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(54) Titre : METHODE ET APPAREIL D'ENREGISTREMENT DES DONNEES SUR UN SUPPORT D'ENREGISTREMENT OPTIQUE
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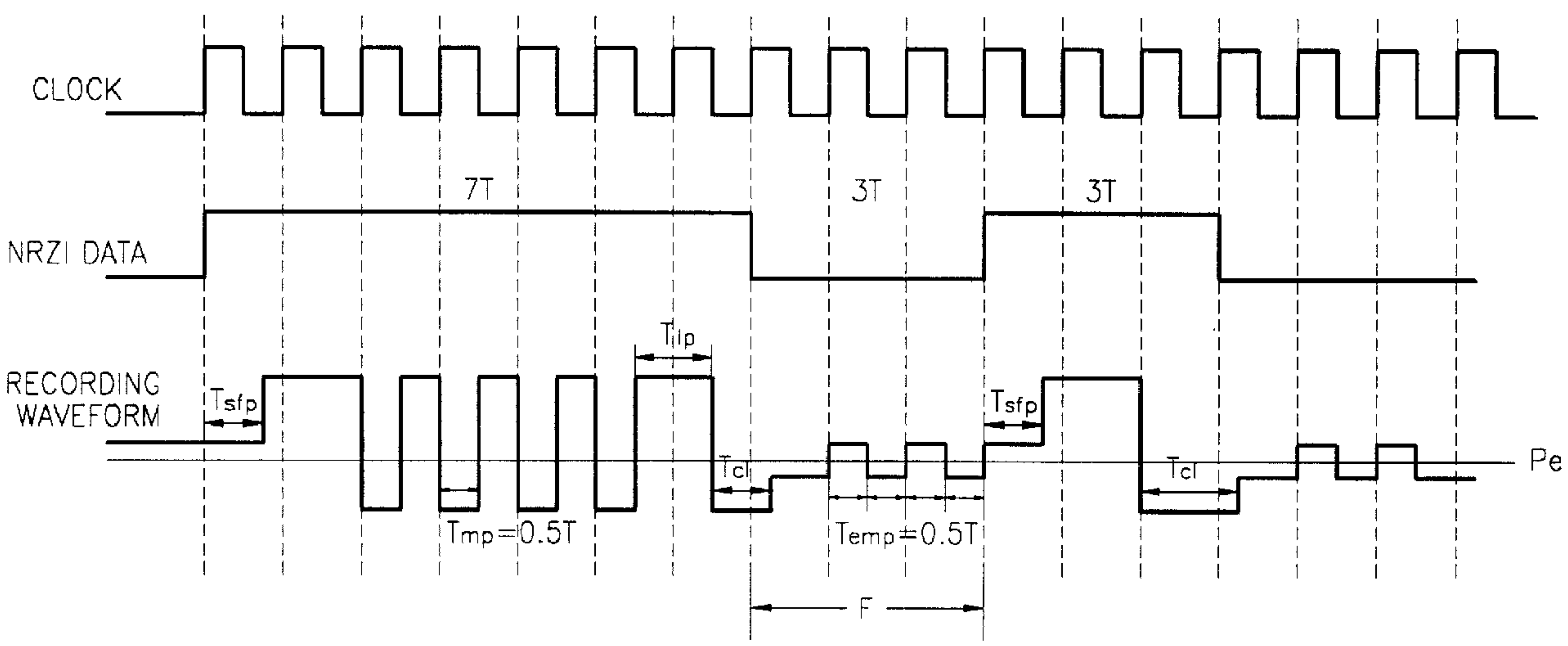

(57) Abrégé/Abstract:
A method and apparatus for recording data on an optical recording medium are provided. In the method of recording data on the optical recording medium, a mark or a space is formed using a recording waveform having an erase pattern including a predetermined pulse whose high level is higher than an erase power level and whose low level is lower than the erase power level. Thus, the shape of the mark can be prevented from being distorted and be improved, which results in an improvement in the recording/reproducing characteristics.

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Abstract of the Disclosure

A method and apparatus for recording data on an optical recording medium are provided. In the method of recording data on the optical recording medium, a mark or a space is formed using a recording waveform having an erase pattern including a predetermined pulse whose high level is higher than an erase power level and whose low level is lower than the erase power level. Thus, the shape of the mark can be prevented from being distorted and be improved, which results in an improvement in the recording/reproducing characteristics.

METHOD AND APPARATUS FOR RECORDING DATA ON OPTICAL RECORDING MEDIUM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and apparatus for recording data on an optical recording medium, and more particularly, to a method and apparatus for recording digital data by forming a mark on an optical disc.

2. Description of the Related Art

When recording data on an optical recording medium such as an optical disc, a mark is formed in a track formed in the optical disc. A mark is formed as a pit of a read only disc such as a CD-ROM, a DVD-ROM and the like. A mark is formed on a recordable disc such as CD-R/RW, DVD-R/RW//RAM and the like when a phase change occurs in a phase change layer, which is changed to be crystalline or amorphous depending on the temperature and coats a recording layer.

Data recording methods include a mark edge recording method and mark position recording method in view of signal detection. In the mark position recording method, the amplitude of a detected radio frequency (RF) signal is changed from positive/negative to negative/positive in a position where a mark is recorded. In the mark edge recording method, the amplitude of a detected RF signal is changed from positive/negative to negative/positive at the edges of a mark. Thus, it is important to accurately record the edges of the mark to improve the quality of a reproduced signal.

However, by observing the trailing edge of a mark recorded on a disc coated with a phase change layer according to a conventional recording method, it can be seen that the shape of the mark depends on the length of the mark or the distance between marks, i.e., the length of a space. In other words, the trailing edge is wider than the leading edge of the mark, which degrades the recording/reproducing characteristics. The relatively long length of the mark further degrades recording/reproducing characteristics due to thermal accumulation.

FIG. 1A shows recording waveforms according to a conventional recording method. Referring to FIG. 1A, there are various recording waveforms for recording Non Return to Zero Inverted (NRZI) data. A first recording waveform (a) is for DVD-RAM. Recording waveforms (b) and (c) are for DVD-RW. T represents a cycle of a reference clock signal. According to mark edge recording, the high level of NRZI data is recorded using marks and the low level of NRZI data is recorded using spaces. A recording waveform used for recording the mark is called "a recording pattern", and a recording waveform used for forming the space (erasing the mark) is called "an erase pattern". Conventional recording waveforms (a), (b), and (c) are each made of multiple pulses. The power level of each pulse is controlled to have one of four levels: Ppeak, P_{b1}, P_{b2}, and P_{b3}. As shown in section E, the power of the erase pattern is maintained to be a uniform predetermined DC level.

Since the erase pattern included in the conventional recording waveform is maintained at a uniform DC level for a predetermined time, heat of about 0 - 200°C is continuously applied to a corresponding area. Thus, if the mark is recorded a plurality of times, the mark is degraded and the shape thereof is distorted. As a result, the recording/reproducing characteristics are remarkably degraded. In particular, the cycle T of the reference clock signal is reduced as the recording density and linear velocity for recording a large amount of data on a disc increase. As a result, recording/reproducing characteristics are much more degraded when thermal interference between pulses constituting a recording waveform is increased.

FIGS. 1B and 1C show the shapes of marks formed on an optical recording medium. Referring to FIGS. 1B and 1C, a track of the optical recording medium is composed of a groove and a land. To record predetermined data on the optical recording medium, marks are formed on or erased from the groove and the land. However, a laser beam applies heat to the optical recording medium to form or erase the marks. This heat may cause a Thermal Crossing phenomenon in which adjacent tracks or adjacent marks are affected. FIG. 1B illustrates a method of recording predetermined data by forming marks on both the groove and the land where the Thermal Crossing phenomenon easily occurs. FIG. 1C illustrates a method of forming marks only on the groove, which is currently used for most optical recording media since the Thermal Cross phenomenon hardly occurs. However, in the method shown in FIG. 1C, previously-formed marks may also be affected by applying too much heat when forming predetermined marks.

Different recording waveforms are used for different kinds of discs, i.e., DVD-RAM, DVD-RW, and the like. This is because the characteristics of recording layers are different from each other. The use of different recording waveforms for different discs becomes a problem when manufacturing drives for recording data on all kinds of discs. This is because drives that can read all kinds of discs should realize various recording waveforms, which increases costs.

SUMMARY OF THE INVENTION

To solve the above-described problems, it is a first object of the present invention to provide a method and apparatus for recording data using a recording waveform which is capable of preventing leading and trailing edges of a mark from being distorted and preventing degradation caused by repeated recording.

It is a second object of the present invention to provide a method and apparatus for recording data using a recording waveform having an erase pattern which is capable of improving the shape of a mark.

It is a third object of the present invention to provide a method and apparatus for recording data using a recording waveform which is adaptable to a disc having a recording layer of various characteristics.

It is a fourth object of the present invention to provide a method and apparatus for generating erase pulses based on information about the power level of the erase pulses.

It is a fifth object of the present invention to provide a method and apparatus for controlling the power level of predetermined erase pulses to uniformly erase a recording mark.

Accordingly, to achieve the above objects, there is provided a method of recording data on an optical recording medium. Generated is a recording waveform having an erase pattern including a predetermined pulse having a high level which is higher than an erase power level and having a low level which is lower than the erase power level.

The mark and the space are recorded according to a run length limited scheme (2, 10). It is preferable that the mark is recorded using a first level of predetermined NRZI and the space is recorded using a second level of the predetermined NRZI data.

The above objects can be achieved by a method of recording data on a recording medium. Digital data whose channel is modulated is generated. Generated is a recording waveform having an erase pattern including a predetermined pulse having a high level which is higher than an erase power level and having a low level which is lower than the erase power level. Marks are formed according to a first level data of the digital data and spaces are formed according to a second level data of the digital data using the generated recording waveform on the level information.

When generating the digital data, level information of an erase pulse recorded on the optical recording medium is read. Also, when generating the recording waveform, the erase pattern included in the generated recording waveform is formed by an erase pulse generated based on the level information. The level information of the erase pulse is input from a user.

The method is performed based on a (2, 10) run length limited scheme or a (1,7) run length limited scheme.

It is preferable that the power level of a first pulse of the erase pattern is a low level of the erase pattern and the power level of a last pulse of the erase pattern is a high level. It is preferable that the power level of a first pulse of the erase pattern is a high level of the erase pattern and the power level of a last pulse of the erase pattern is a high level or the power level of a first pulse of the erase pattern is a low level of the erase pattern and the power level of a last pulse of the erase pattern is a low level or the power level of a first pulse of the erase pattern is a high level of the erase pattern and the power level of a last pulse of the erase pattern is a low level.

It is preferable that a ratio of the time for which a high level of a multi-pulse lasts to the time for which a low level of the multi-pulse lass is 1:1, and the time for which the high level lasts is 1/2 of a clock cycle.

The mark is formed using a first level of predetermined NRZI data and the space is formed using a second level of the NRZI data.

The recording waveform includes cooling pulses and the erase pattern comprises a portion of the cooling pulses. If an ending point of the cooling pulse is smaller or greater than 0.5T from a trailing edge of the NRZI signal, the time for which the first pulse constituting the erase pattern lasts is increased to more than 0.5T.

It is preferable that a unit pulse constituting the erase pattern has a high level and a low level which are controlled according to the time for which the first pulse constituting the recording waveform lasts.

The recording pattern includes a multi-pulse. It is preferable that the recording pattern has at least two power levels.

To achieve the above objects, there is provided an apparatus for recording data on an optical recording medium. The apparatus includes a recording waveform generator and a pickup unit. The recording waveform generator generates a recording waveform having an erase pattern including a multi-pulse. The pickup unit radiates light onto the optical recording medium according to the generated recording waveform to form a mark or a space.

The apparatus further includes a power information management unit which reads pulse level information of the erase pattern recorded on the optical recording medium and provides it to the recording waveform generator. The recording waveform generator generates the recording waveform having the erase pattern including the multi-pulse based on the level information of the erase pattern. The power information management unit may receive the pulse level information of the erase pattern from a user and provide it to the recording waveform generator.

It is preferable that the apparatus further includes a channel modulator which modulates a channel of data provided from the outside to generate NRZI data and outputs NRZI data to the recording waveform generator.

It is preferable that pickup unit includes a motor, an optical head, a servo circuit, and a laser driver. The motor rotates the optical recording medium. The optical head radiates light onto the optical recording medium or receives laser light reflected from the optical recording medium. The servo circuit servo-controls the motor and the optical head. The laser driver drives a laser installed on the optical head.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1A is a view of recording waveforms according to a conventional method;

FIGS. 1B and 1C are views of shapes of marks formed on an optical recording medium;

FIGS. 2A and 2B are block diagrams of recording apparatuses according to preferred embodiments of the present invention;

FIGS. 3A and 3B are examples realized by the recording apparatus shown in FIGS. 2A and 2B, respectively;

FIGS 4A through 4C are examples of recording waveforms generated by a recording waveform generator 2;

FIG. 5 is another example of a recording waveform generated by the recording waveform generator 2;

FIG. 6 is a view of waveforms explaining four types of erase patterns according to a preferred embodiment of the present invention;

FIG. 7 is a view of more examples of (a) LH shown in FIG. 6;

FIGS. 8 through 10 are views of shapes of marks recorded through simulation;

FIGS. 11 through 15 are graphs illustrating the characteristics of DVD-RAM;

FIGS. 16 through 20 are graphs illustrating the characteristics of DVD-RW;

FIGS. 21A and 2B are graphs illustrating nucleation and crystal growth rate according to temperatures of a AgInSbTe recording layer and a GeSbTe recording layer, respectively; and

FIGS. 22A and 22B are flowcharts illustrating recording methods according to preferred embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the attached drawings.

FIGS. 2A and 2B are block diagrams of recording apparatuses according to preferred embodiments of the present invention. Referring to FIG. 2A, the recording apparatus, which forms a mark or space to record data on an optical recording medium 200, includes a pickup unit 1, a recording waveform generator 2, and a channel modulator 3.

The channel modulator 3 modulates input data to a channel bit sequence. The recording waveform generator 2 is supplied with information about the channel bit sequence and erase powers P_{b1} and P_{b2} and generates a recording waveform for recording the channel bit sequence. The generated recording waveform includes an erase pattern having erase mulit-pulses. The recording waveform will be described in detail later. The pickup unit 1 radiates light onto the optical recording medium 200 according to the generated recording waveform to form a mark or a space.

Referring to FIG. 2B, the recording apparatus, which forms a mark or a space to record data on the optical recording medium 200, includes a pickup unit 1, a recording waveform generator 2, a channel modulator 3, and a power information management unit 4.

The channel modulator 3 modulates input data to a channel bit sequence. The power information management unit 4 reads information about erase powers P_{b1} and

P_{b2} from the optical recording medium 200 or receives the information from the outside.

The recording waveform generator 2 is supplied with information about the channel bit sequence and the erase powers P_{b1} and P_{b2} and generates a recording waveform for recording the channel bit sequence based on information about the erase powers P_{b1} and P_{b2}. The generated recording waveform includes an erase pattern having erase multi-pulses. The recording waveform will be described in detail later. The pickup unit 1 radiates light onto the optical recording medium 200 according to the generated recording waveform to form a mark or a space.

The power information management unit 4 first performs tests for recording and erasing predetermined test data (random data or predetermined data) in a test area of the optical recording medium 200 at predetermined value intervals (e.g., a value of 3 – 4 % of a level value) within a predetermined range (e.g., a range of ±20%) based on information about the erase powers P_{b1} and P_{b2}. Next, the power information management unit 4 selects optimum conditions among the test conditions (e.g., conditions in which a jitter value is minimum, the resolution is the highest, the degree of modulation is maximum, and the like) based on the test results, and provides the optimum conditions to the recording waveform generator 2.

FIGS. 3A and 3B are examples realized by the recording apparatuses shown in FIGS. 2A and 2B, respectively. Elements that are the same as those in FIGS. 2A and 2B are described with the same numerals, and thus their detailed descriptions are omitted.

Referring to FIG. 3A, the recording apparatus includes a pickup unit 1, a recording waveform generator 2, and a channel modulator 3. The pickup unit 1 has a motor 11, a servo circuit 12, an optical head 13, and a laser driver 14. The motor 11 rotates an optical disc 200. The servo circuit 12 servo-controls the motor 11 and the optical head 13. The optical head 13 radiates laser light onto the optical disc 200 and receives laser light reflected from the optical disc 200. The laser driver 14 drives a laser (not shown) installed on the optical head 13.

The channel modulator 3 modulates input data to a channel bit sequence and outputs Non Return to Zero Inverted (NRZI) data. The recording waveform generator 2 generates a recording waveform for recording NRZI data based on information about erase powers P_{b1} and P_{b2} and provides it to the laser driver 14 in the pickup unit 1.

The laser driver 14 controls the laser using the received recording waveform to form a mark or a space on the optical recording medium 200.

Referring to FIG. 3B, the recording apparatus includes a pickup unit 1, a recording waveform generator 2, a channel modulator 3, and a power information management unit 4. The pickup unit 1 includes a motor 11, a servo circuit 12, an optical head 13, and a laser driver 14. The motor 11 rotates an optical recording medium 200. The servo circuit 12 servo-controls the motor 11 and the optical head 13. The optical head 13 radiates laser light onto the optical disc 200 and receives laser light reflected from the optical disc 200. The laser driver 14 drives a laser (not shown) installed on the optical head 13.

The channel modulator 3 modulates input data to a channel bit sequence and outputs NRZI data. The power information management unit 4 reads information about erase powers P_{b1} and P_{b2} recorded on the optical recording medium or receives the information from the outside. The recording waveform generator 2 generates a recording waveform for recording NRZI data based on the information about the erase powers P_{b1} and P_{b2} and provides it to the laser driver 14 in the pickup unit 1.

The laser driver 14 controls the laser using the received recording waveform to form a mark or a space on the optical disc 200.

FIGS. 4A through 4C are examples of recording waveforms generated by the recording waveform generator 2. In FIG. 4A, N-2 pulses are necessary for recording a mark for arbitrary N periods of a reference clock signal of integers 2 – 14, and N-1 pulses are necessary for generating a space for erasing the existing mark for the arbitrary N periods of the reference clock signal. In FIG. 4B, N-1 pulses are necessary for recording the mark for arbitrary N periods T of a reference clock signal of integers 2 – 14, and N-1 pulses are necessary for generating a space for erasing the existing mark for the arbitrary N periods of the reference clock signal so that the end position of a first one of recording pulses corresponds to the end portion of a first clock pulse. In FIG. 4C, N-1 pulses are necessary for recording a mark for arbitrary N periods T of a reference clock signal of integers 2 – 14, and N-2 pulses are necessary for generating a space for erasing the existing mark for arbitrary N periods of the reference clock signal so that the end position of a first one of recording pulses corresponds to the end portion of a second clock pulse and the last one of the recording pulses corresponds to the end portion of NRZI.

Referring to FIG. 4A, NRZI data varies depending on the modulation method of the channel modulator 3. In other words, in a case where NRZI data is modulated to Run Length Limited (RLL) (2, 10) data, i.e., the minimum length of a mark is 3T and the maximum length of the mark is 11T according to Eight to fourteen Modulation (EFM), Eight to fourteen Modulation plus (EFM+), D(8-15), and Dual modulation (?). Here, D(8-15) is a modulation method published in "Optical Disc Recording System of 25GB Capacity" by Massida in Optical Data Storage (ODS), 2001. Dual modulation is disclosed in Korea Patent Application No. 99-42032, titled "Method Of Arranging RLL Code Having Improved DC Restraint Capability, Modulation and Demodulation Method, and Demodulation Apparatus", which was filed on 30 September, 1999 and published on 25 November, 2000, by the applicant of the present invention. The minimum recording mark is 2T and the maximum recording mark is 8T when using RLL(1,7).

When forming a high level of NRZI data with a mark and a low level with a space, the recording waveform includes a recording pattern for recording a mark having a length of 7T, an erase pattern for forming a space having a length of 3T, and a recording pattern for recording a mark having a length of 3T.

