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(54) Title: PRE-COMPENSATED OPTICAL TAPE WOBBLE PATTERNS

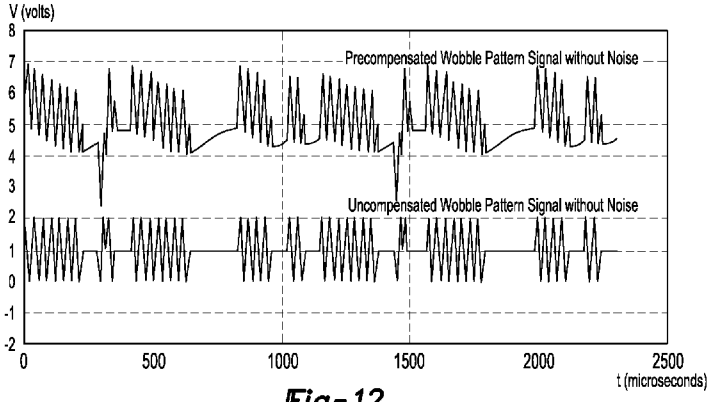

Fig-12

(57) Abstract: Amplitude or phase modulated un-compensated wobble patterns representing address patterns for track addresses of optical media are generated. A filter is applied to the un-compensated wobble patterns to pre-compensate the un-compensated wobble patterns. When an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered.

PRE-COMPENSATED OPTICAL TAPE WOBBLE PATTERNS

TECHNICAL FIELD

[0001] This disclosure relates to optical tape and the encoding of information thereon and decoding of information therefrom in the presence of noise.

BACKGROUND

[0002] Preformatting an optical media with wobbled edge land and groove tracks is an effective method for embedding recording track addresses on the media. Wobble pattern blocks are normally a sequence of frequency, amplitude or phase modulated sine waves and are utilized as building blocks for a complete address field of the media recording tracks. These address fields usually include an index subfield (IF), a timing recovery subfield (TRF) and an address bits subfield (AF).

SUMMARY

[0003] A method for encoding data on an optical media includes generating un-compensated wobble patterns representing address patterns for track addresses of the optical media and applying a filter to the un-compensated wobble patterns to generate pre-compensated wobble patterns such that when an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered. The method further includes embossing the pre-compensated wobble patterns on the optical media.

[0004] An optical media encoding system includes an encoder that generates un-compensated wobble patterns representing address patterns for track addresses of an optical media and applies a filter to the un-compensated wobble patterns to generate pre-compensated wobble patterns such that when an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered.

[0005] A computer-readable medium has instructions stored thereon that, when executed by a computer, cause the computer to generate un-compensated wobble patterns representing address patterns for track addresses of an optical media and to apply a filter to the un-compensated wobble patterns to generate pre-compensated wobble patterns such that when an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 shows an index block waveform.

[0007] Figure 2 shows an address bit block waveform.

[0008] Figure 3 shows a timing recovery block waveform.

[0009] Figure 4 shows an address pattern waveform including the blocks of Figures 1 through 3.

[0010] Figure 5 is a block diagram of a track address decoder.

[0011] Figure 6 shows a wobble pattern waveform (without noise) added to a delayed version of itself, and the resulting index pattern waveform.

[0012] Figure 7 shows a wobble pattern waveform (without noise) and resulting index pattern waveform.

[0013] Figure 8 shows an un-filtered wobble pattern waveform (with noise) and resulting index pattern waveform.

[0014] Figure 9 shows a filtered wobble pattern waveform and resulting index pattern waveform.

[0015] Figures 10 and 11 are block diagrams of signal processing systems.

[0016] Figures 12 and 13 show waveform output, without and with noise respectively, from a wobble format pattern generator.

[0017] Figure 14 shows a waveform output of a band pass filter.

[0018] Figure 15 shows a waveform for an index pattern in a 2 cycle tape format.

[0019] Figure 16 shows a waveform for a '1' bit in the 2 cycle tape format.

[0020] Figure 17 shows a waveform for an address in the 2 cycle tape format.

[0021] Figure 18 shows the application of a matched filter tuned to the index pattern of Figure 15.

[0022] Figure 19 shows the result of the application of the matched filter of Figure 18.

[0023] Figure 20 shows the application of a matched filter tuned to the '1' bit pattern of Figure 16.

[0024] Figure 21 shows timing requirements to confirm an index.

[0025] Figure 22 shows a waveform having an index, three '1' bits, and address bits.

DETAILED DESCRIPTION

[0026] Embodiments of the present disclosure are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments can take various and alternative forms. The figures are not necessarily to scale; some features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention. As those of ordinary skill in the art will understand, various features illustrated and described with reference to any one of the figures can be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be desired for particular applications or implementations.

[0027] Referring to Figures 1 through 4, dual cycle wobble block patterns, such as the index block of Figure 1, the address bit block of Figure 2, and the timing recovery block of Figure 3, have been implemented as example foundational elements of an address field pattern, such as the pattern of Figure 4, for optical tape media. Phase modulated dual cycle blocks, in this example, represent the index or sync field (IF), a set of monotone cycle fields (TRF) around the index fields can be used for timing recovery of the decoder, and the eight subsequent pairs of cycles represent the 8 bits of the address field (AF).

[0028] Referring to Figures 5 and 6, a track address decoder 10 may include a delay filter 12, threshold detector 18, phase lock loop (PLL) 20, synchronizer 22, synchronized rectifier 24, synchronized resettable integrator 26 and threshold detector 28. The delay filter 12 may include a delay block 14 and sum block 16. A wobble pattern, such as the wobble pattern of Figure 6, can be input to the delay block 14 and sum block 16. The resulting output of the delay block 14, such as the delay pattern of Figure 6, can also be input to the sum block 16. The resulting output of the sum block 16, such as the index pattern of Figure 6, can be input to the threshold detector 18. An output of the threshold detector 18 and the wobble pattern of Figure 6 can be input to the phase lock loop 20. The resulting output of the phase lock loop 20 can be input to the synchronizer 22. An output of the synchronizer 22 and the wobble pattern of Figure 6 can be input to the synchronized rectifier 24. The resulting output of the synchronized rectifier 24 and the wobble pattern of Figure 6 can be input to the synchronized resettable integrator 26. The resulting output of the synchronized resettable integrator 26 can be input to the threshold detector 28. In this arrangement, an output of the threshold detector 28 yields the address associated with the wobble pattern.

[0029] The delay filter or buffer 12 generates a half cycle delayed pattern relative to the original wobble pattern. Adding the two patterns at the sum block 16 yields a detectable sync half cycle (index) that can be detected by the threshold comparator 18 when a peak value of the index pattern exceeds the index threshold. Once detected, the phase lock loop 20, locked to the monotone pattern of the timing recovery subfields discussed with reference to Figure 4, establishes the timing of each bit of the address subfield and the address is decoded via the synchronizer 22, synchronized rectifier 24, synchronized resettable integrator 26 and threshold detector 28 as known in the art.

[0030] A robust and efficient track address coding/decoding scheme may be useful to a reliable data recoding and retrieval process as wobble patterns in optical recording systems can be

susceptible to media noise and pre-formatting process imperfections. This susceptibility is due to the fact that the amplitude of physical wobble nanostructures is relatively small compared to the land and groove structures, which is caused by limitations imposed by read/write channel Inter-Symbol Interference. Hence, disclosed herein are wobble coding, pre-compensating and decoding technologies that can improve, in certain examples, effective signal-to-noise ratio (SNR) of wobble signal patterns.

Pre-Compensated Wobble Patterns

[0031] Referring to Figures 7 and 8 respectively, example decoder performance is examined without and with noise in the channel. Under excessive noise, the reliability of decoder functionality may be compromised as the decoder may be unable to distinguish between data embedded in the signal and noise associated with the signal. Peak values of the index pattern (with noise) that do not correspond with an index field of the wobble pattern (with noise), for example, may exceed the index threshold. This may lead the decoder to falsely detect an index field. Likewise, peak values of the index pattern (with noise) that correspond with an index field of the wobble pattern (with noise), for example, may not exceed the index threshold. This may lead the decoder to not detect an index field.

