal stored in the address portion does not contain any strong frequency components within the frequency band intended for the control signals. Figure 6 thus shows that the frequency band below approximately $0.2 f_0$ is suitable for such control signals.

When the recorded information is read it is essential that this read-out is effected in synchronism with a clock signal. According to the recognition on which the invention is based the information signal being read already contains such a clock signal when the information has been recorded in the form of unit-areas, shown in the Figures as unit-pits. Figure 5 therefore schematically represents the signal obtained when reading a track in accordance with Figure 4. This signal comprises components which are produced by the transitions, between the individual pits, which in the frequency spectrum, shown in Figure 6, appears as a comparatively strong frequency component S_c of the frequency $2 f_0$. This frequency coincides with a zero point in the power spectrum of a digitally coded signal of the bit frequency f_0 and can thus be extracted from the signal being read without any problems.

Figure 8 schematically represents an apparatus in accordance with the invention. For the sake of simplicity various elements of the apparatus which are not essential for explaining the invention, such as the drive of the record carrier and servo controls for controlling the focussing of the laser beam and for the tracking, are not shown. These elements are inter alia described in Patent

Application No. 2,016,744A. A laser 16, via a mirror 17, which may serve for the radial positioning of the beam on the disc, and an objective 18, projects a laser beam 19 on the track 4 of the record carrier 1, which moves relative to the projected beam 19 in the direction of the arrow 15. A detector 20, for example a photo-diode, detects the reflection or transmission of the beam 19, so that a signal as shown in Figure 5 is obtained. This signal contains the frequency component S_c of the frequency $2 f_o$ (Figure 6), which is equal to V/L , where L is the centre-to-centre distance of two adjacent information areas (see Figure 4) at the location of scanning and V the tangential speed of the record carrier 1 at the location of scanning. This frequency component is extracted with band-pass filter 21 and applied to a phase-locked loop 22, which improves the filtration, increases the stability and compensates for any brief signal dropouts. Thus, a clock signal of a frequency $2 f_o$ is obtained, from which by division the bit frequency f_o may be recovered. This division, as is generally known, may be effected in a phase-locked loop, which may comprise a highly stable oscillator whose phase is locked to the signal supplied by the filter 21.

From the signal detected by the detector 20 the digitally coded signal is recovered with a circuit 23, which for this purpose is synchronized by the clock signal obtained by a method in accordance with the invention.

The invention is not limited to a use as illustrated with reference to the Figures, but may also be employed for the reproduction of digitally coded audio or video signals and the like for which in most cases the sector arrangement with synchronization areas 8 described with reference to Figure 1 does not occur.

Instead of a laser beam it is frequently possible to use a non-coherent radiation beam, especially at low information densities.

CLAIMS:-

1. Apparatus for reproducing digitally coded information, which has been recorded on a disc-shaped record carrier in the form of optically detectable information areas arranged in a concentric ring or spiral track pattern, said areas being unit areas as defined herein which have a centre-to-centre separation L along the track at a reading location, which apparatus comprises a radiation source, an optical system for projecting a radiation beam onto the track pattern at the reading location, means for rotating the record carrier to produce a tangential speed V at the reading location, a detector for detecting the presence of a unit area in said beam, a read circuit for reproducing the recorded digitally coded signal, and a clock-signal generation device for synchronizing the read circuit comprising a band-pass filter, having a centre frequency which is substantially equal to V/L for filtering the detector signal in order to obtain the clock signal, the digital code of the information on the record being chosen to have a zero in its power spectrum at the frequency V/L .
2. An apparatus for reproducing digitally coded information substantially as described with reference to Figures 6 and 8 of the accompanying drawings.

The text of the specification has been reproduced by photocopying the applicants original typescript. It may contain a few amendments which are difficult to read. The original typescript containing these amendments may be inspected on the premises of the Patent Office