The recording pattern is composed of a pulse sequence. The erase pattern is also composed of a pulse sequence as shown in section F. Tmp represents a width of multi-pulses constituting the recording pattern. Here, the multi-pulses represent at least one pulse whose width and power strength are identical. In this embodiment, Tmp is 0.5T. Tlp represents a width of the last pulse constituting the recording pattern. Tcl represents the time for which a cooling pulse lasts. The cooling pulse ranges over the recording pattern and the erase pattern. Temp represents a width of an erase multi-pulse constituting the erase pattern. In this embodiment, Temp is 0.5T. Tsfp represents the time from a point when NRZI data is switched from low level to high level to a point when a first pulse constituting the recording pattern starts. Tsfp affects the power level of the erase pattern. In other words, as shown, if Tsfp is greater than 0.5T, the multi-pulse included in the erase pattern is ended at the low level P_{b1} and subsequent Tsfp starts at the high level P_{b2} of the multi-pulse. In contrast, if Tsfp is smaller than 0.5T, the multi-pulse included in the erase pattern is ended at a low level P_{b1} and subsequent Tsfp maintains the low level P_{b1} of the multi-pulse.

Referring to FIG. 4B, two recording pattern examples are shown: when forming a high level of NRZI data with a mark and a low level with a space, the recording waveform includes a recording pattern for recording a mark having a length of 7T, an erase pattern for forming a space having a length of 3T, and a recording pattern for recording a mark having a length of 2T; and when forming a high level of NRZI with a mark and a low level with a space, the recording waveform includes a recording pattern for recording a mark having a length of 7T, an erase pattern for forming a space having a length of 5T, and a recording pattern for recording a mark having a length of 2T. The number of pulses in the recording mark section is 1 more than the number of pulses shown in FIG. 4A.

Referring to FIG. 4C, two recording pattern examples are shown: when forming a high level of NRZI data with a mark and a low level with a space, the recording waveform includes a recording pattern for recording a mark having a length of 7T, an erase pattern for forming a space having a length of 3T, and a recording pattern for recording a mark having a length of 2T; and when forming a high level of NRZI data with a mark and a low level with a space, the recording waveform includes a recording pattern for recording a mark having a length of 7T, an erase pattern for forming a space having a length of 5T, and a recording pattern for recording a mark having a length of 2T. The number of pulses is 1 more than the number of pulses shown in FIG. 4A in the recording mark section, but 1 less than the number of pulses shown in FIG. 4A in the space mark section.

FIG. 5 shows another recording waveform generated by the recording waveform generator 2. Referring to FIG. 5, when forming a high level of NRZI data with a mark and a low level with a space, the recording waveform includes a recording pattern for recording a mark having a length of 7T, an erase pattern for forming a space having a length of 5T, and a recording pattern for recording a mark having a length of 3T.

The recording pattern is composed of a pulse sequence. The erase pattern is also composed of a pulse sequence as shown in section G. Tmp represents a width of a multi-pulse constituting the recording pattern. The multi-pulse represents at least one pulse whose width and power strength are identical. In this embodiment, Tmp is 0.5T. Tlp represents a width of the last pulse constituting the recording pattern. Tcl represents the time for which a cooling pulse lasts. The cooling pulse ranges over the recording pattern and the erase pattern. Temp represents a width of an erase multi-pulse constituting the erase pattern. In this embodiment, Temp is 0.5T. Tsfp represents the time from a point when NRZI data is switched from low level to high level to a point when a first pulse constituting the recording pattern starts. Tsfp affects the power level of the erase pattern. In other words, as shown, if Tsfp is greater than 0.5T, the multi-pulse included in the erase pattern is ended at the low level P_{b1} and subsequent Tsfp starts at the high level P_{b2}. In contrast, if Tsfp is smaller than 0.5T, the multi-pulse included in the erase pattern is ended at the low level P_{b1} and subsequent Tsfp maintains the low level P_{b1} of the multi-pulse.

FIG. 6 is a view of waveforms for explaining four types of erase patterns according to a preferred embodiment of the present invention. Referring to FIG. 6, an erase pattern according to the present invention is classified into four types: (a) LH, (b) HH, (c) HL, and (d) LL. Each erase pattern is marked with a circle for easy identification of the differences. (a) LH represents that the power of a first pulse constituting the erase pattern is equal to the low level P_{b1} of a subsequent erase multi-pulse, the last erase multi-pulse constituting the erase pattern is ended at the low level P_{b1}, and power level of subsequent Tsfp is equal to the high level P_{b2} of the erase multi-pulse. (b) HH represents that the power of a first pulse constituting the erase pattern is equal to the high level P_{b2} of a subsequent erase multi-pulse, the last erase multi-pulse constituting the erase pattern is ended at the high level P_{b2}, and level of subsequent Tsfp is maintained at the high level P_{b2} of the erase multi-pulse. (c) HL represents that the power of a first pulse constituting the erase pattern is equal to the high level P_{b2} of a subsequent erase multi-pulse, the last erase multi-pulse constituting the erase pattern is ended at the high level P_{b2}, and the level of subsequent Tsfp is equal to the low level P_{b1} of the erase multi-pulse. Finally, (d) LL represents that power of a first pulse constituting the erase pattern is equal to low the level P_{b1} of a subsequent erase multi-pulse, the last erase multi-pulse constituting the erase pattern is ended at the low level P_{b1}, and level of subsequent Tsfp is maintained at the low level P_{b1} of the erase multi-pulse.

In examples of the recording waves shown in FIGS. 4A through 6, the level of Tcl of the last pulse of the recording waveform is equal to the high level of the recording pulse, but may have any intermediate level value of level values between the high level of the recording pulse and the high level of the erase pulse.

FIG. 7 shows other examples of (a) LH shown in FIG. 6. Referring to FIG. 7, (e) LH2 is identical to (a) LH of FIG. 6, except that the time Temp1, for which the high level P_{b2} of the erase multi-pulse constituting one period lasts, and the time Temp2, for which the low level P_{b1} lasts, are 0.7T and 0.3T, respectively. (f) LH3 is also identical to (a) LH of FIG. 6 except that the time Temp, for which the high level P_{b2} lasts and for which the low level P_{b1} of an erase multi-pulse lasts, is 1.0T. Here, the ratio of the time Temp1, for which the high level P_{b2} of the erase multi-pulse constituting one period lasts, to the time Temp2 for which the low level P_{b1} lasts, is m:n (m and n are integers). This value may vary.

The recording waveform according to the present invention has an erase pattern including an erase multi-pulse with high level and low level powers P_{b1} and P_{b2} so as to reduce distortion of the trailing edge of a mark and improve the reproduction characteristic of the mark. In particular, the recording waveforms described in previous embodiments are formed by controlling the times for which the high level P_{b1} and the low level P_{b2} of the erase multi-pulse last, i.e., the "lasting times", to be within a range of 0.25 – 0.75T of the clock period T to select a lasting time suitable for thermal characteristics of the disc 200. Thus, the recording waveforms greatly reduce distortion of the trailing edge of a mark and improve the reproduction characteristic of the mark.

Information about four types of erase patterns (information about type or erase pulse levels P_{b1} and P_{b2}) may be recorded in a lead-in region of a recordable disc or may be included as header information in a wobble signal. Thus, when recording data, the recording apparatus reads information about the type or level of the erase pulse from the lead-in region or the wobble signal to generate a corresponding recording waveform so as to form a mark and a space.

Four types of erase patterns may be used as sings for representing the speed factor of a disc or the kinds of marks when recording/reproducing data. For example, the signs can say information "A disc using an LH type erase pattern has a speed factor of 20".

To obtain optimized recording/reproducing conditions for four types of erase patterns, level values of the erase pulse are recorded in and reproduced from a predetermined test area of the disc within a predetermined range (e.g., a range of ±20) in each predetermined unit (e.g., a unit of 3 – 4% of the erase pulse level). A corresponding recording waveform is generated from these results to form a mark and a space. Here, there are several methods of determining optimized recording conditions: measuring jitter to select the conditions under which a jitter value becomes minimum; measuring bit error rate to select a condition where bit error rate becomes minimum; deducing a condition where resolution (a value obtained by diving an amplitude value of the shortest signal by an amplitude value of the longest signal) is maximum; measuring modulation (a value obtained by dividing a high level value of the longest signal by a low level value of the longest signal) to deduce a recording condition where modulation is maximum; and measuring asymmetry to deduce a recording condition within a predetermined standard. In the test method, a random pattern or a predetermined pattern may be used.

To ascertain effects of the present invention, the shapes of marks recorded through simulation were observed. A structure used in the simulation is shown in table 1. A used disc has a four-layer structure.

[Table 1]

	Substrate	Dielectric layer	Recording layer	Dielectric layer	Reflective layer
Material	PC	ZnS-SiO2	Sb-Te eutectic	ZnS-SiO2	Ag alloy
Thickness	0.6mm	128nm	14nm	16nm	30nm

The simulation was performed under the conditions of a wavelength of 405nm, a numerical aperture NA of 0.65, and a linear velocity of 6m/s. To observe the shapes of marks, a first mark having a length of 8T was recorded and then a second mark having a length of 8T was recorded so as to overlap 4T of the first mark. FIGS. 8 through 10 show the results of comparing marks when using a conventional recording waveform and marks when using a recording waveform according to the present invention. FIG. 8 (a) is a mark formed through simulation, (b) is a mark formed on the mark (a) by a recording waveform according to the present invention, (c) is a mark formed on the mark (a) by a recording waveform according to the prior art. FIG. 9 (d) is a mark formed through simulation, (e) is a mark formed on the mark (d) by a recording waveform having an erase pattern according to the present invention, and (f) is a mark formed on the mark (d) by a recording waveform having a DC erase pattern according to the prior art. FIG. 10 (g) is a mark formed through simulation, (h) represents the mark (g) after it has been erased by the erase pattern according to the present invention, and (i) represents the mark (g) after it has been erased by the DC erase pattern according to the prior art.

Table 2 shows the parameters of a thin film used for simulation for thermal analysis.

[Table 2]

Material	Λ=405nm		C(J/cm3k)	K(W/cmK)
	n	k		
ZnS-SiO2	2.300	0.000	2.055	0.0058
Sb-Te eutectic (crystal)	1.650	3.150	1.285	0.0060
Sb-Te eutectic (amorphous)	2.900	2.950	1.285	0.0060
Ag alloy	0.170	2.070	2.450	0.2000

Referring to the simulation results shown in FIGS. 8 through 10, it can be seen that a trailing edge of the mark (b) formed by the recording waveform having the erase pattern according to the present invention is similar in shape to the mark formed through the simulation than the trailing edge of the mark (c) formed by the recording waveform having the DC erase pattern according to the prior art. In FIG. 9, it can be seen that the shape of leading edge of the mark formed by the erase pattern according to the present invention is better than that of the leading edge of the mark according to the prior art. From the simulation results, it could be ascertained that the shape of a mark according to the present invention is improved by using a recording waveform having an erase pattern composed of an erase multi-pulse compared to the shape of a conventional mark. The shape, width, and power level of the erase multi-pulse can be controlled to further reduce the distortion of the shape of the mark.

To experimentally verify the effects of the present invention, parameters necessary for obtaining recording waveforms as shown in FIGS. 4 and 5, i.e., lasting time and power level, were obtained from 4.7GB DVD-RAM and 4.7GB DVD-RW discs using a DVD estimator having a wavelength of 650nm and a NA of 0.60. Next, repeated recording/reproducing characteristics were compared with recording/reproducing characteristics obtained by an existing method.

FIGS. 11 through 15 are graphs showing the characteristics of a DVD-RAM. FIGS. 11 through 13 show recording characteristic data according to time changes of power and Tsfp when erasing a mark from the DVD-RAM using an existing DC erase pattern. In FIGS. 11 through 13, power conditions used for testing the DC erasing process are Pw=14.5mW, Pb1=6.0mW, Pb2=4.5mW, and Pb3=3.2mW.

FIG. 11 (a) and (b) show jitter characteristics according to the writing power Pw and an erase power Pe with respect to the leading edge, trailing edge, and both edges of a mark when erasing the mark using the existing DC erase pattern.

FIGS. 12 and 13 show results measured when erasing a mark using an existing DC erase pattern. Referring to FIG. 12 (a), (b), and (c) and FIG. 14 (a) and (b), when Tsfp is 0.5T and 0.4T, respectively, with respect to DC erase patterns of NRZI data having lengths of above 3T and 4T, the jitter characteristics corresponding to the DC erase patterns are the most excellent. When Tlp is 0.7T, the jitter characteristics are good, and the value of Tle is out of relation to the jitter characteristics.

A mark was formed using the recording waveform having the previously described four types of erase pattern based on the obtained parameters and then the characteristics of the mark were measured. The measured results are as follows.

FIGS. 14 shows jitter characteristics of the four types of erase patterns shown in FIG. 6. Referring to FIG. 14 (a), it can be seen that of the four types, LH is the most excellent. When measuring recording characteristics according to the method of the present invention as shown in FIG. 14, power conditions of Pw=14.5mW, Pb2=7.0mW, Pb1=5.0mW, and Pc=3.2mW were obtained. Here, ΔPb (Pb2-Pb1)=2.0mW. Powers P_{b1} and P_{b2} have the following relationship with a recording condition Pe: Pc≤Pb1≤Pe, Pe≤Pb2≤Pw. Here, if P_{b1} is too much lower than Pe, a recording mark is not completely erased. If P_{b2} is too much higher than Pe, another recording mark is created when erasing the recording mark, which results in the degradation of a reproduction signal. Thus, it is preferable that P_{b1} is greater than 0.5*Pe with respect to Pe and P_{b2} is smaller than 1.5*Pe with respect to Pe.

FIG. 14 (b) shows jitter characteristics with respect to the difference ΔPb (Pb2-Pb1) between the high level and the low level of an erase multi-pulse when a mark is erased using an erase pattern composed of the erase multi-pulse. It can be seen that the jitter characteristics are hardly changed up to 5mW.

FIG. 15 shows jitter characteristics when repeatedly recording and reproducing marks using a recording pulse having an erase pattern according to the present invention. Referring to FIG. 15, since the marks are erased using an erase multi-pulse, repeated recording characteristics of the mark are good.

FIGS. 16 through 20 are graphs showing the characteristics of DVD-RW.

FIGS. 16 through 18 show recording characteristic data according to time changes of power and Tsfp when erasing a mark using an existing DC erase pattern from a DVD-RW disc. In FIGS. 16 through 18, it can be seen that power conditions used as test data for the DC erasing process are Pw=14.0mW, Pe=6.0mW, are Pc=0.5mW.

FIGS. 16(a) and 16(b) show jitter characteristics according to the writing power Pw and erase power Pe with respect to the leading edge, trailing edge, and both edges of a mark when erasing the mark using an existing DC erase pattern.

FIGS. 17 and 18 show results measured when erasing a mark using an existing DC erase pattern. Referring to FIGS. 17 and 18, it is preferable that Ttop is 1.2T and 1.45T with respect to marks having lengths of above 3T and 4T, respectively. It is preferable that Tlp, which is the last pulse constituting a recording pattern, is good at 0.55T and Tle is good at 1.0T and 1.1T.

A mark was formed using a recording waveform having the previously-described four types of erase patterns based on the obtained parameters and then the reproducing characteristics of the mark were measured. The measured results are as follows.

FIG. 19 shows jitter characteristics of the four types of erase patterns shown in FIG. 6. Referring to FIG. 19, it can be seen that, of the four types, HH is the most excellent. When measuring recording characteristics according to the method of the present invention shown in FIG. 19, power conditions of Pw=14.0mW, P_{b2}=6.5mW, P_{b1}=5.5mW, and Pc=0.5mW were obtained. Here, the difference between P_{b1} and P_{b2} is 1.0mW, i.e., ΔPb (P_{b2}-P_{b1})=1.0mW. Powers P_{b1} and P_{b2} have the following relationship with a recording condition Pe when erasing a mark with a DC erase pattern: $Pc \leq P_{b1} \leq Pe$, $Pe \leq P_{b2} \leq Pw$. If P_{b1} is too much lower than Pe, the recording mark is not completely erased. If P_{b2} is too much higher than Pe, another recording mark is created when erasing the recording mark, which results in the degradation of a reproduction signal. Thus, it is preferable that P_{b1} is greater than 0.7*Pe with respect to Pe and P_{b2} is smaller than 1.3*Pe with respect to Pe.

Jitter characteristics can be obtained with respect to a difference ΔPb (Pb2-Pb1) between the high level and the low level of an erase multi-pulse when erasing the mark using an erase pattern composed of the erase multi-pulse according to the present invention. Since the jitter characteristics were sharply degraded above 3mW, a power of 1mW was selected as the recording/reproducing condition.

FIG. 20 shows jitter characteristics obtained when repeatedly recording/reproducing a mark using a recording pulse having an erase pattern according to the present invention. Referring to FIG. 20, it can be seen that since the mark is erased using the erase multi-pulse, the repeated recording characteristics of the mark are good. However, when the recording of the mark is repeated more than

2000 times, jitter characteristics are sharply degraded. Thus, it is advantageous to use a pulse erase method according to the present invention when the mark is repeatedly recorded 1000 times, which is guaranteed to happen in a DVD-RW disc.

The above experiments used the EFM+ modulation method of the DVD format. In a case where other modulation methods generally used for stably recording a recording mark, e.g., RLL(1,7), D(8-15), Dual modulation, and the like, are adopted, the same results can also be obtained.

FIGS. 21A and 21 B are graphs showing nucleation frequency and crystal growth rate according to temperatures of an AgInSbTe recording layer and a GeSbTe recording layer, respectively. As shown in FIGS. 4A through 7, in the present invention, the erase power P_{b1} of the erase multi-pulse is greater than the erase power Pe and the erase power P_{b2} is smaller than the erase power Pe. In other words, the erase powers are controlled according to the characteristics of the recording layers. Also, information about the erase powers P_{b1} and P_{b2} is recorded on an optical recording medium and a drive reads information about the erase powers P_{b1} and P_{b2}. Thus, information about the erase powers P_{b1} and P_{b2} can be used as reference information for generating erase pulses. In the case of an optical recording medium on which the erase power P_{b1} or P_{b2} is not recorded, information about the erase powers P_{b1} and P_{b2} can be input from the outside and used as reference information for generating erase pulses.

Referring to FIG. 21A, temperatures of crystal growth rate and nucleation frequency are equal in the AgInSbTe recording layer which is mainly used in DVD-RW. The temperature of a portion of the erase region in which erasing is ended becomes higher than the temperature of a portion of the erase region in which erasing starts due to thermal accumulation when erasing a mark with DC erase power. As a result, the quality of the reproduction signal may be degraded. However, in the present invention, it is possible to set pulse erase powers P_{b2} and P_{b1} where crystal growth is maximum. Here, the temperatures of the portion of the erase region where erasing starts and the portion of the erase region where erasing ends can be maintained to be almost identical. Thus, the recording mark is uniformly erased, which reduces noise so as to improve the quality of the reproduction signal.

Referring to FIG. 2B, in the GeSbTe recording layer which is mainly used in DVD-RAM, the temperature of crystal growth rate is higher than the temperature of nucleation frequency. Thus, after nucleation is achieved by a pulse erase, crystal growth rate becomes higher when an existing mark is overwritten by Pe having a high temperature and high level P_{b2}. As a result, the erasing (crystallization) is not performed well. Thus, the characteristics of the leading and trailing edges of the recording mark are improved when recording the recording mark by the pulse erase method of the present invention. Also, the recording mark is uniformly erased, which reduces noise so as to improve the quality of the reproduction signal.

A recording method according to a preferred embodiment of the present invention will be described based on the above-described structure.

FIGS. 22A and 22B are flowcharts explaining a recording method according to the preferred embodiment of the present invention. Referring to FIG. 22A, a recording apparatus receives data from the outside, modulates it, and generates NRZI data in step 1801. In step 1802, a recording waveform having an erase pattern containing an erase multi-pulse is generated. A mark or space is formed on the disc 200 using the generated recording waveform in step 1803.