[0032] Referring to Figure 9, index pattern SNR can be improved by applying a narrow band pass (BP) filter to the wobble signal centered at pattern carrier frequency. Because the wobble signal is amplitude and phase modulated, however, the application of a narrow BP filter can change the shape of the patterns and thus impact the performance of the decoder. That is, the decoder may be unable to decode the filtered index signal because, for example, peak values of the filtered index that exceed the index threshold signal may no longer correspond to address index blocks.

[0033] Certain pre-compensating strategies can apply an inverse filter (e.g., an inverse BP filter centered at the carrier frequency, an inverse low pass (LP) filter having a corner frequency at the carrier frequency, etc.) to wobble patterns prior to imprinting (formatting) of the media. The imprinted wobble patterns on the media are pre-compensated such that decoder filtering (e.g., BP filtering, LP filtering, etc.) of the read back wobble pattern yields (substantially) the original signal shape at an output of the filter.

[0034] Referring to Figure 10, a traditional signal processing block diagram includes a media pre-formatting process 30 and drive address decoding process 32 for an optical media 34. During the pre-formatting process 30, track address information 36 is input to a wobble format pattern generator 38 to pre-format the optical media 34. During the drive address decoding process 32, an optical pickup unit 40 reads data from the optical media 34. The data then is input to a wobble pattern detector 42 and track address decoder 44 as known in the art. As mentioned above however, the drive address decoding process 32 may be hampered by excessive noise associated with the signal.

[0035] Referring to Figure 11, an example of an improved signal processing block diagram includes a media pre-formatting process 46 and drive address decoding process 48 for an optical media 50. During the pre-formatting process 46, track address information 52 is input to a wobble format pattern generator 54, which generates, in certain examples, amplitude and phase modulated un-compensated wobble patterns representing address patterns for track addresses of the optical media 50. An inverse BP filter 56 is applied to pre-compensate the un-compensated wobble patterns. The pre-compensated wobble patterns are then embossed on the optical media 50.

[0036] During the drive address decoding process 48, an optical pickup unit 58 reads data from the optical media 50. The data is then input to a wobble pattern detector 60, a BP filter 62 and track address decoder 64. Application of the BP filter 62, however, does not change the shape of the wobble patterns in such a way so as to make them unrecognizable to the track address decoder 64 because the inverse BP filter 56 pre-compensated the wobble patterns to account for shape altering effects associated with the application of the BP filter 62.

[0037] Referring to Figures 12 and 13 respectively, example output without and with noise in the channel from the wobble format pattern generator 54 (original wobble pattern signal) and inverse BP filter 56 (pre-compensated wobble pattern signal) is illustrated. As discussed above, application of the BP filter 56 prior to embossing on the optical media 50 alters the waveform of the wobble patterns such that after application of the BP filter 62 during the drive address decoding process 48, the wobble patterns can be decoded by the track address decoder 64.

[0038] Referring to Figure 14, example output from the BP filter 62 (filtered wobble pattern) is illustrated along with the index pattern that results from adding a delayed version to itself as discussed with reference to Figure 5. BP filtering suppresses noise and substantially yields the

original wobble address pattern. As mentioned above, this signal is then input to the track address decoder 64, which operates much like the track address decoder 10 of Figure 5. The index decoder of the track address decoder is thus able to detect the sync field of the index wobble pattern by detecting index wobble pattern peak values above a threshold even though noise was in the channel because there is little change to cycle pattern shape of the original wobble signal. That is, peak values greater than the index threshold still correspond to address index blocks of the decoded wobble pattern.

Matched Filter Based Optical Tape Decoding

[0039] Referring to Figures 15 though 17, track addresses in certain tape formats can be coded in wobble as a series of sine waves as mentioned above. Blocks of address bits are delineated by index patterns, such as the index pattern of Figure 15. The addresses are encoded as gray-coded values with the presence of a multi-cycle (e.g., dual cycle) sine wave, such as the '1' bit waveform of Figure 16, representing a '1' bit and the absence of such representing a '0' bit. Rapid and reliable address decoding for the address pattern of Figure 17, which includes the waveforms of Figures 15 and 16, in the presence of tracking noise, for example, can facilitate timely reading and writing of data. Technology described herein can decode addresses using a matched filter approach for index and bit detection. These matched filters, in certain circumstances, can be advantageous because of their ability to reject out-of band signal noise.

[0040] In one example, track address information can be decoded using two different matched filters: one having coefficients representing the index waveform of Figure 15 and another having coefficients representing the '1' bit waveform of Figure 16. Referring to Figure 18, an index encoded within an address waveform, such as the address waveform of Figure 17, can be detected by applying a matched filter 66 including a multiplier 68 and integrator 70 and tuned to the dual cycle waveform of Figure 15 according to

$$Ri(T) = \sum_{x=0}^{33} l\big((T+1) * 33 - x\big) * A(33 * T + x) \qquad \text{Equation 1}$$

where Ri(T) is the output of the filter 66 and T is the sample time of the decoder (T = 0, 1, 2, 3, . . .). That is, the filter output, Ri(T), is the convolution of the index waveform, l(n), and the address waveform, A(n). Put a different way, a prototype dual cycle index signal pattern 72 similar to that

illustrated in Figure 15 can be input to the multiplier 68 along with an address pattern 74 similar to that illustrated in Figure 17; output of the multiplier 68 is then input to the integrator 70.

[0041] Referring to Figure 19, output of the integrator 70 is illustrated. Index detection occurs when a peak signal value exceeds a predetermined threshold. This threshold can be determined for each coding scheme through, for example, experimentation, etc. The address decoder first searches for an index. Once detected, it then switches modes and searches for a predetermined pattern of bits to confirm a location of the index.

[0042] Referring to Figure 20, a '1' bit can be detected by applying a matched filter 76 including a multiplier 78 and integrator 80 and tuned to the '1' bit waveform of Figure 16 according to

$$Ra(T) = \sum_{x=0}^{33} a\big((T+1)*33-x\big)*A(33*T+x) \qquad \text{Equation 2}$$

where Ra(T) is the output of the filter 76 and T is the sample time of the decoder (T = 0, 1, 2, 3, . . .). That is, the filter output, Ra(T), is the convolution of the '1' bit waveform, a(n), and the address waveform, A(n). Put a different way, a prototype '1' bit signal pattern 82 similar to that illustrated in Figure 16 can be input to the multiplier 78 along with an address pattern 84 similar to that illustrated in Figure 17; output of the multiplier 78 is then input to the integrator 80.

[0043] Referring to Figure 21, output of the integrator 80 is shown. Certain address formats place three '1' bits at a pre-determined time after the index waveform. The index can be confirmed by detecting these three '1' bits. '1' bits are detected based on the result of a matched filter tuned to the '1' bit of Figure 16. To be valid, these '1' bits should have correct amplitude and timing from the index. Once the index has been confirmed, address bits are detected by searching for peaks in the matched filter response to the '1' bit of Figure 16. '1' bits are confirmed by amplitude and timing from the most recently detected '1' bit. For address detection, a quality of the bit is also assigned. This quality provides an indication of the likelihood of the bit having been mis-detected.

[0044] Referring to Figure 22, a fully decoded address from the signal of Figure 17 is illustrated. A high quality (HQ) '1' bit is detected if the peak in the '1' bit tuned matched filter output is above a pre-determined threshold and is at the expected time after the last '1' bit detection. An HQ '0' bit is detected if the peak is below a different pre-determined threshold. Low quality bits

are detected if the peak is between these two thresholds. A low quality (LQ) '1' bit is detected if the peak is below the HQ '1' bit threshold but above an intermediate threshold (LQ threshold). A low quality '0' bit is detected if the peak is below the intermediate threshold but above the HQ '0' bit threshold. These threshold values can be determined for each coding scheme through, for example, experimentation, etc.