Referring to FIG. 22B, the recording apparatus receives data from the outside, modulates it, generates NRZI data, and obtains information about erase powers P_{b1} and P_{b2} in step 2201. In step 2202, a recording waveform having an erase pattern is generated based on information about the erase powers P_{b1} and P_{b2}. A mark or space is formed on the disc 200 using the generated recording waveform in step 2203.

As described above, in a method and apparatus for recording data according to the present invention, a recording waveform can prevent the shape of a mark from being distorted due to thermal interference and thermal accumulation between adjacent marks when recording the marks and improve the shape of the mark. As a result, the recording/reproducing characteristics of the mark can be improved.

What is claimed is:

1. A method of recording data on an optical recording medium, the method comprising:

generating a recording waveform having an erase pattern comprising a multi-pulse having a high level and a low level;

setting a power level of a first pulse of the erase pattern, and a power level of a period between an end of the erase pattern and a start point of a first pulse of a recording pattern, to the high level of the multi-pulse or the low level of the multi-pulse based on pulse information stored on the optical recording medium; and

radiating a light onto the optical recording medium according to the generated recording waveform to form a mark or a space;

wherein the pulse information stored on the optical recording medium comprises:

power level information regarding the power level of the first pulse of the erase pattern, and the power level of the period between the end of the erase pattern and the start point of the first pulse of the recording pattern; and

duration information regarding a duration of the period between the end of the erase pattern and the start point of the first pulse of the recording pattern.

2. The method of claim 1, further comprising forming a mark and a space according to a run length limited scheme.

3. The method of claim 1, further comprising forming a mark in response to a first level of NRZI data, and forming a space in response to a second level of the NRZI data.

4. The method of claim 1, wherein the power level of the first pulse of the erase pattern is set to the low level of the multi-pulse, and the power level

of the period between the end of the erase pattern and the start point of the first pulse of the recording pattern is set to the high level of the multi-pulse.

5. The method of claim 1, wherein the power level of the first pulse of the erase pattern is set to the high level of the multi-pulse, and the power level of the period between the end of the erase pattern and the start point of the first pulse of the recording pattern is set to the high level of the multi-pulse.

6. The method of claim 1, wherein the power level of the first pulse of the erase pattern is set to the low level of the multi-pulse, and the power level of the period between the end of the erase pattern and the start point of the first pulse of the recording pattern is set to the low level of the multi-pulse.

7. The method of claim 1, wherein the power level of the first pulse of the erase pattern is set to the high level of the multi-pulse, and the power level of the period between the end of the erase pattern and the start point of the first pulse of the recording pattern is set to the low level of the multi-pulse.

8. The method of claim 1, wherein a ratio of a time for which the high level of the multi-pulse lasts to a time for which the low level of the multi-pulse lasts is 1:1.

9. The method of claim 8, wherein the time for which the high level of the multi-pulse lasts is 1/2 of a clock cycle.

10. The method of claim 1, wherein a ratio of a time for which the high level of the multi-pulse lasts to a time for which the low level of the multi-pulse lasts is m:n, where m and n are integers.

11. The method of claim 1, wherein the pulse information stored on the optical recording medium is determined according to a thermal characteristic of the optical recording medium.

12. The method of claim 1, wherein the pulse information stored on the optical recording medium is determined according to a reproduction speed characteristic of the optical recording medium.

Application number / numéro de demande: 2414172

Figures: 8-9-10

Pages:

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(Commander les documents originaux dans la section de préparation des dossiers au 10ème étage)

FIG. 1A (PRIOR ART)

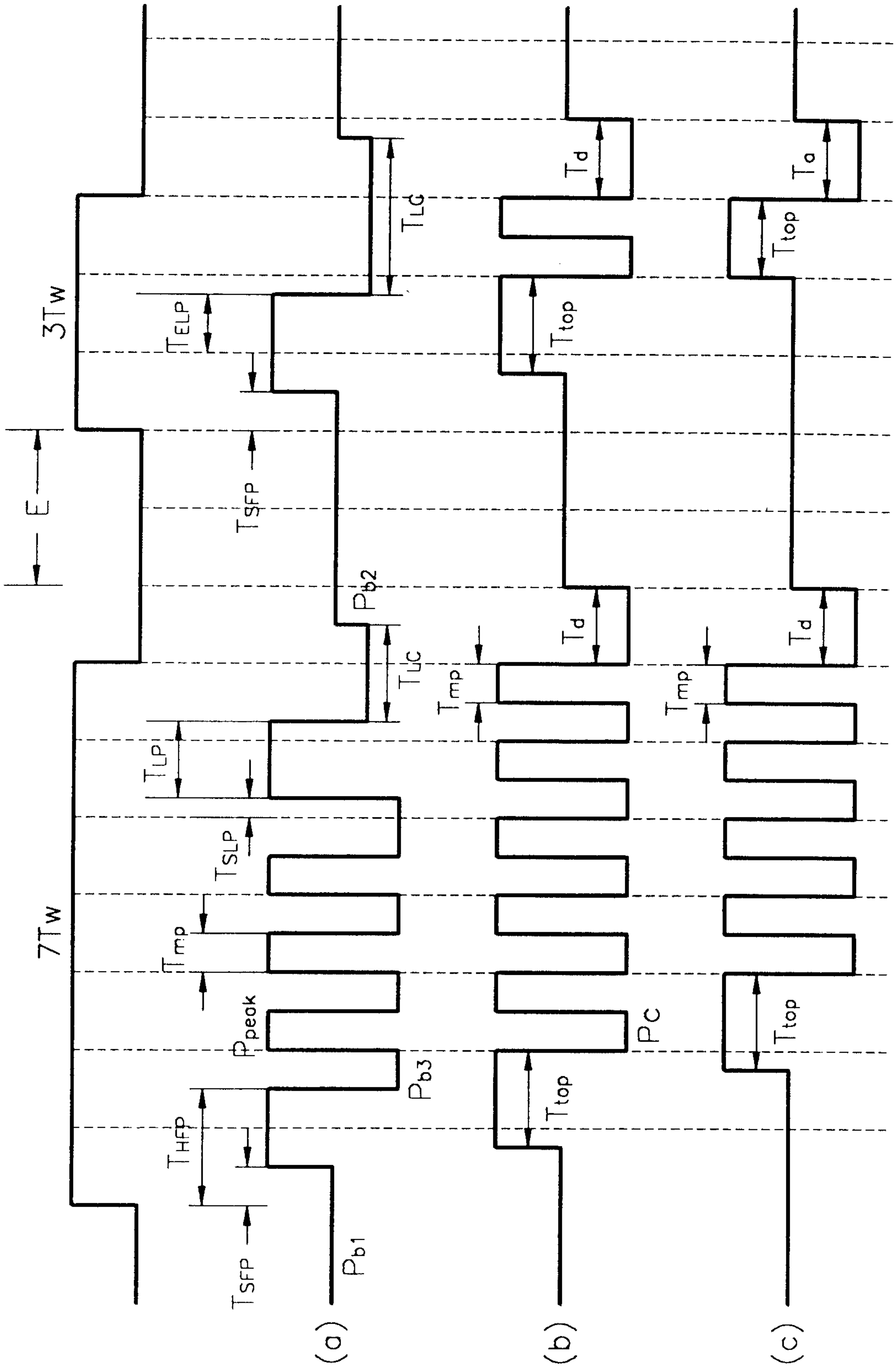


FIG. 1B (PRIOR ART)

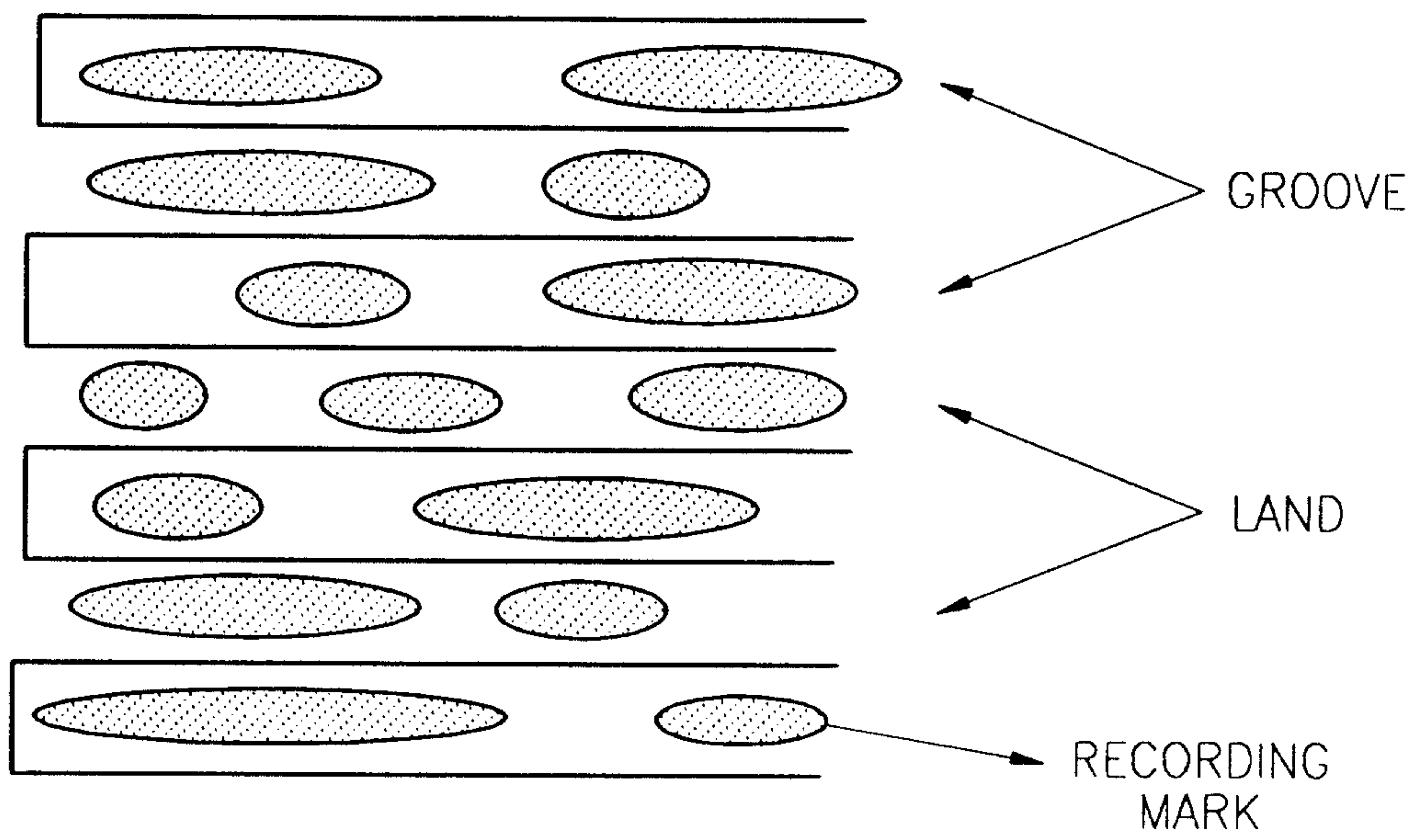


FIG. 1C (PRIOR ART)

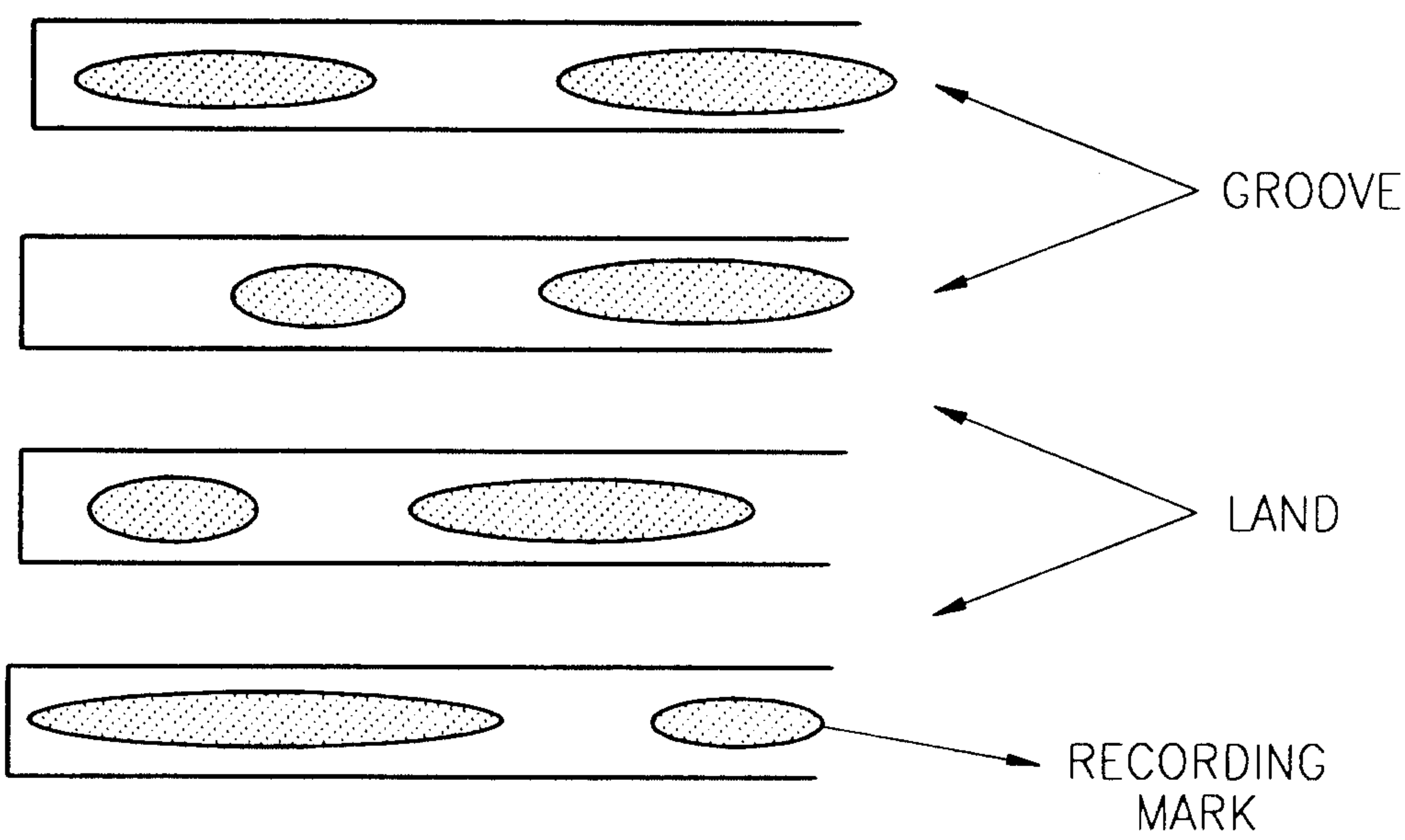


FIG. 2A

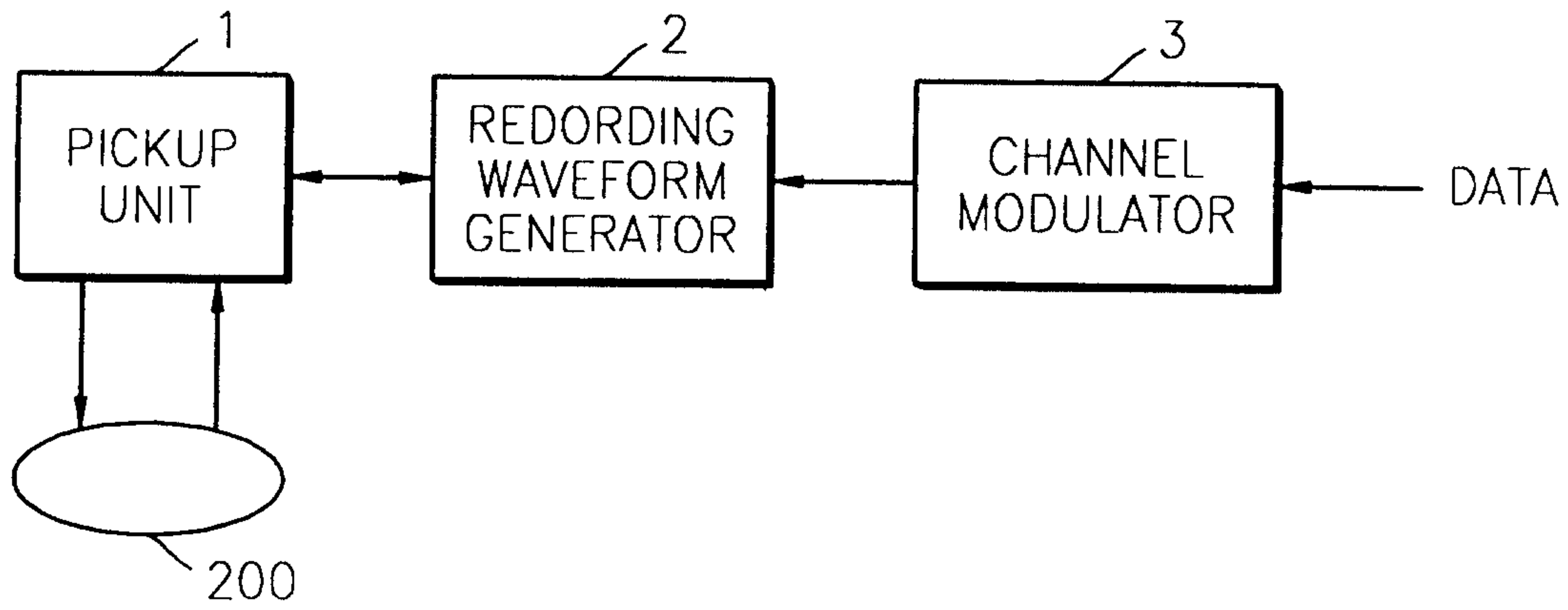

1
PICKUP UNIT
2
REDORDING WAVEFORM GENERATOR
3
CHANNEL MODULATOR
DATA
200

FIG. 2B

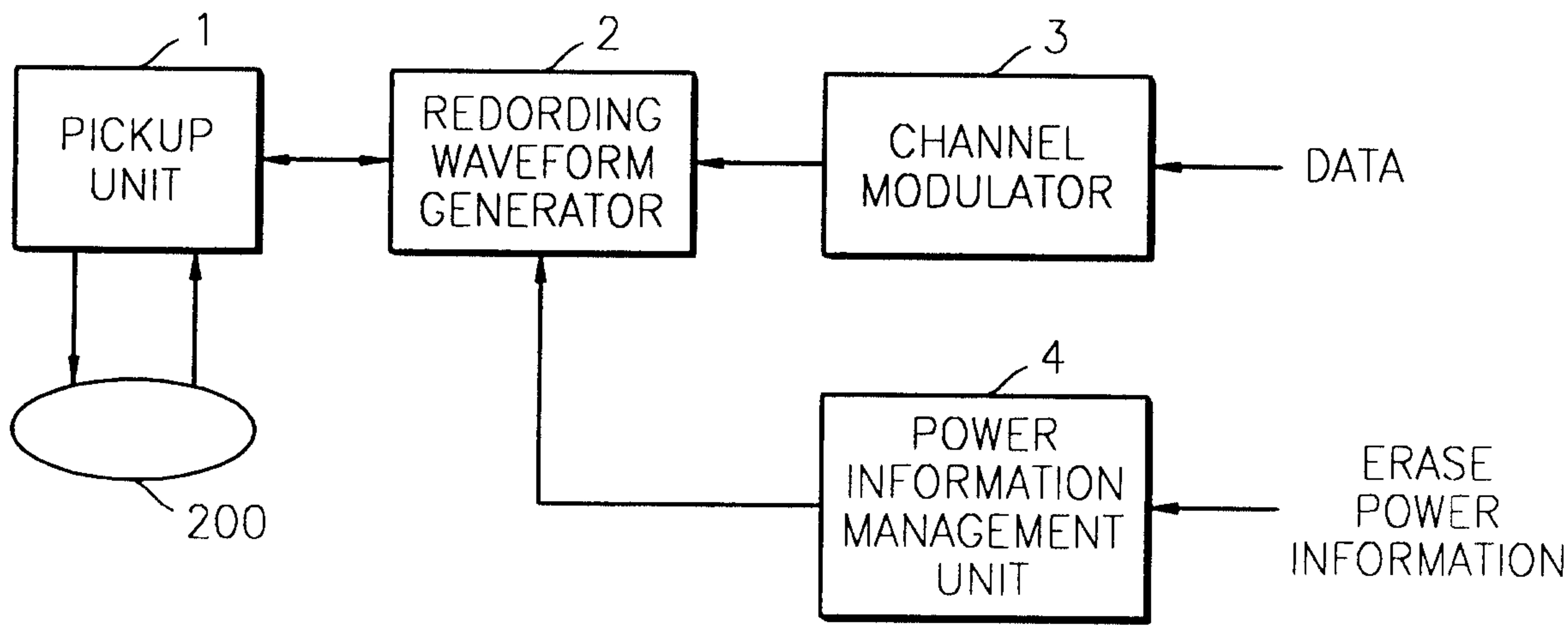

1
PICKUP UNIT
2
REDORDING WAVEFORM GENERATOR
3
CHANNEL MODULATOR
DATA
4
POWER INFORMATION MANAGEMENT UNIT
ERASE POWER INFORMATION
200

FIG. 3A

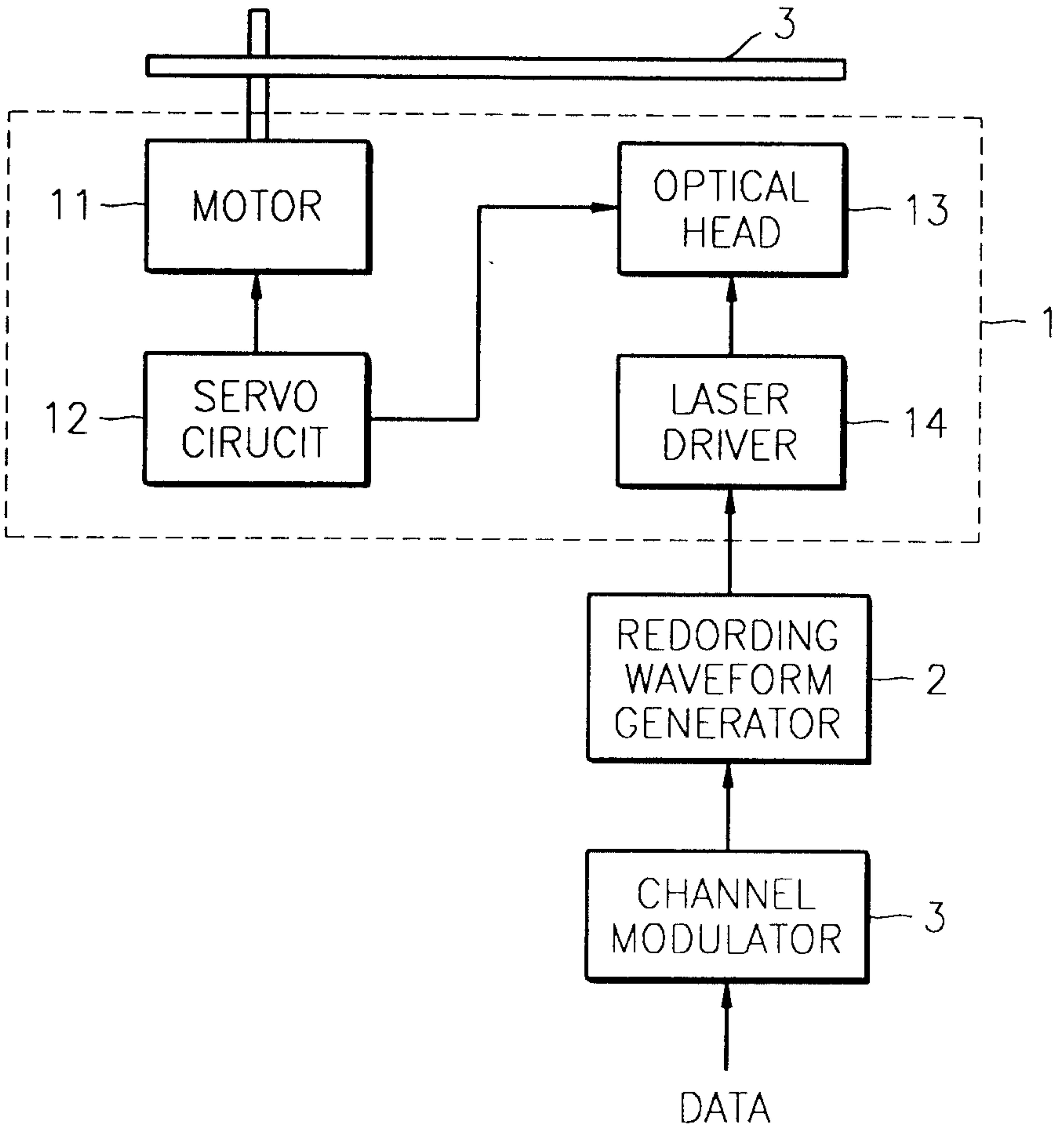

3
11
MOTOR
OPTICAL HEAD
13
1
12
SERVO CIRUCIT
LASER DRIVER
14
REDORDING WAVEFORM GENERATOR
2
CHANNEL MODULATOR
3
DATA

FIG. 3B

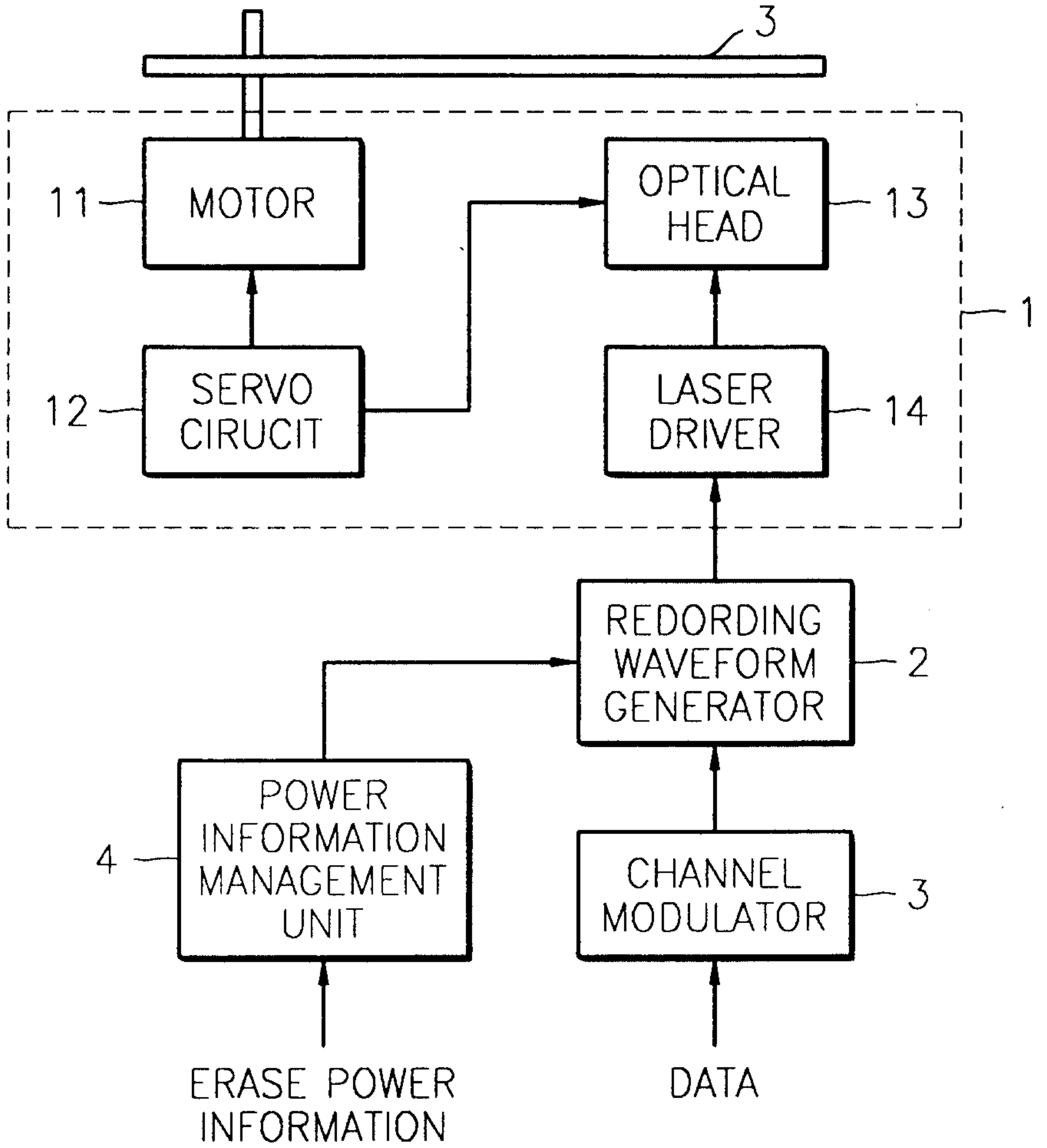

3
MOTOR
11
OPTICAL
HEAD
13
1
SERVO
CIRUCIT
12
LASER
DRIVER
14
REDORDING
WAVEFORM
GENERATOR
2
POWER
INFORMATION
MANAGEMENT
UNIT
4
CHANNEL
MODULATOR
3
ERASE POWER
INFORMATION
DATA

FIG. 4A

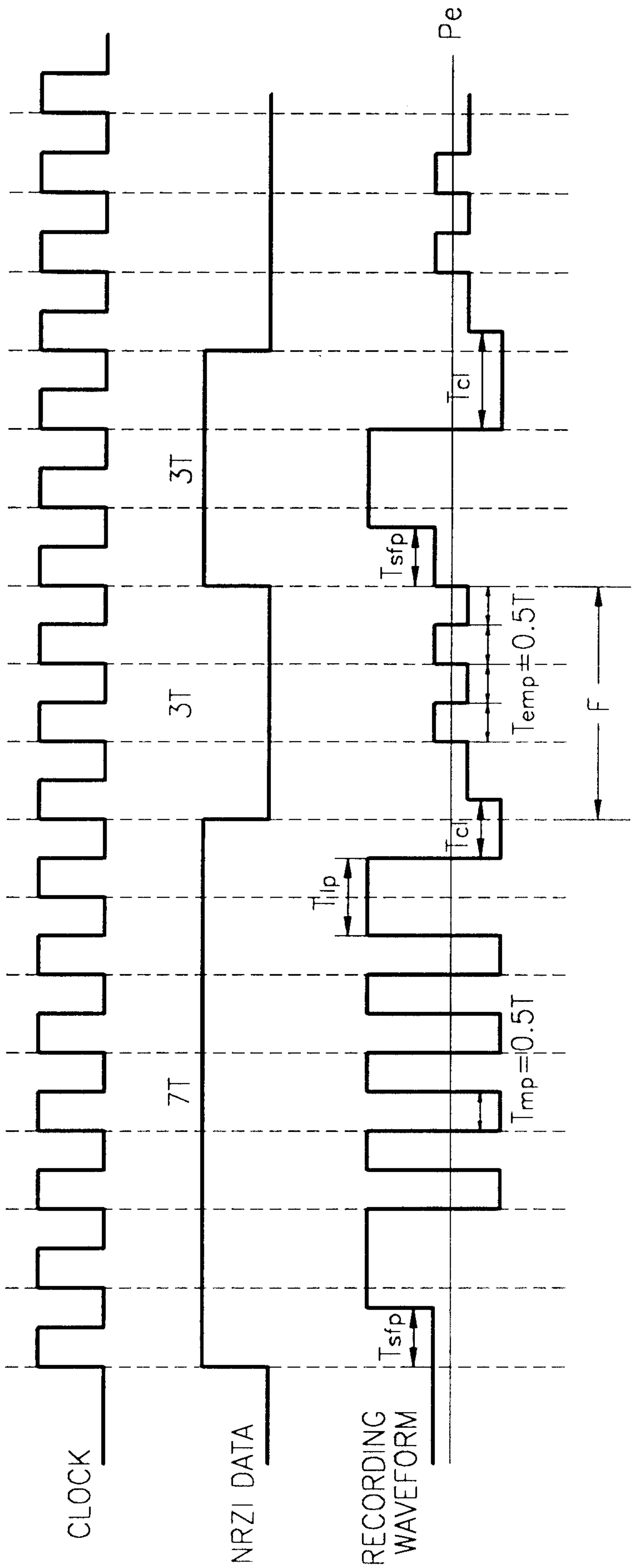

CLOCK
NRZI DATA
RECORDING WAVEFORM
7T
3T
3T
Tsfp
Tmp=0.5T
Tlp
Tcl
Temp±0.5T
F
Tsfp
Tcl
Pe

FIG. 4B

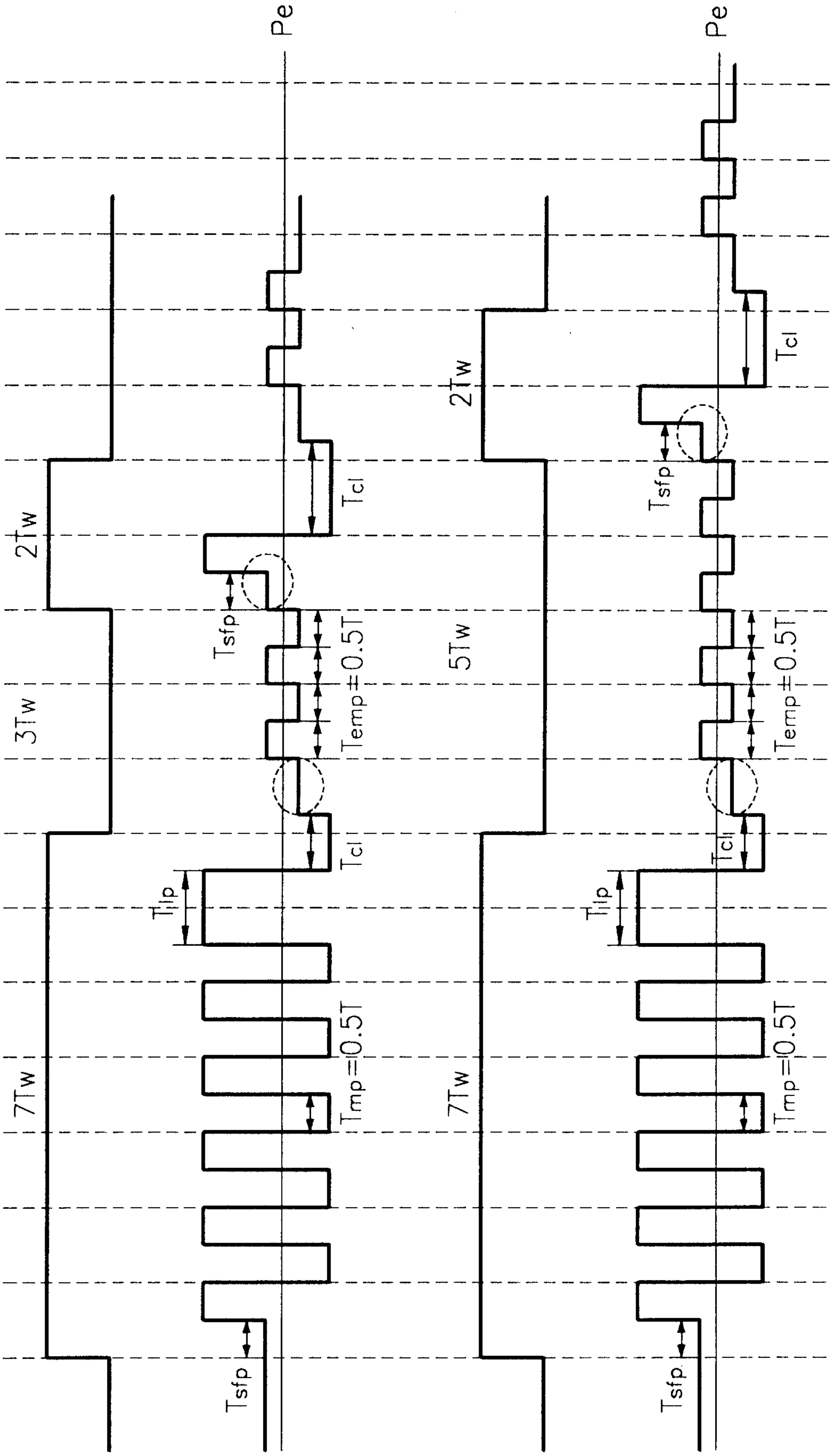

Pe
7Tw
3Tw
2Tw
Tsfp
Tmp=0.5T
Tlp
Tcl
Temp=0.5T
Tsfp
Tcl
Pe
7Tw
5Tw
2Tw
Tsfp
Tmp=0.5T
Tlp
Tcl
Temp=0.5T
Tsfp
Tcl