[0045] In the example of Figure 22, the index is confirmed by three '1' bits (monotone) with the correct timing from the index. The address, in this example [1 1 0 0 0 1 0 1], is then detected. All 8 address bits happen to be of high quality. This same approach can be used to decode addresses coded with tri cycle or other patterns.

[0046] The processes, methods, or algorithms disclosed herein can be deliverable to/implemented by a processing device, controller, or computer, which can include any existing programmable electronic control unit or dedicated electronic control unit. Similarly, the processes, methods, or algorithms can be stored as data and instructions executable by a controller or computer in many forms including, but not limited to, information permanently stored on non-writable storage media such as ROM devices and information alterably stored on writeable storage media such as floppy disks, magnetic tapes, CDs, RAM devices, and other magnetic and optical media. The processes, methods, or algorithms can also be implemented in a software executable object. Alternatively, the processes, methods, or algorithms can be embodied in whole or in part using suitable hardware components, such as Application Specific Integrated Circuits (ASICs), Field-Programmable Gate Arrays (FPGAs), state machines, controllers or other hardware components or devices, or a combination of hardware, software and firmware components.

[0047] While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms encompassed by the claims. The words used in the specification are words of description rather than limitation, and it is understood that various changes can be made without departing from the spirit and scope of the disclosure. As previously described, the features of various embodiments can be combined to form further embodiments of the invention that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics can be compromised to achieve desired overall

system attributes, which depend on the specific application and implementation. These attributes may include, but are not limited to cost, strength, durability, life cycle cost, marketability, appearance, packaging, size, serviceability, weight, manufacturability, ease of assembly, etc. As such, embodiments described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics are not outside the scope of the disclosure and can be desirable for particular applications.

WHAT IS CLAIMED IS:

1. A method for encoding data on an optical media comprising:

generating un-compensated wobble patterns representing address patterns for track addresses of the optical media;

applying a filter to the un-compensated wobble patterns to generate pre-compensated wobble patterns such that when an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered; and

embossing the pre-compensated wobble patterns on the optical media.

2. The method of claim 1, wherein the wobble patterns have a carrier frequency and wherein the filter is an inverse band-pass filter centered at the carrier frequency.

3. The method of claim 1, wherein the wobble patterns have a carrier frequency and wherein the filter is an inverse low-pass filter having a corner frequency at the carrier frequency.

4. The method of any preceding claim, wherein the wobble patterns include dual cycle phase shifted wobbles representing address index sub-fields.

5. The method of any of claims 1 to 3, wherein the wobble patterns include dual cycle wobbles representing address bits sub-fields.

6. The method of any of claims 1 to 3, wherein the wobble patterns include multi-cycle wobbles representing timing recovery sub-fields.

7. A computer program comprising instructions that, when executed by a computer system, cause the computer system to perform the method of any preceding claim.

8. An optical media encoding system comprising:

an encoder configured to generate un-compensated wobble patterns representing address patterns for track addresses of an optical media and to apply a filter to the un-compensated

wobble patterns to generate pre-compensated wobble patterns such that when an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered.

9. The system of claim 8, wherein the wobble patterns have a carrier frequency and wherein the filter is an inverse band-pass filter centered at the carrier frequency.

10. The system of claim 8, wherein the wobble patterns have a carrier frequency and wherein the filter is an inverse low-pass filter having a corner frequency at the carrier frequency.

11. The system of any of claims 8 to 10, wherein the wobble patterns include dual cycle phase shifted wobbles representing address index sub-fields.

12. The system of any of claims 8 to 10, wherein the wobble patterns include dual cycle wobbles representing address bits sub-fields.

13. The system of any of claims 8 to 10, wherein the wobble patterns include multi-cycle wobbles representing timing recovery sub-fields.

14. A computer-readable medium having instructions stored thereon that, when executed by a computer, cause the computer to (i) generate un-compensated wobble patterns representing address patterns for track addresses of an optical media and (ii) apply a filter to the un-compensated wobble patterns to generate pre-compensated wobble patterns such that when an inverse of the filter is applied to a signal representing the pre-compensated wobble patterns in the presence of noise, the noise is suppressed and the un-compensated wobble patterns are substantially recovered.

15. The medium of claim 14, wherein the wobble patterns have a carrier frequency and wherein the filter is an inverse band-pass filter centered at the carrier frequency or an inverse low-pass filter having a corner frequency at the carrier frequency.