FIG. 4C

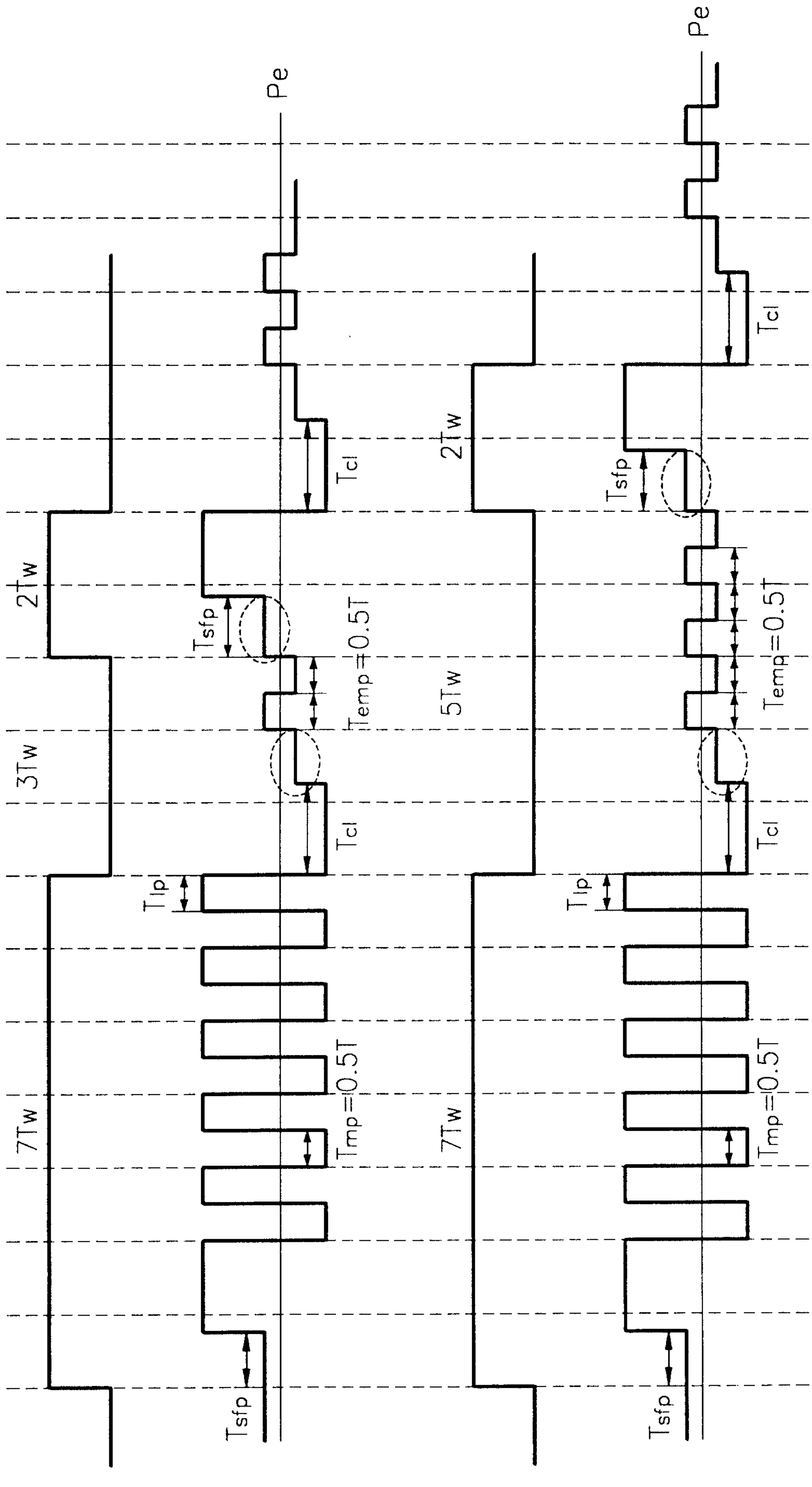


FIG. 5

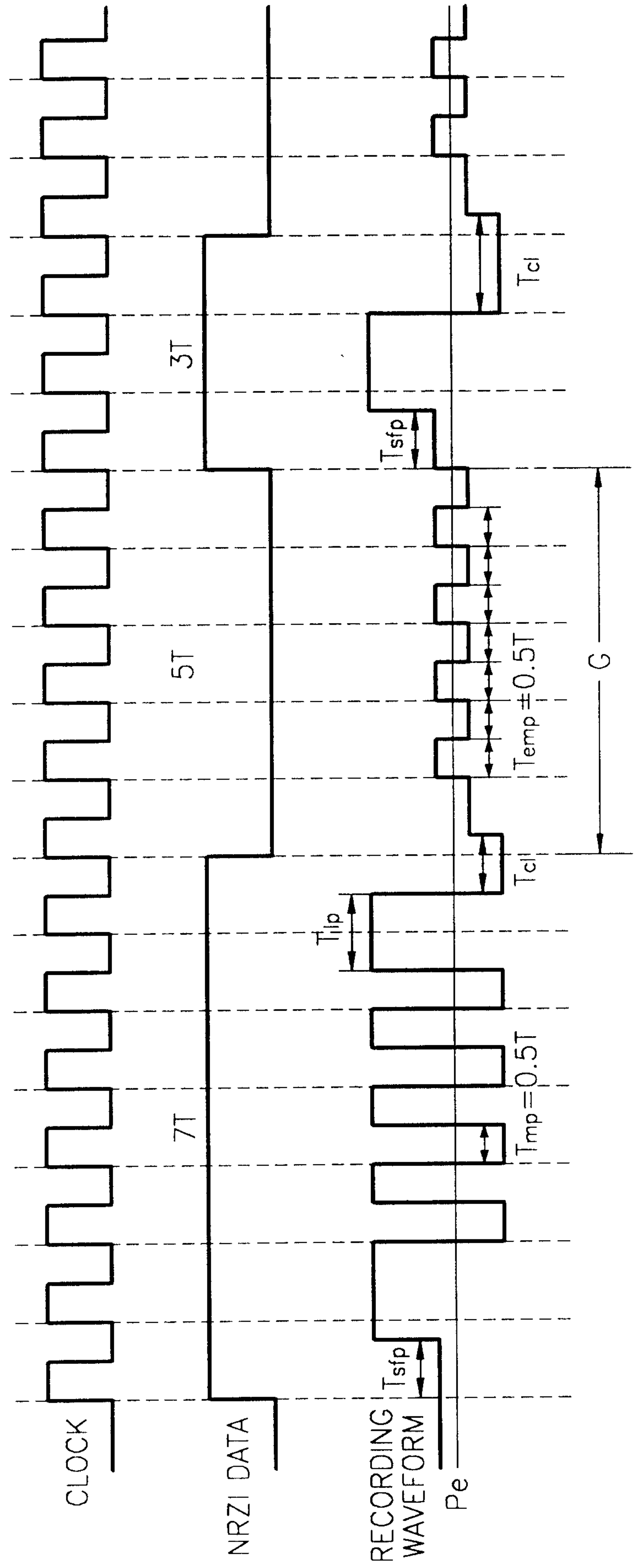

CLOCK
NRZI DATA
RECORDING WAVEFORM
Pe
Tsfp
7T
Tmp=0.5T
Tlp
Tcl
5T
Temp±0.5T
G
3T
Tsfp
Tcl

FIG. 6

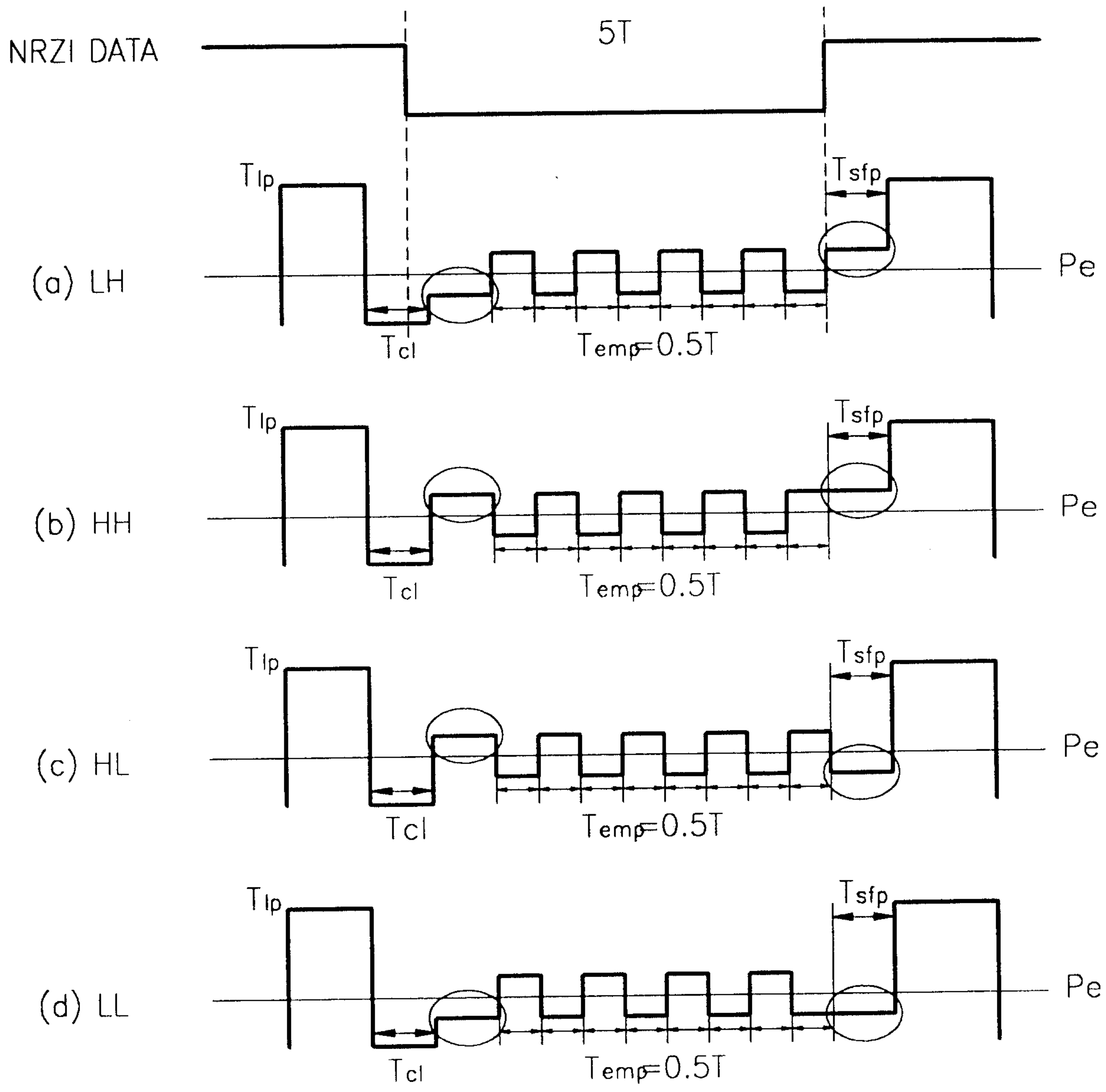

NRZI DATA
5T
Tlp
Tsfp
(a) LH
Pe
Tcl
Temp=0.5T
Tlp
Tsfp
(b) HH
Pe
Tcl
Temp=0.5T
Tlp
Tsfp
(c) HL
Pe
Tcl
Temp=0.5T
Tlp
Tsfp
(d) LL
Pe
Tcl
Temp=0.5T

FIG. 7

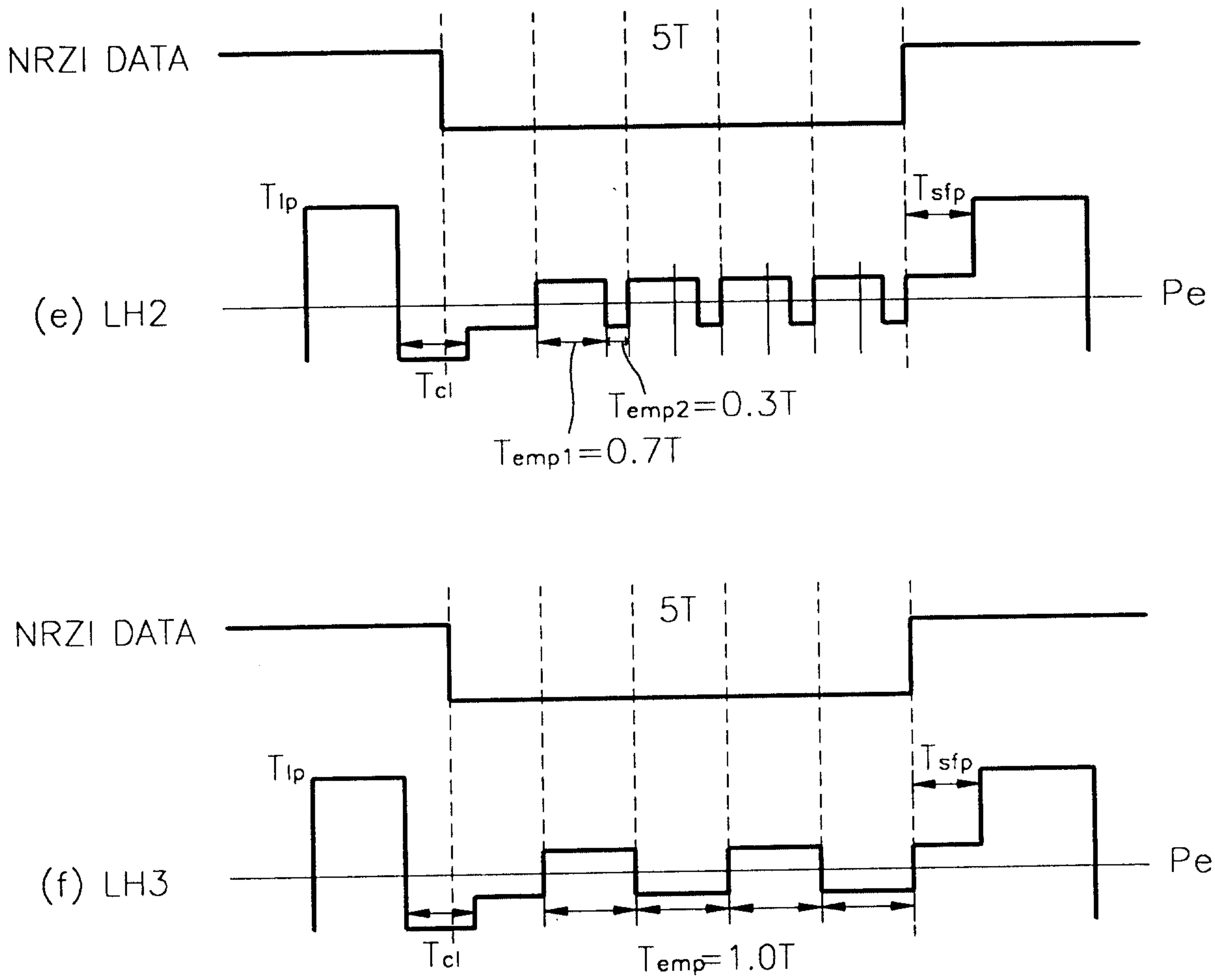
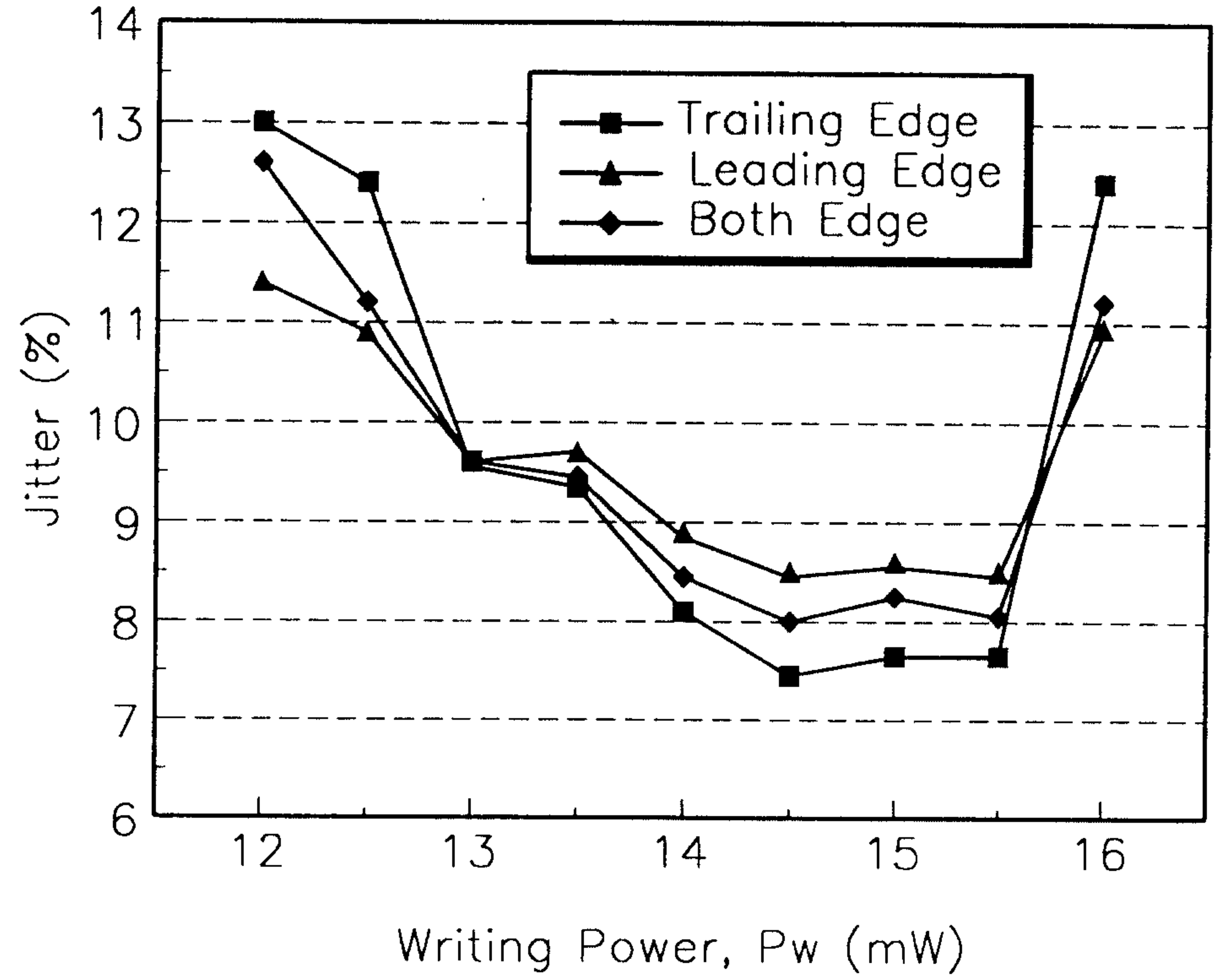

NRZI DATA
5T
T_{lp}
T_{sfp}
(e) LH2
Pe
T_{cl}
T_{emp2}=0.3T
T_{emp1}=0.7T
NRZI DATA
5T
T_{lp}
T_{sfp}
(f) LH3
Pe
T_{cl}
T_{emp}=1.0T

FIG. 11

(a)


14
13
12
11
10
9
8
7
6
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
12
13
14
15
16
Writing Power, Pw (mW)

(b)

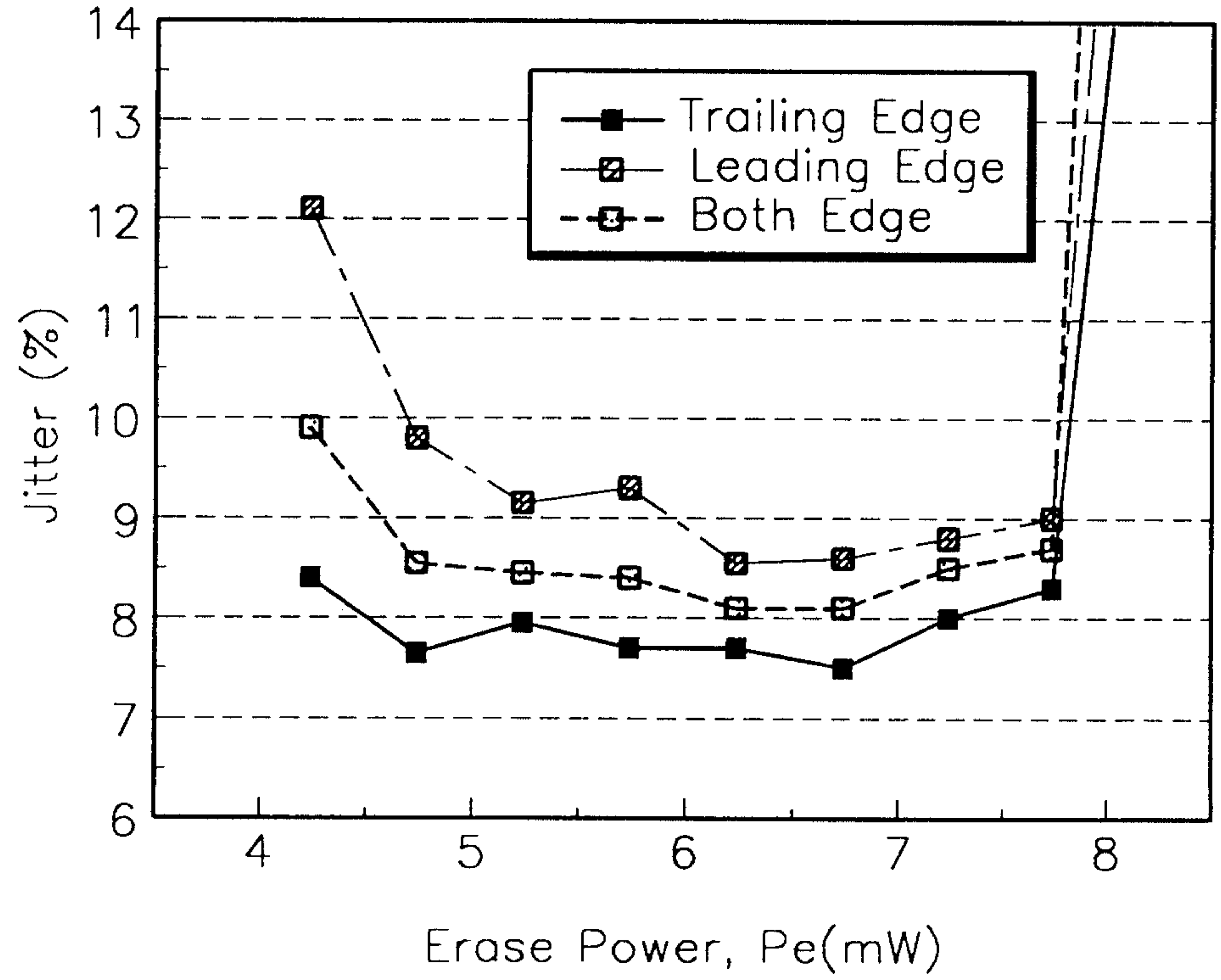

14
13
12
11
10
9
8
7
6
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
4
5
6
7
8
Erase Power, Pe(mW)

FIG. 12

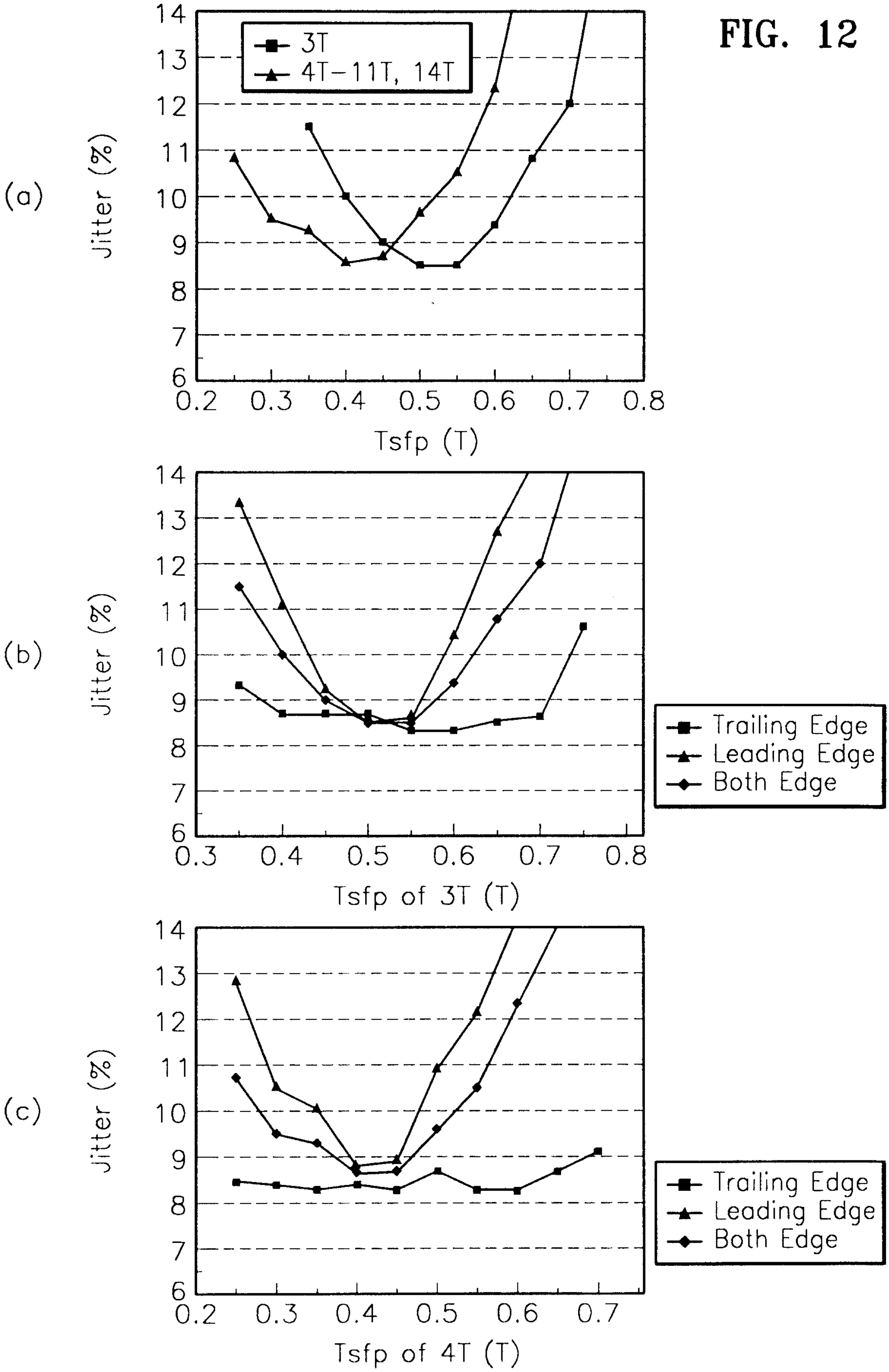
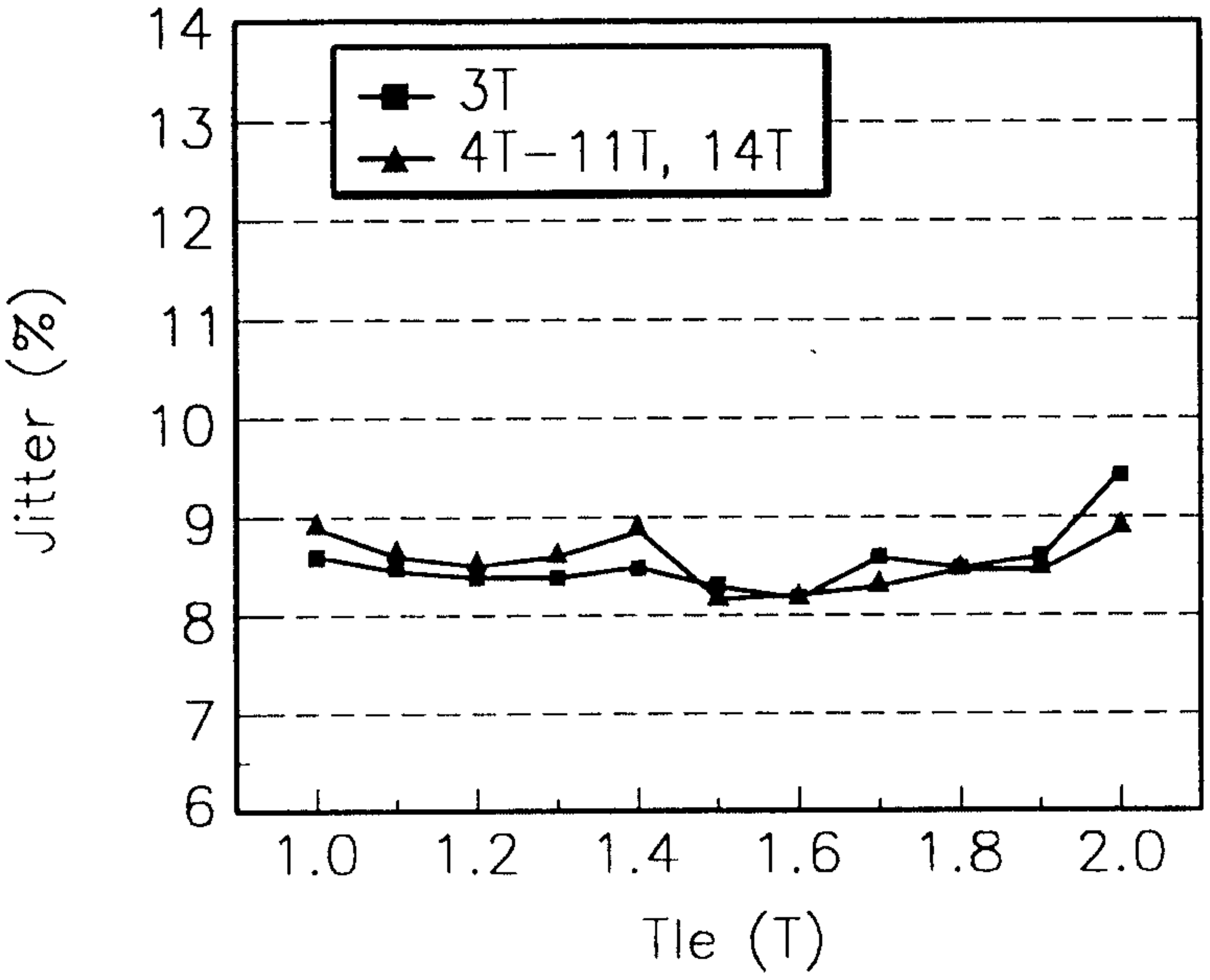

(a)
Jitter (%)
3T
4T-11T, 14T
Tsfp (T)
(b)
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
Tsfp of 3T (T)
(c)
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
Tsfp of 4T (T)

FIG. 13

(a)


14
13
12
11
10
9
8
7
6
Jitter (%)
3T
4T-11T, 14T
1.0
1.2
1.4
1.6
1.8
2.0
Tle (T)

(b)

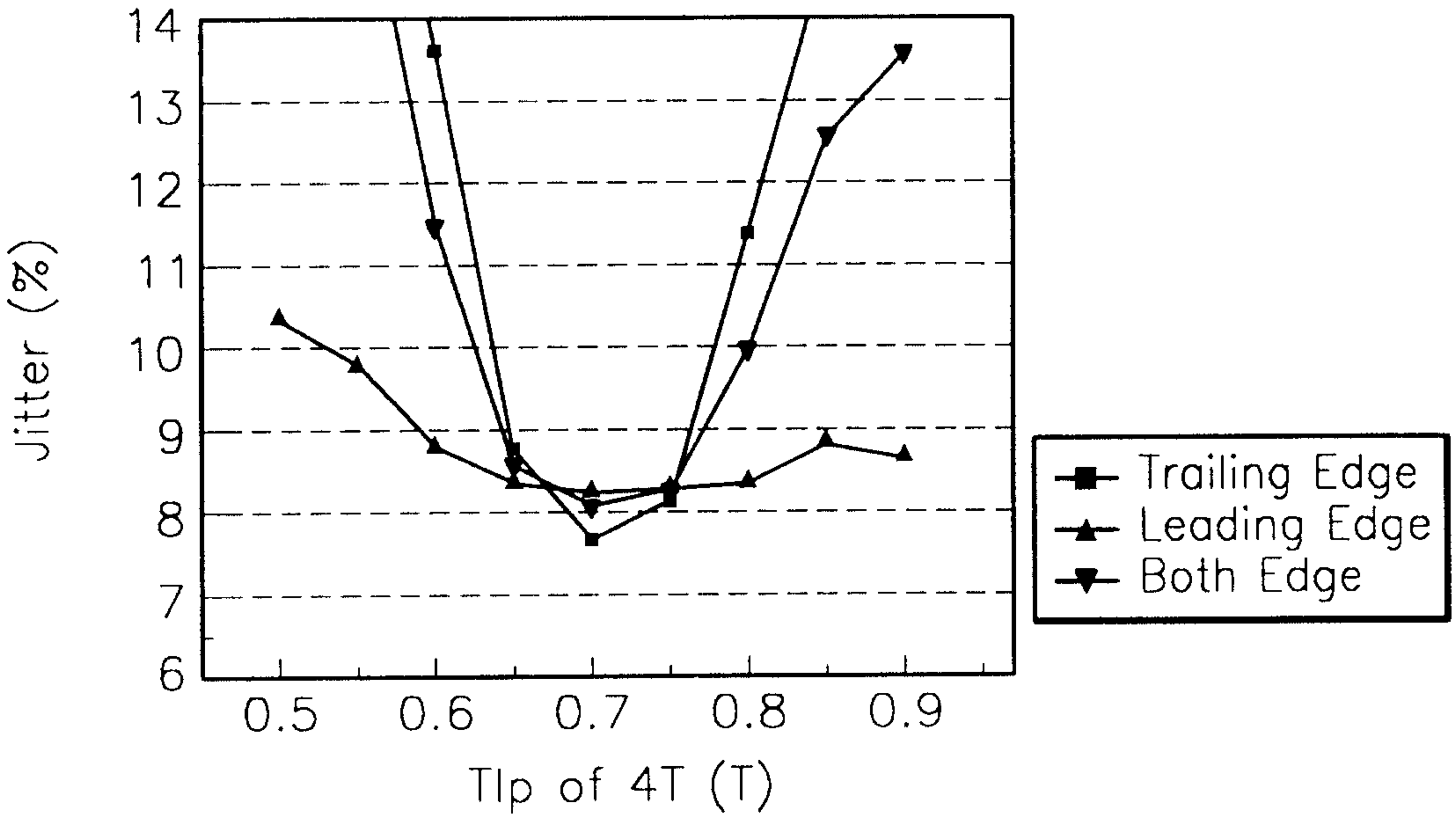

14
13
12
11
10
9
8
7
6
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
0.5
0.6
0.7
0.8
0.9
Tlp of 4T (T)

FIG. 14

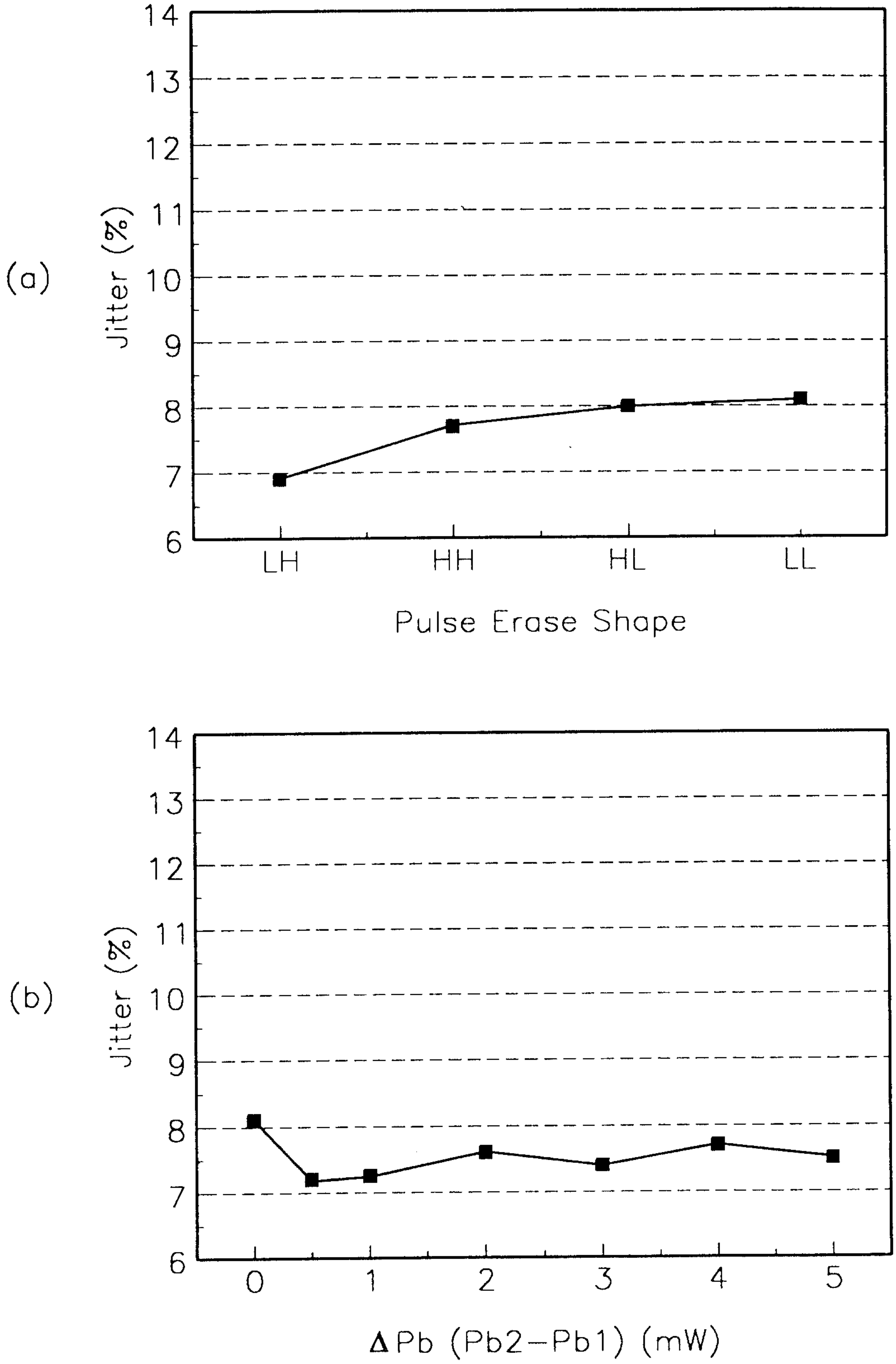

(a)
Jitter (%)
14
13
12
11
10
9
8
7
6
LH
HH
HL
LL
Pulse Erase Shape
(b)
Jitter (%)
14
13
12
11
10
9
8
7
6
0
1
2
3
4
5
ΔPb (Pb2–Pb1) (mW)