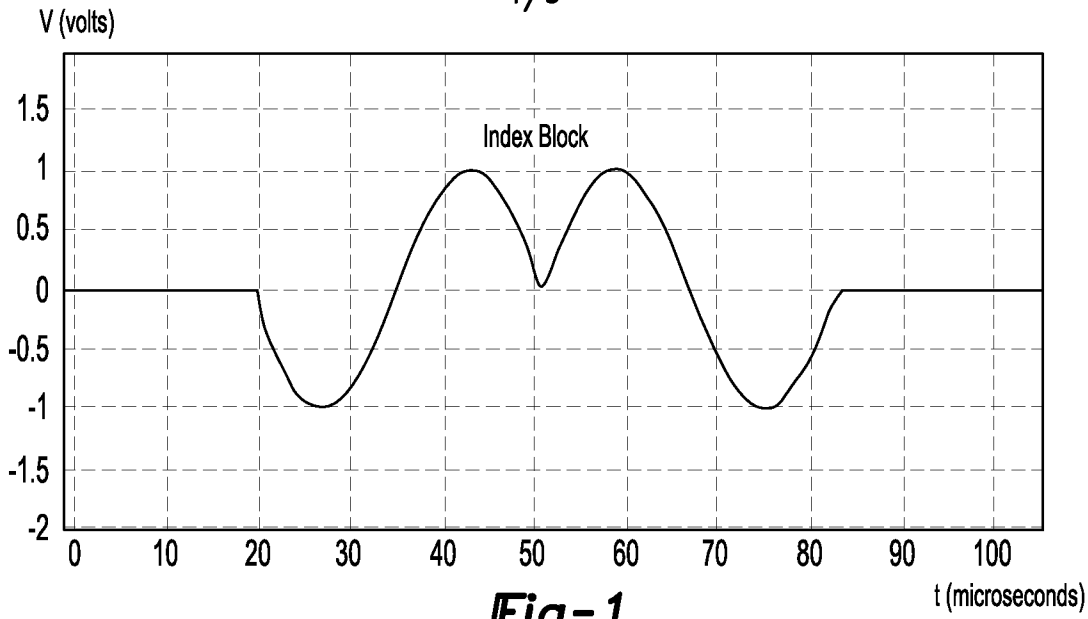

Fig-1

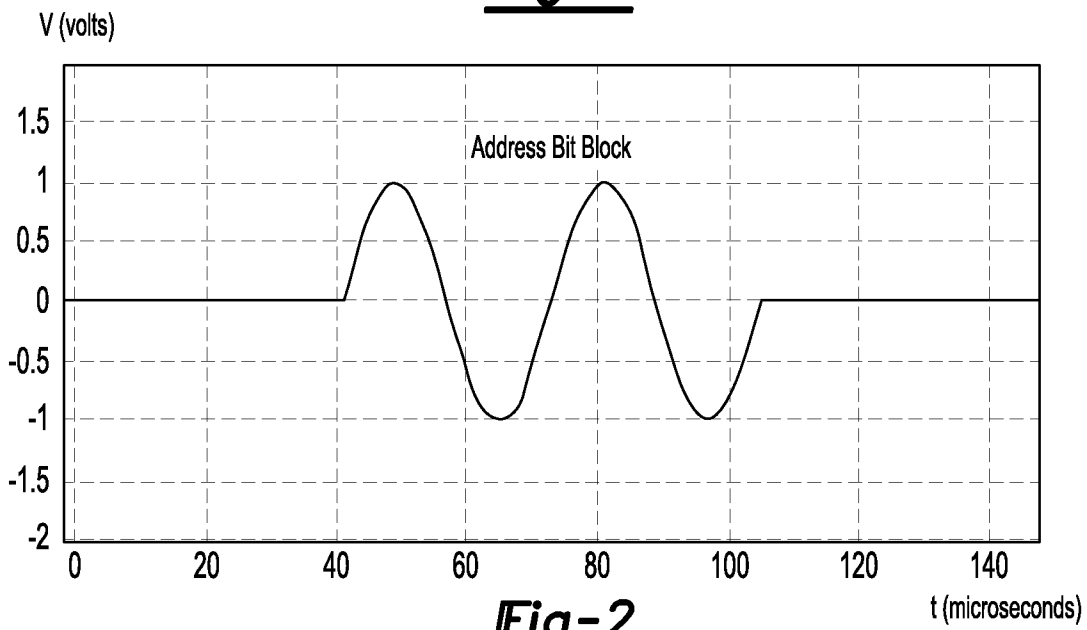

Fig-2

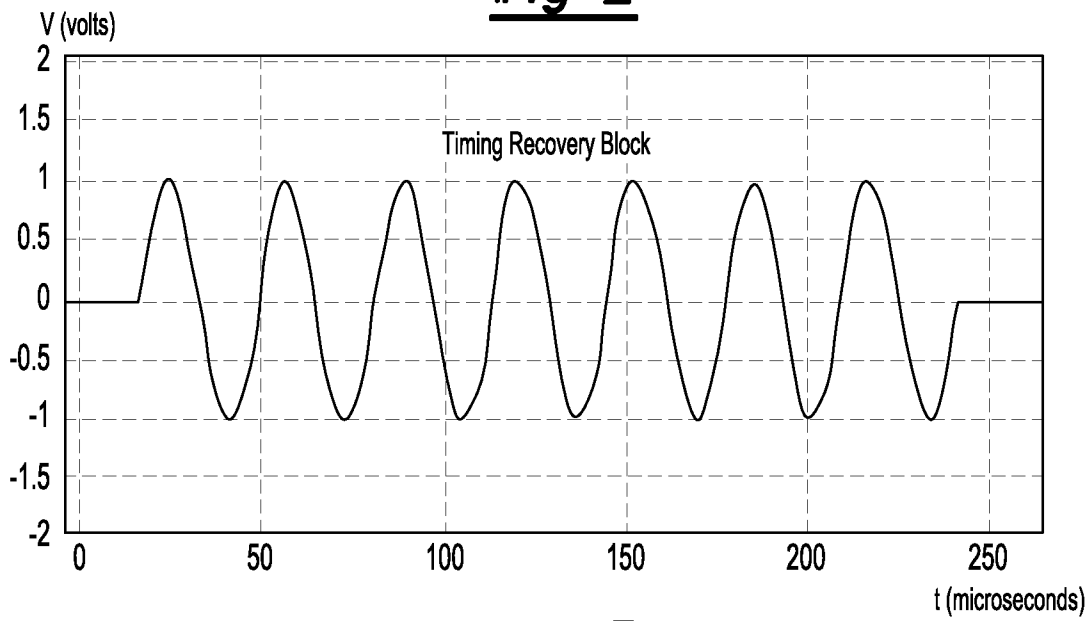

Fig-3

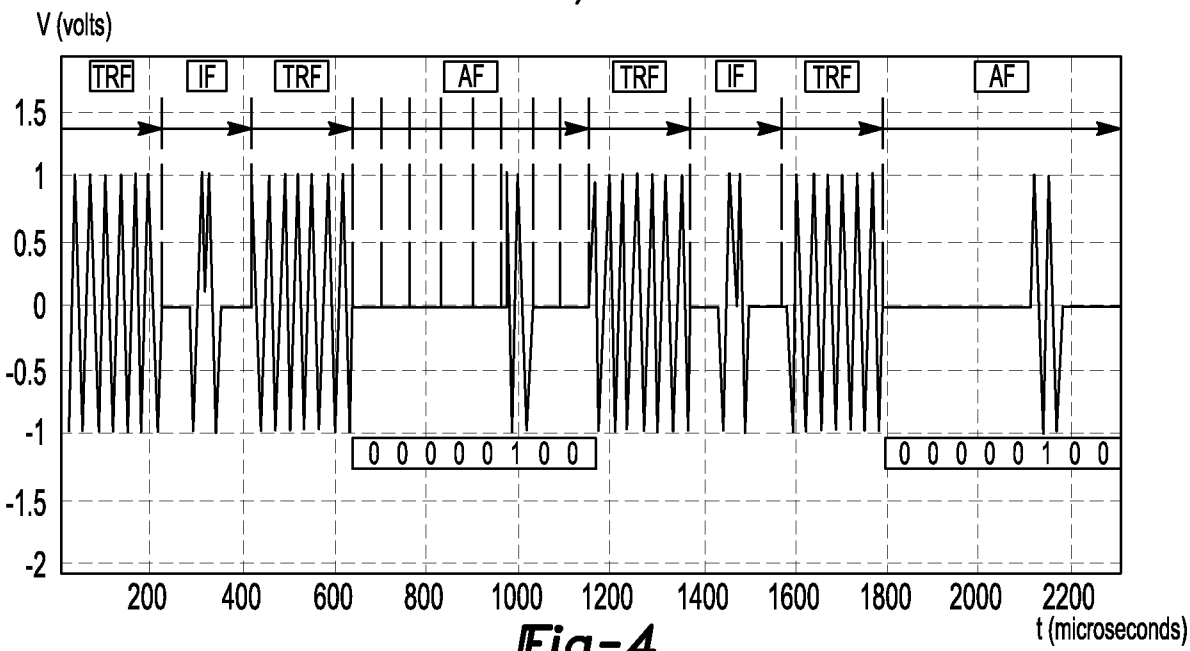

Fig-4

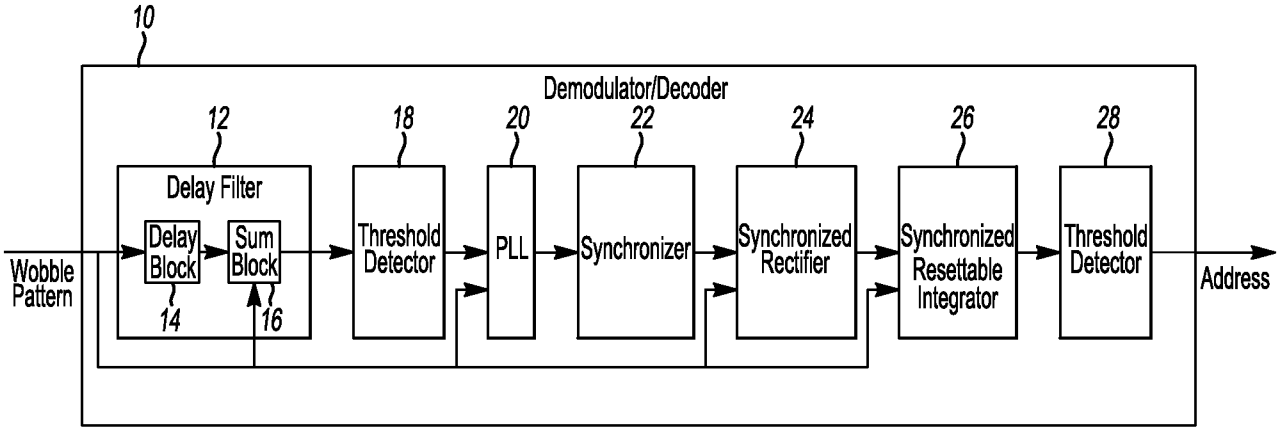

Fig-5

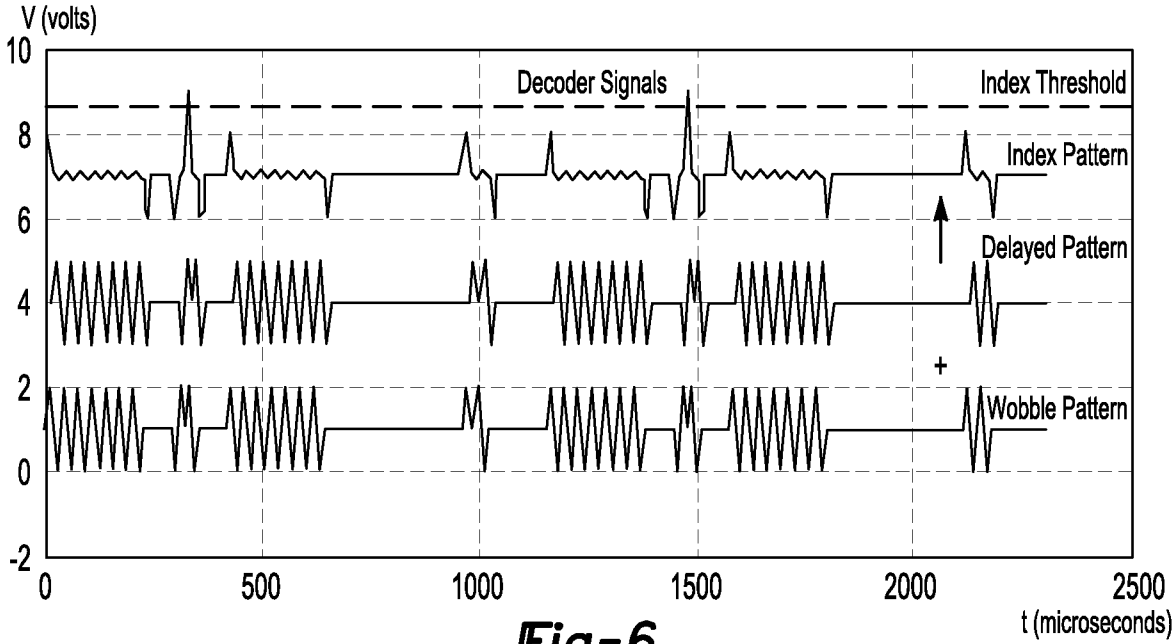

Fig-6

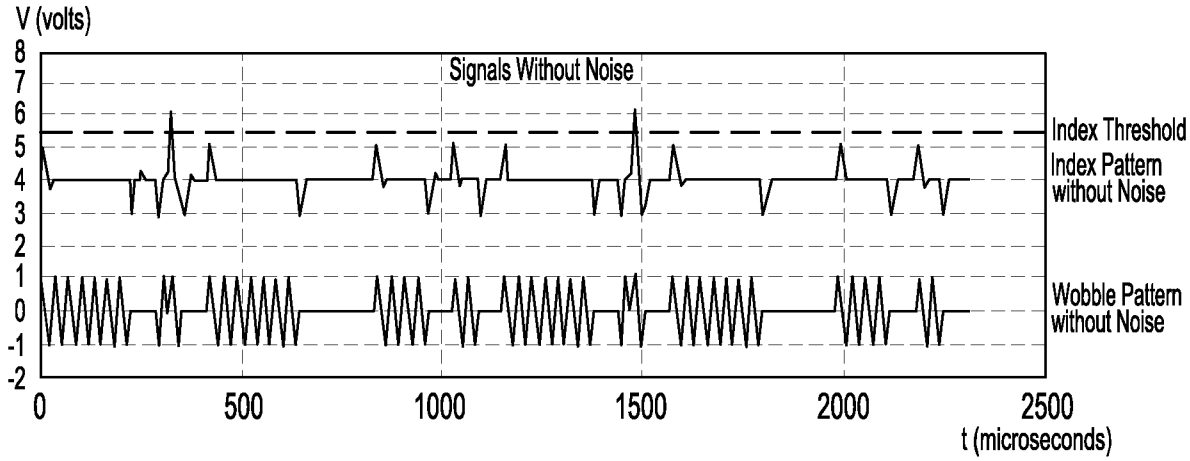

Fig-7

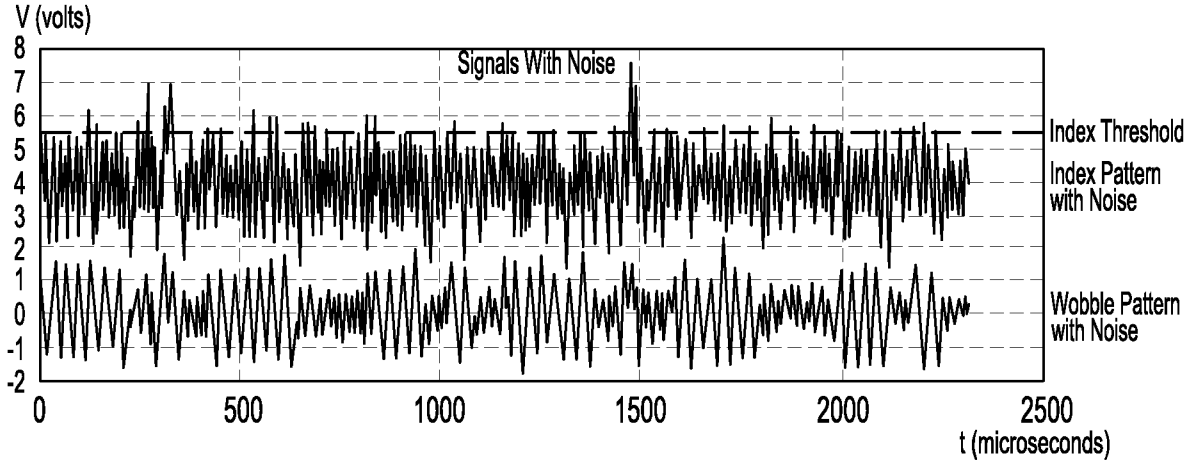

Fig-8

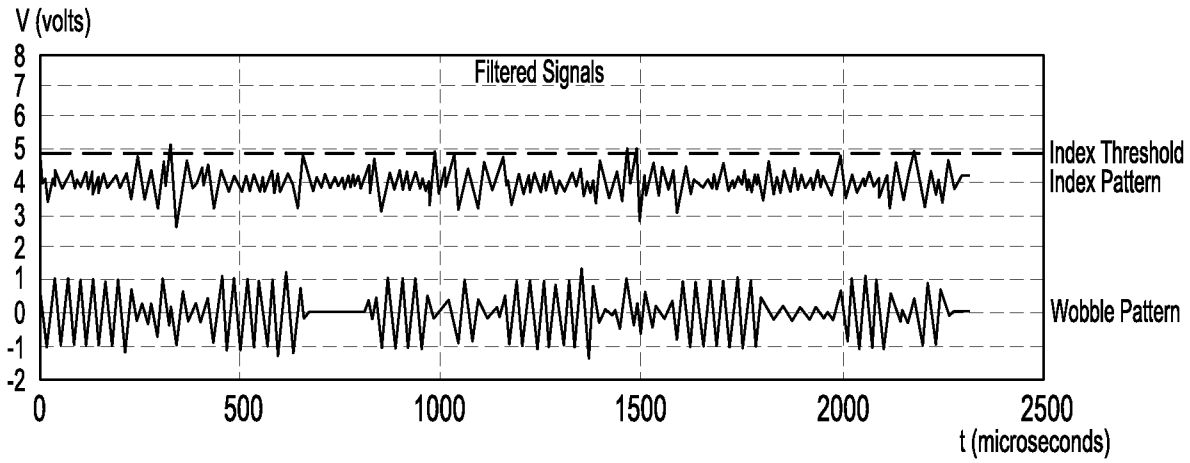

Fig-9

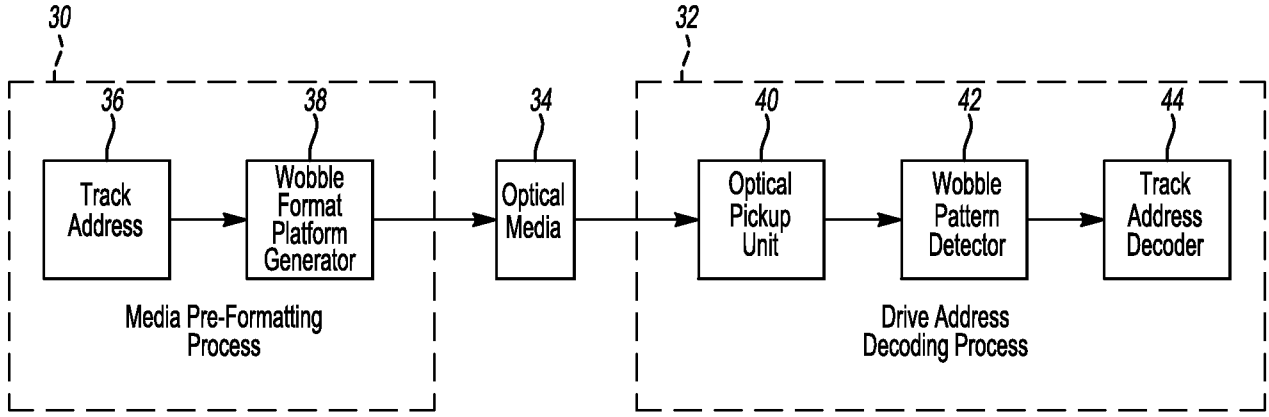

Fig-10

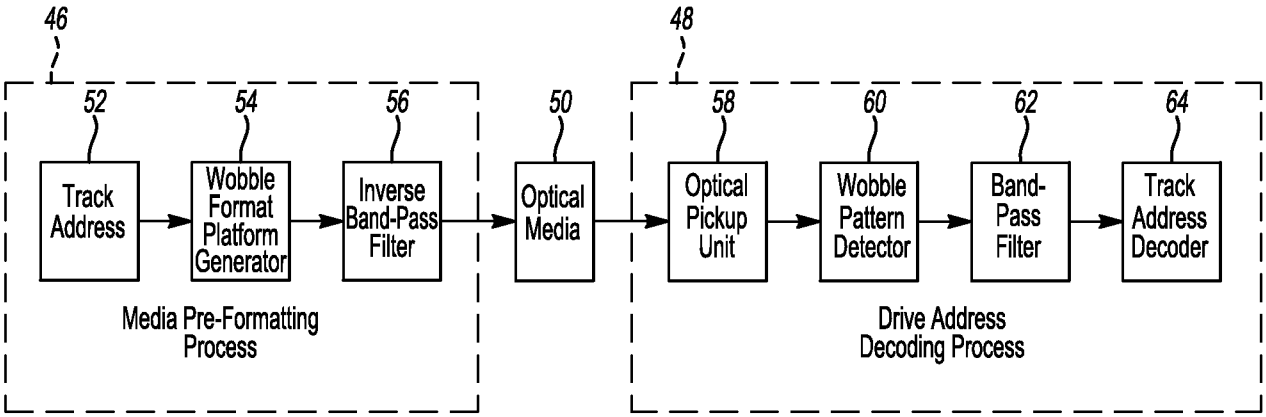

Fig-11

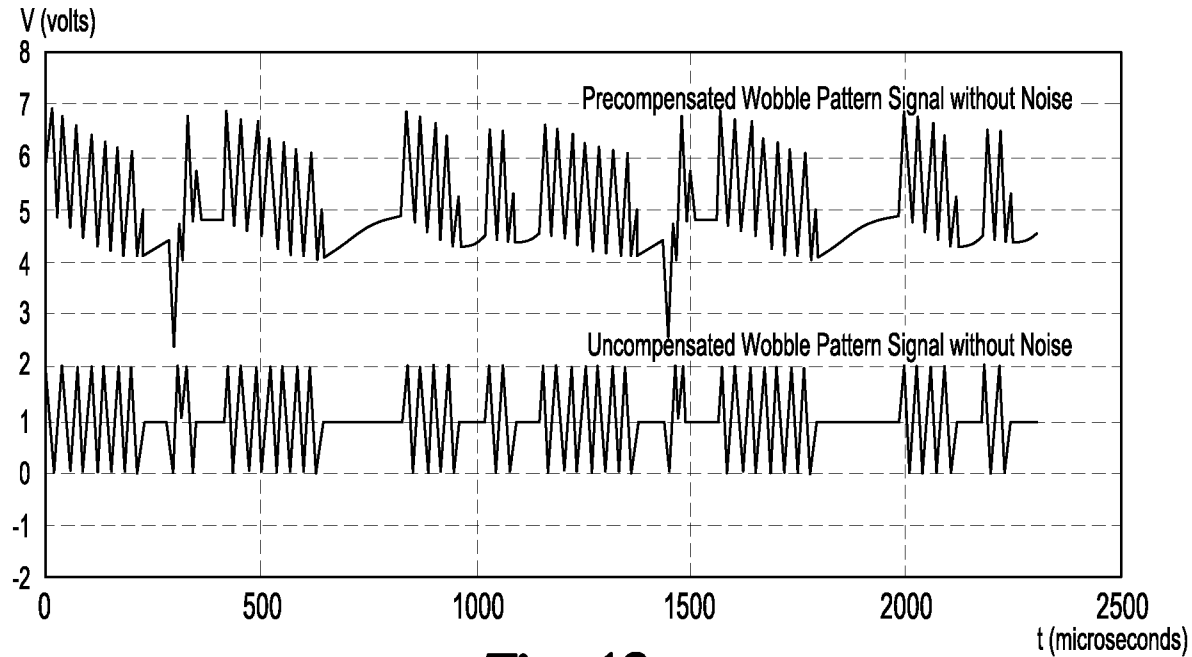

Fig-12

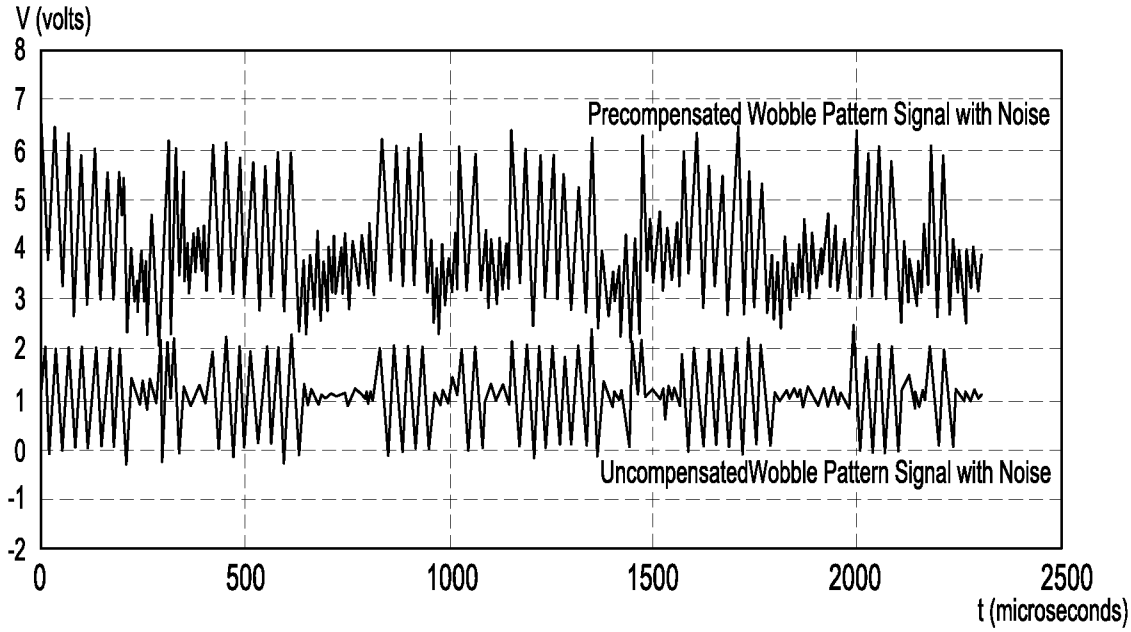