FIG. 15

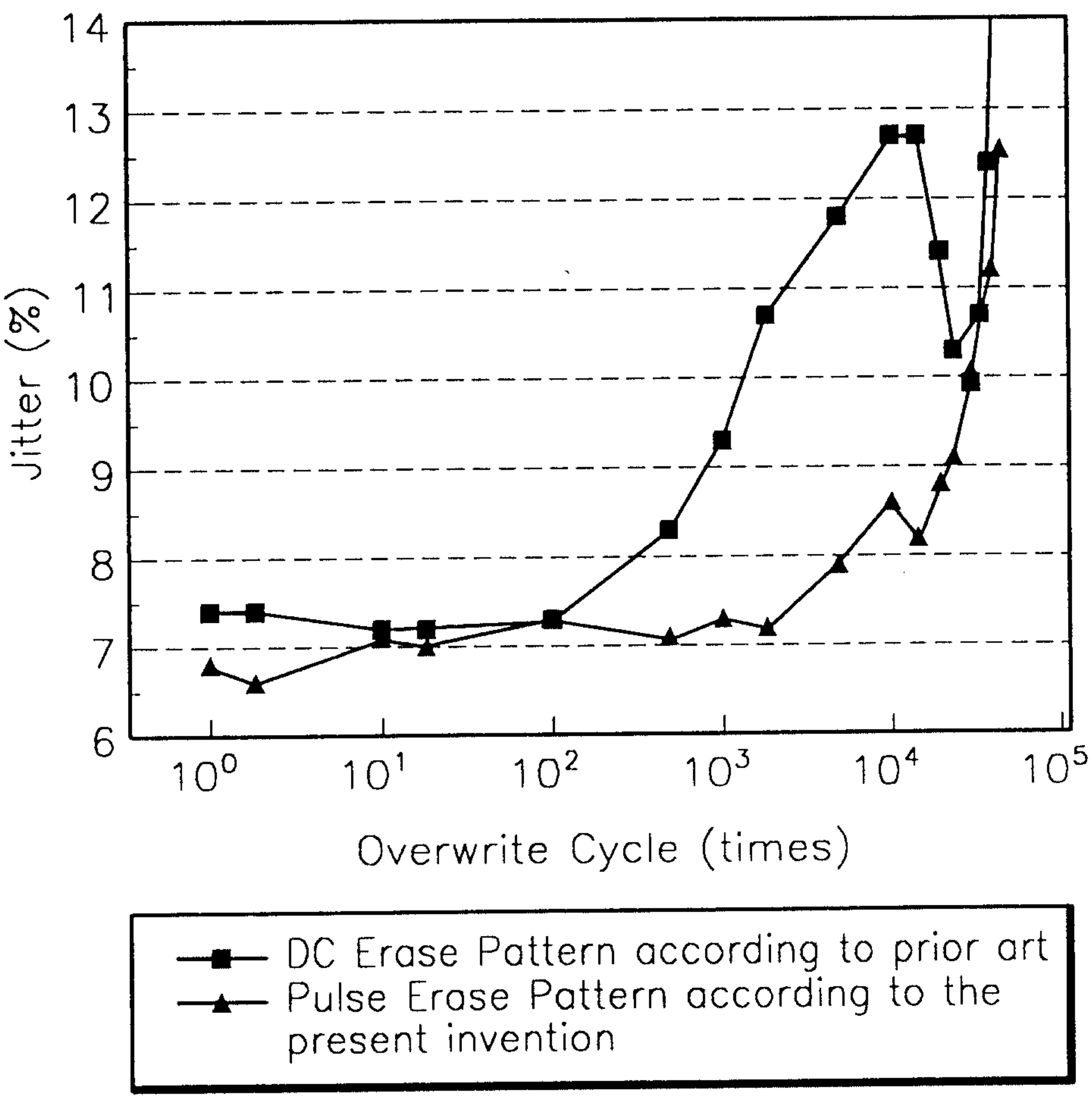
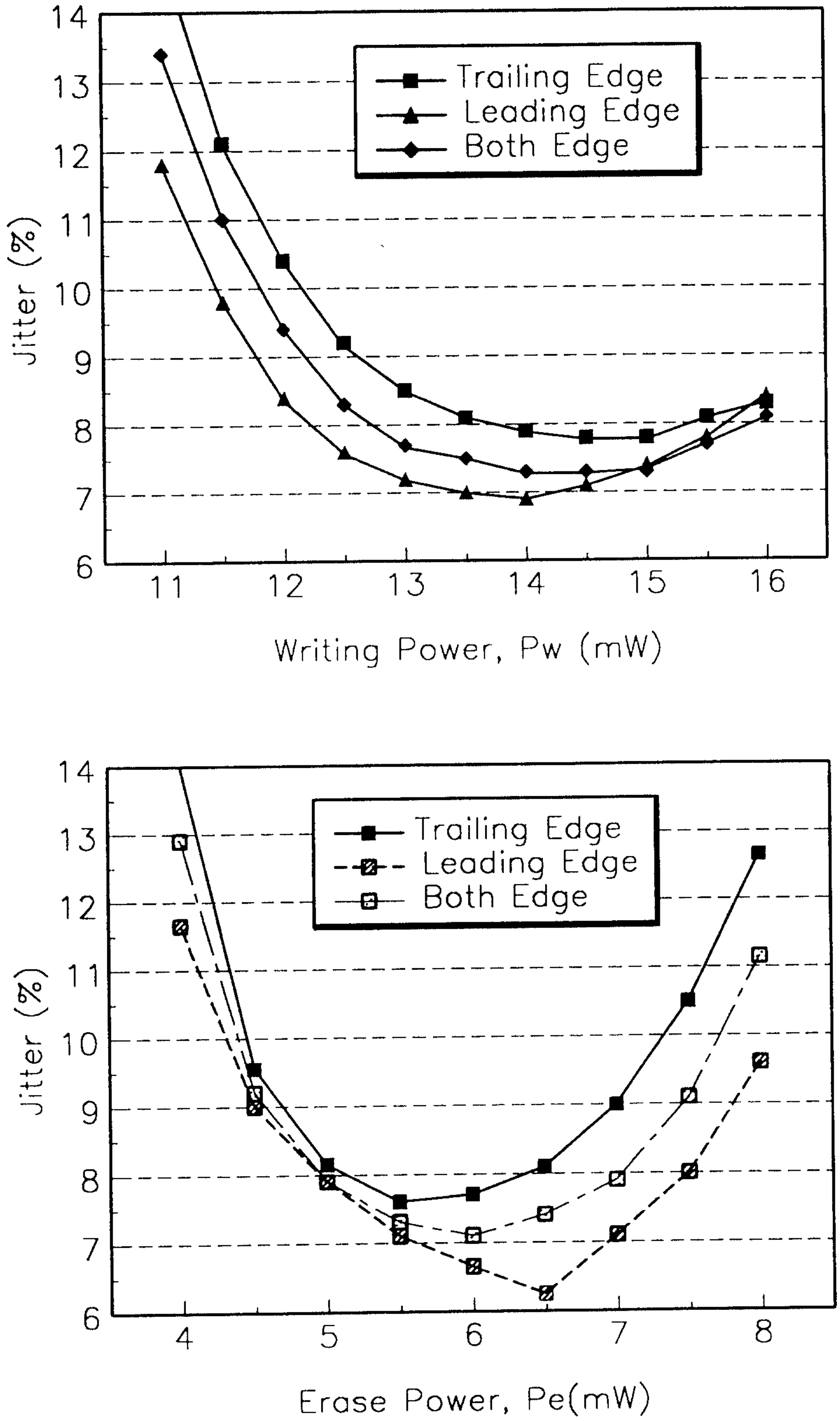

Jitter (%)
14
13
12
11
10
9
8
7
6
10^0
10^1
10^2
10^3
10^4
10^5
Overwrite Cycle (times)
DC Erase Pattern according to prior art
Pulse Erase Pattern according to the present invention

FIG. 16

(a)

(b)


Jitter (%)
Writing Power, Pw (mW)
Trailing Edge
Leading Edge
Both Edge
Jitter (%)
Erase Power, Pe(mW)
Trailing Edge
Leading Edge
Both Edge

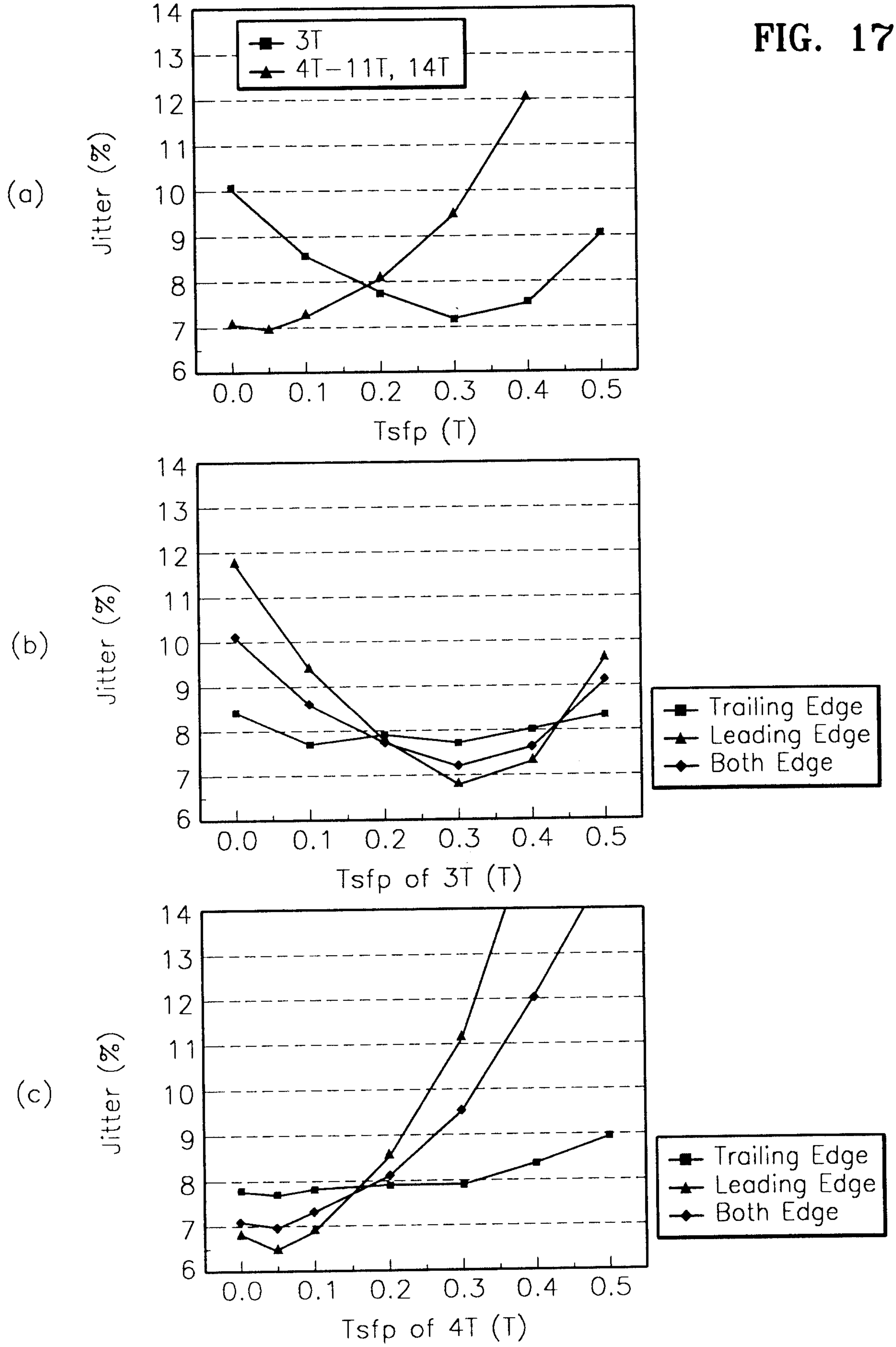

(a)
Jitter (%)
14
13
12
11
10
9
8
7
6
3T
4T–11T, 14T
0.0
0.1
0.2
0.3
0.4
0.5
Tsfp (T)
(b)
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
Tsfp of 3T (T)
(c)
Jitter (%)
Trailing Edge
Leading Edge
Both Edge
Tsfp of 4T (T)

FIG. 17

FIG. 18

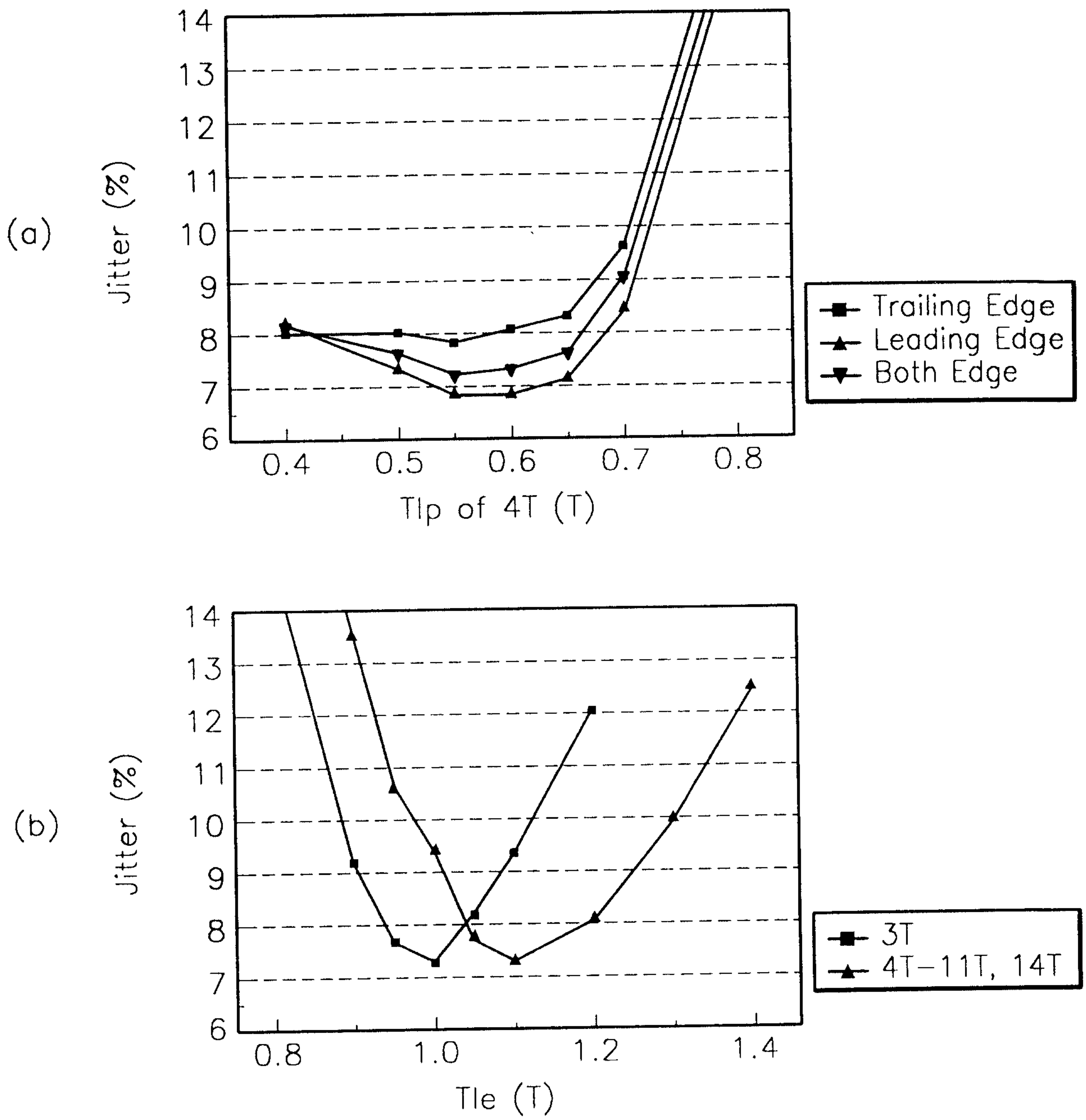
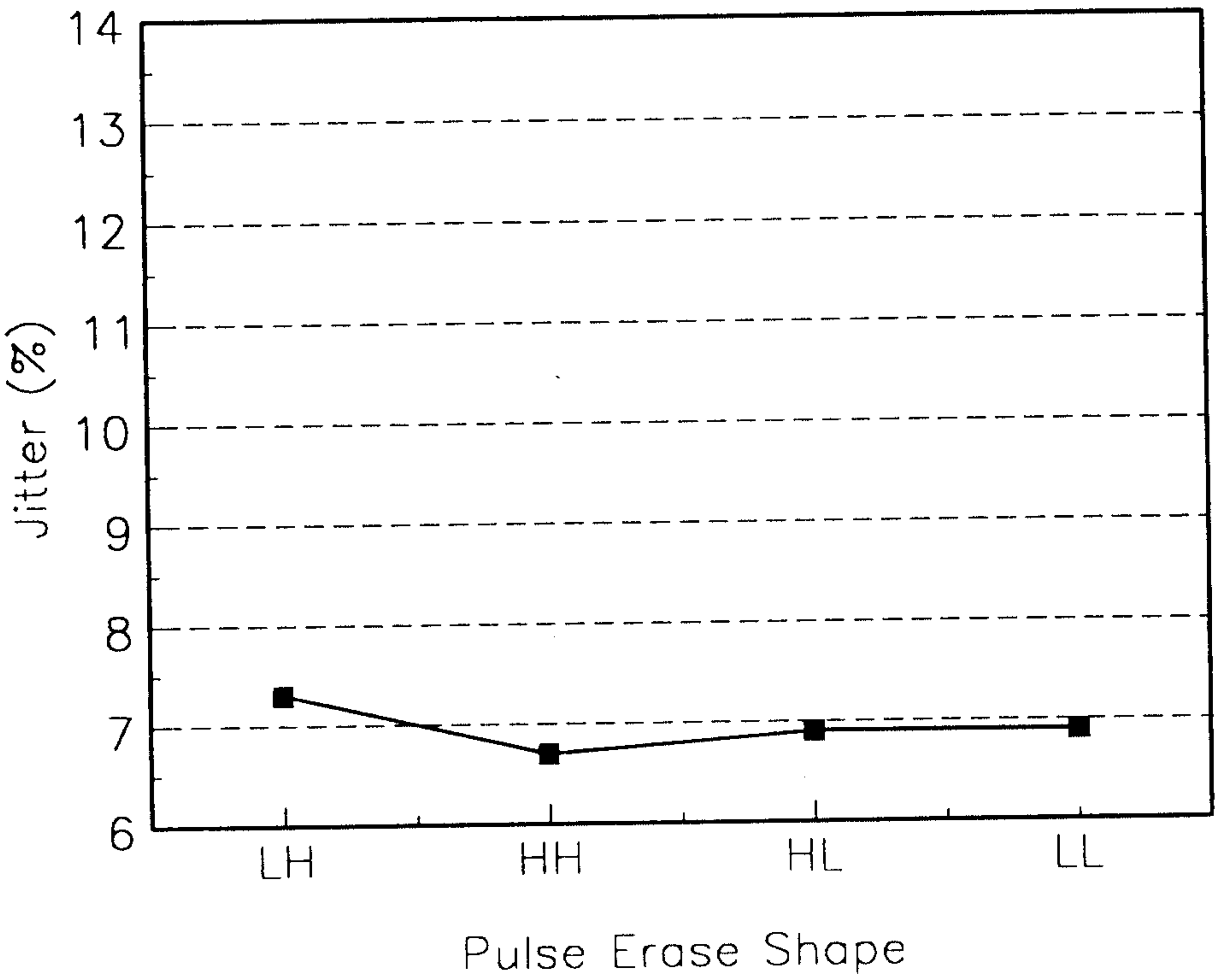

(a)
Jitter (%)
14
13
12
11
10
9
8
7
6
0.4
0.5
0.6
0.7
0.8
Tlp of 4T (T)
Trailing Edge
Leading Edge
Both Edge
(b)
Jitter (%)
14
13
12
11
10
9
8
7
6
0.8
1.0
1.2
1.4
Tle (T)
3T
4T-11T, 14T

FIG. 19

(a)


14
13
12
11
10
9
8
7
6
Jitter (%)
LH
HH
HL
LL
Pulse Erase Shape

(b)