Fig-13

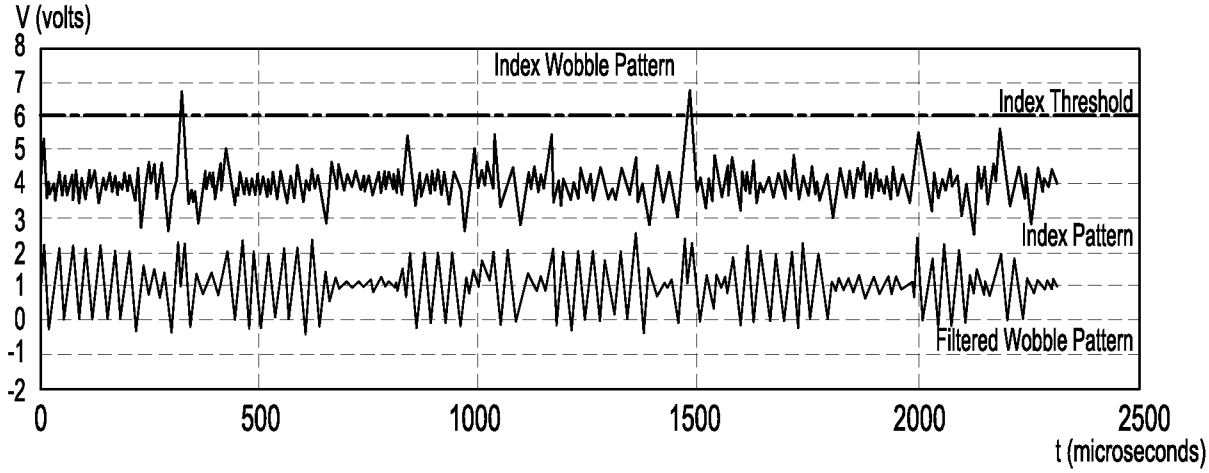

Fig-14

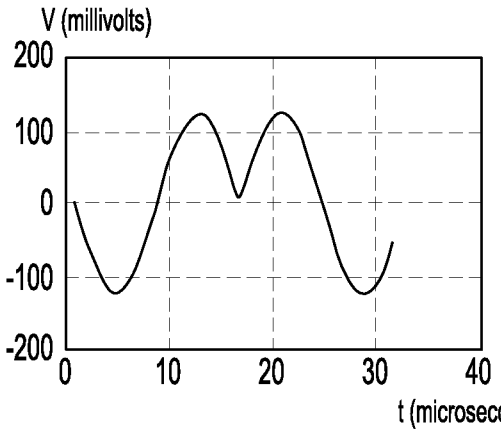

Fig-15

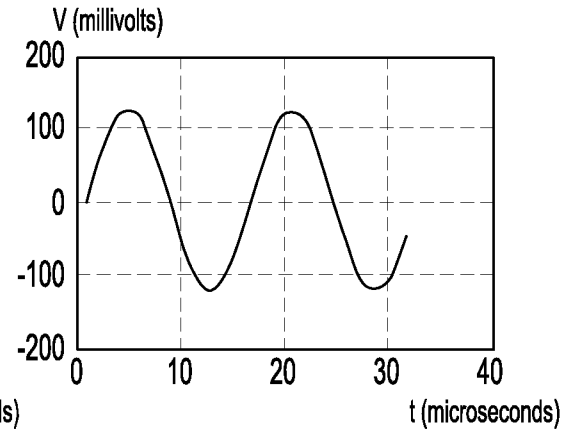

Fig-16

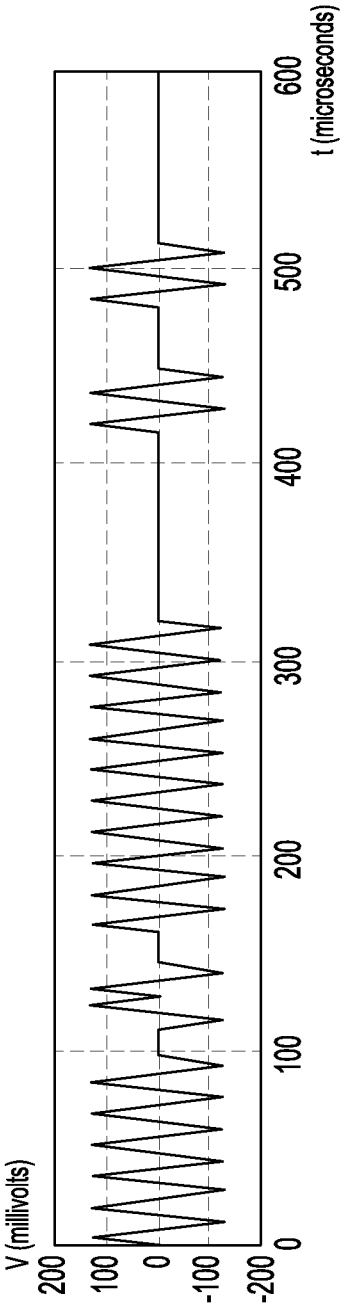

Fig-17

Fig-18

Fig-19

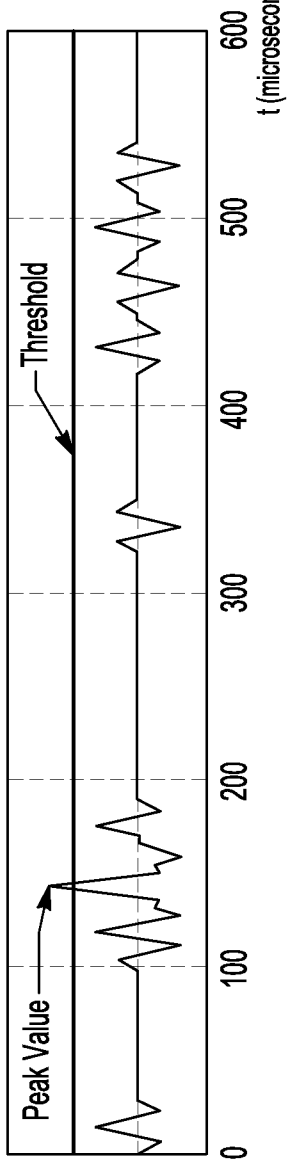

Fig-19

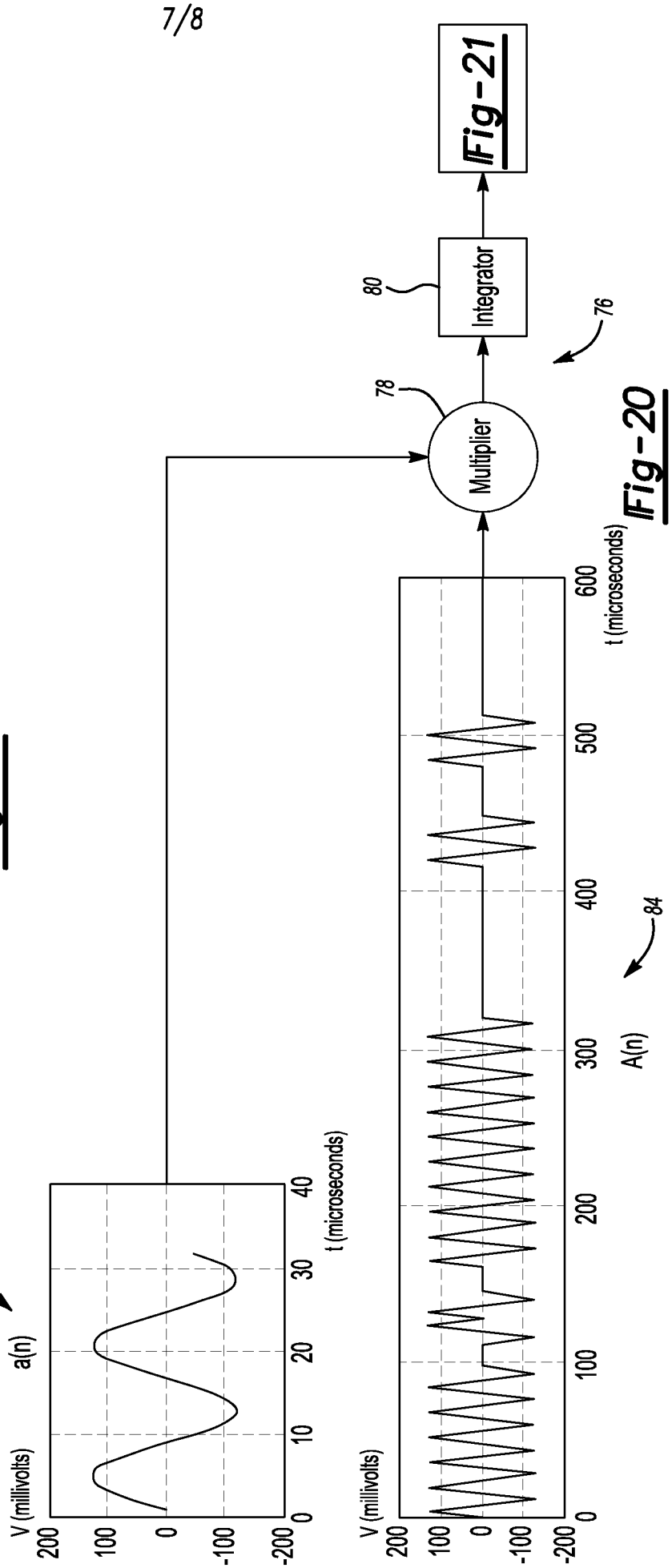

Fig-20

Fig-21

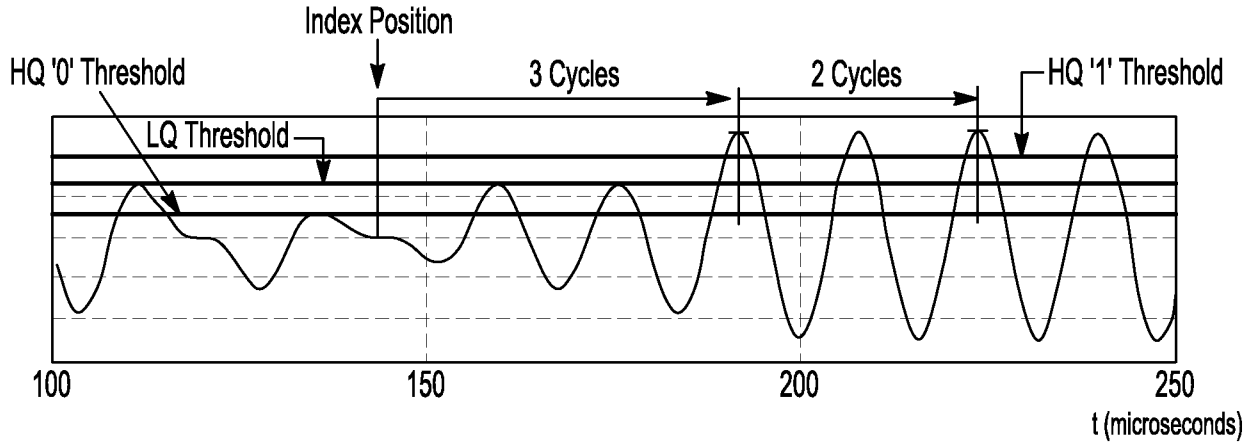
Index Position
HQ '0' Threshold
3 Cycles
2 Cycles
HQ '1' Threshold
LQ Threshold
100
150
200
250
t (microseconds)

Fig-21

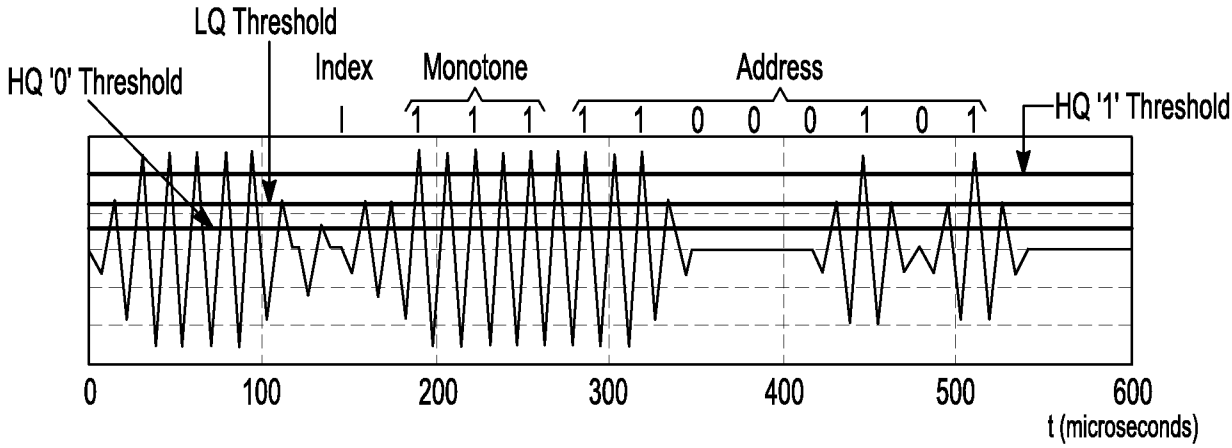
LQ Threshold
HQ '0' Threshold
Index
Monotone
Address
I
1 1 1
1 1 0 0 0 1 0 1
HQ '1' Threshold
0
100
200
300
400
500
600
t (microseconds)

Fig-22

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/061118

A. CLASSIFICATION OF SUBJECT MATTER
INV. G11B20/10 G11B20/12 G11B7/007
ADD. G11B20/14

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

B. FIELDS SEARCHED

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

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/141868 A1 (MAHNAD FARAMARZ [US]) 16 June 2011 (2011-06-16) paragraphs [0140] - [0146] figures 14-16	1-15

Y	DAVID R SMITH: "Digital Modulation Techniques", 2004, DIGITAL TRANSMISSION SYSTEMS, 3RD EDITION, SPRINGER US, US, PAGE(S) 363 - 436, XP008166320, ISBN: 978-1-4613-4726-2 pages 370-374	1-15

A	US 3 792 356 A (KOBAYASHI H ET AL) 12 February 1974 (1974-02-12) column 1, lines 14-27 column 2, line 9 - column 3, line 29 figures 1,2	1,7,8,14

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

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 2013	08/01/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hermes, Lothar

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/061118

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	HARASHIMA H ET AL: "MATCHED-TRANSMISSION TECHNIQUE FOR CHANNELS WITH INTERSYMBOL INTERFERENCE", IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ. USA, vol. COM-20, no. 4, August 1972 (1972-08), pages 774-780, XP000990996, ISSN: 0090-6778, DOI: 10.1109/TCOM.1972.1091221 figure 7	1,7,8,14

A	KOBAYASHI H ET AL: "APPLICATION OF PARTIAL-RESPONSE CHANNEL CODING TO MAGNETIC RECORDING SYSTEMS", IBM JOURNAL OF RESEARCH AND DEVELOPMENT, INTERNATIONAL BUSINESS MACHINES CORPORATION, NEW YORK, NY, US, vol. 14, January 1970 (1970-01), pages 368-375, XP000915656, ISSN: 0018-8646 figure 2(c)	1,7,8,14

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International application No
PCT/US2013/061118

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