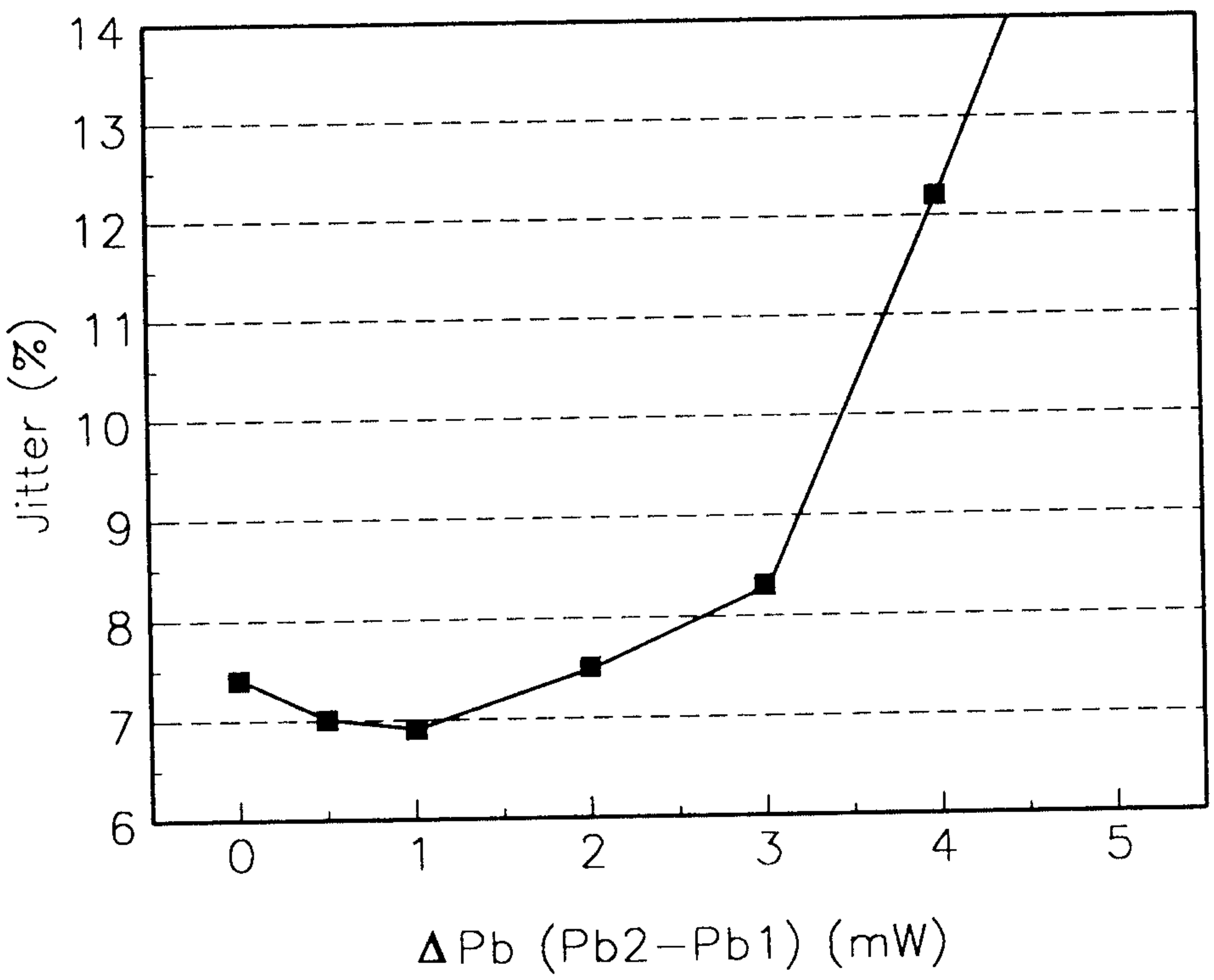
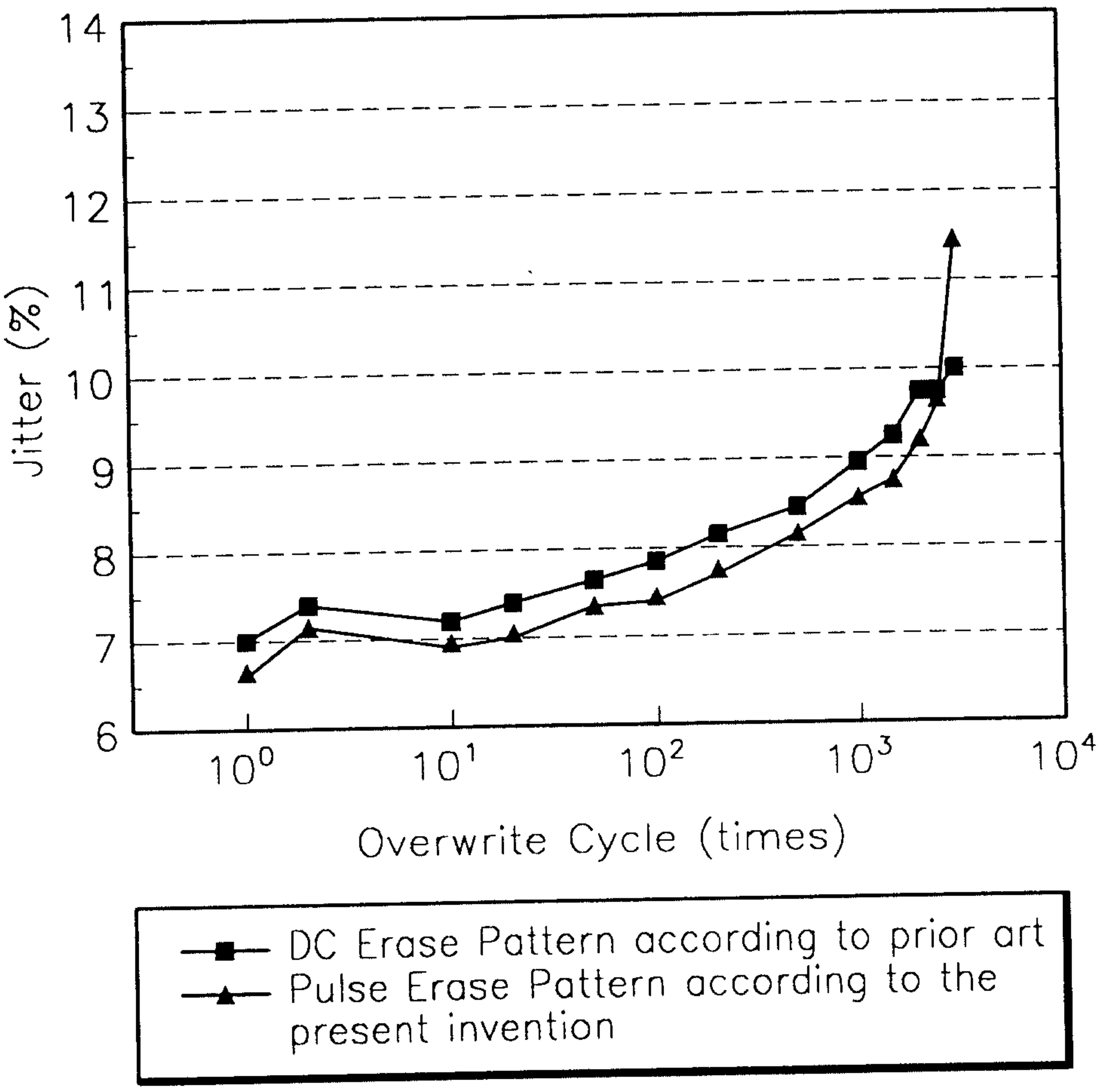

14
13
12
11
10
9
8
7
6
Jitter (%)
0
1
2
3
4
5
ΔPb (Pb2−Pb1) (mW)

FIG. 20



14
13
12
11
10
9
8
7
6
Jitter (%)
10^0
10^1
10^2
10^3
10^4
Overwrite Cycle (times)
DC Erase Pattern according to prior art
Pulse Erase Pattern according to the present invention

FIG. 21A

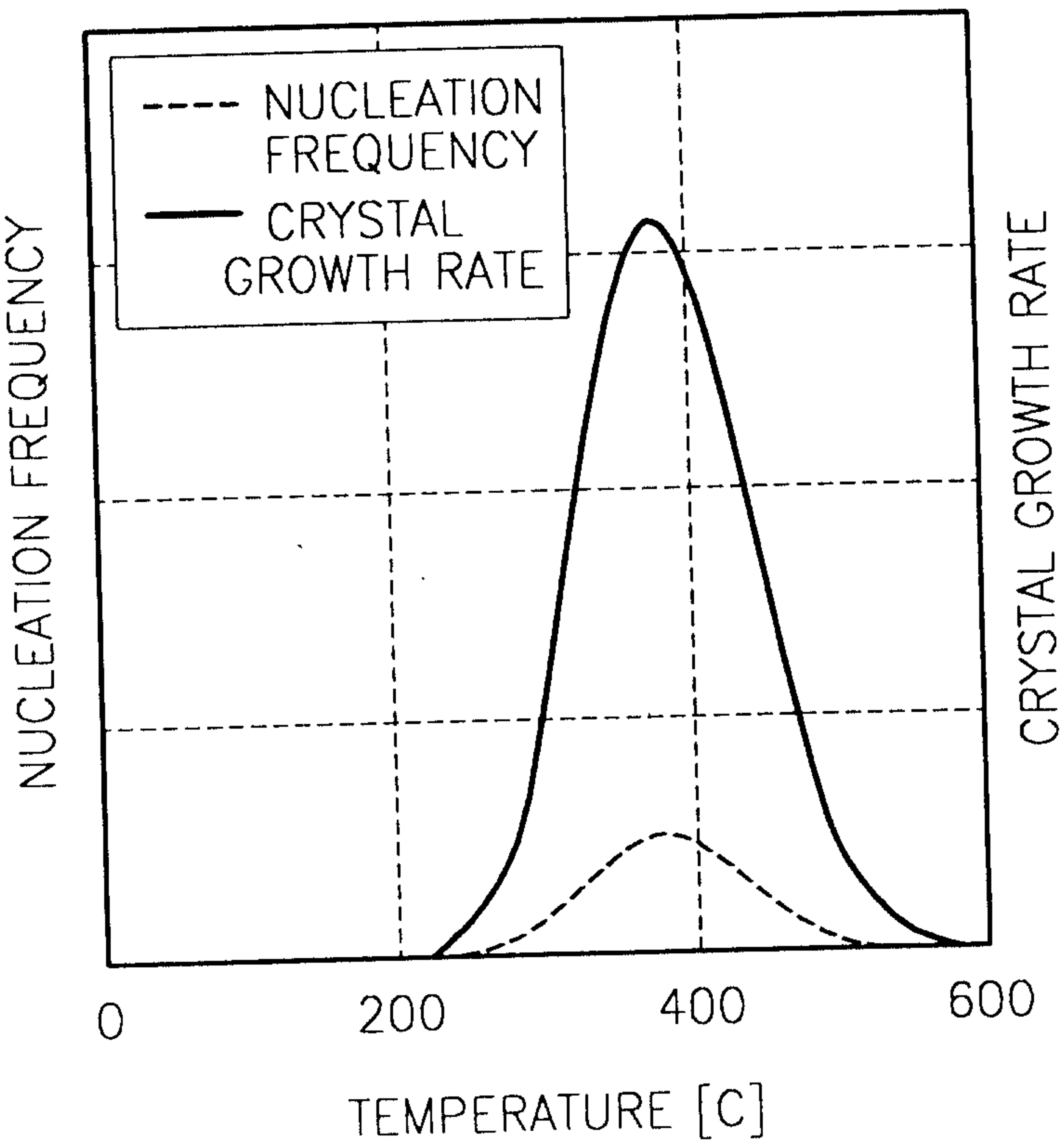


FIG. 21B

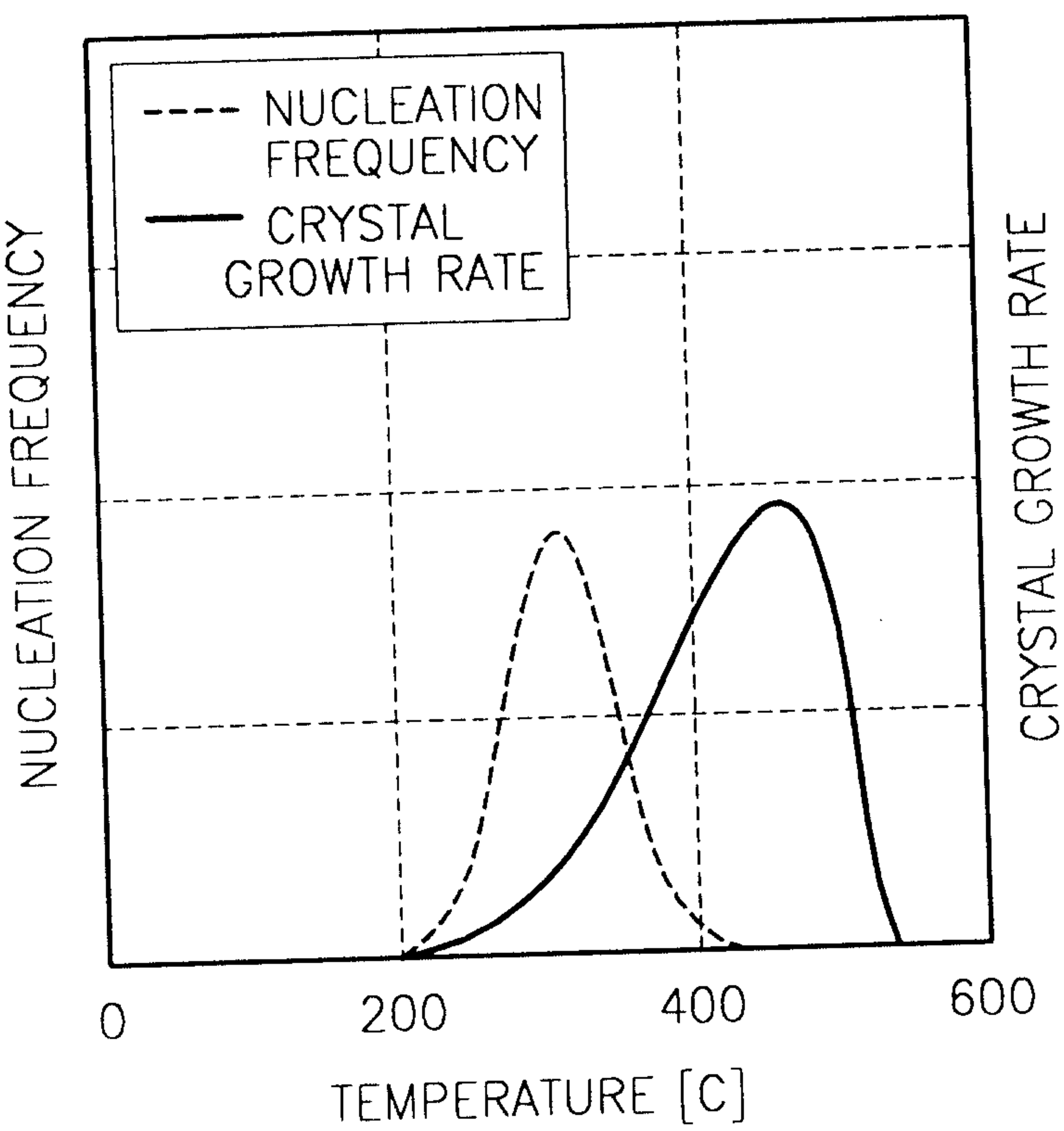


FIG. 22A

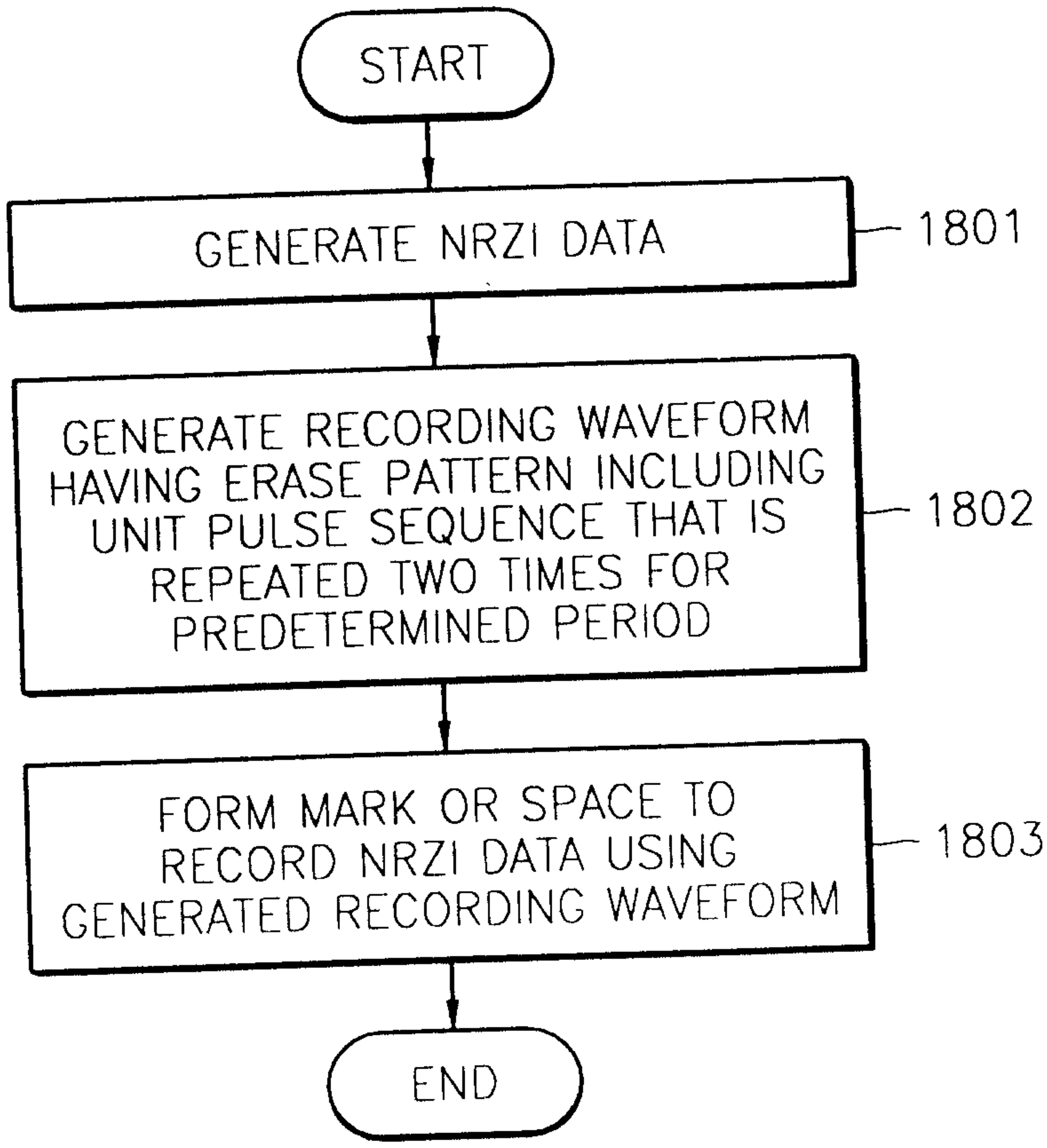
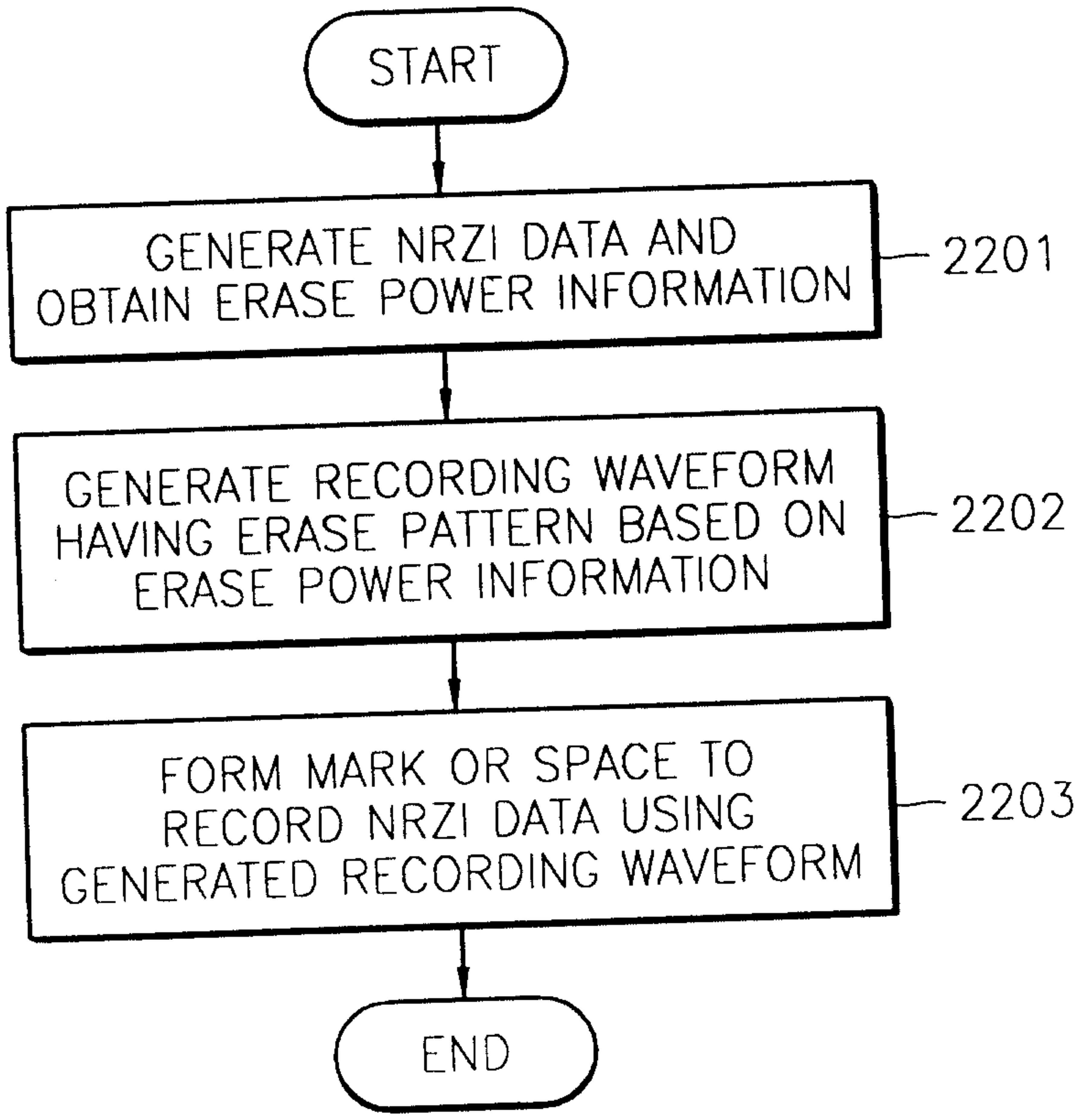
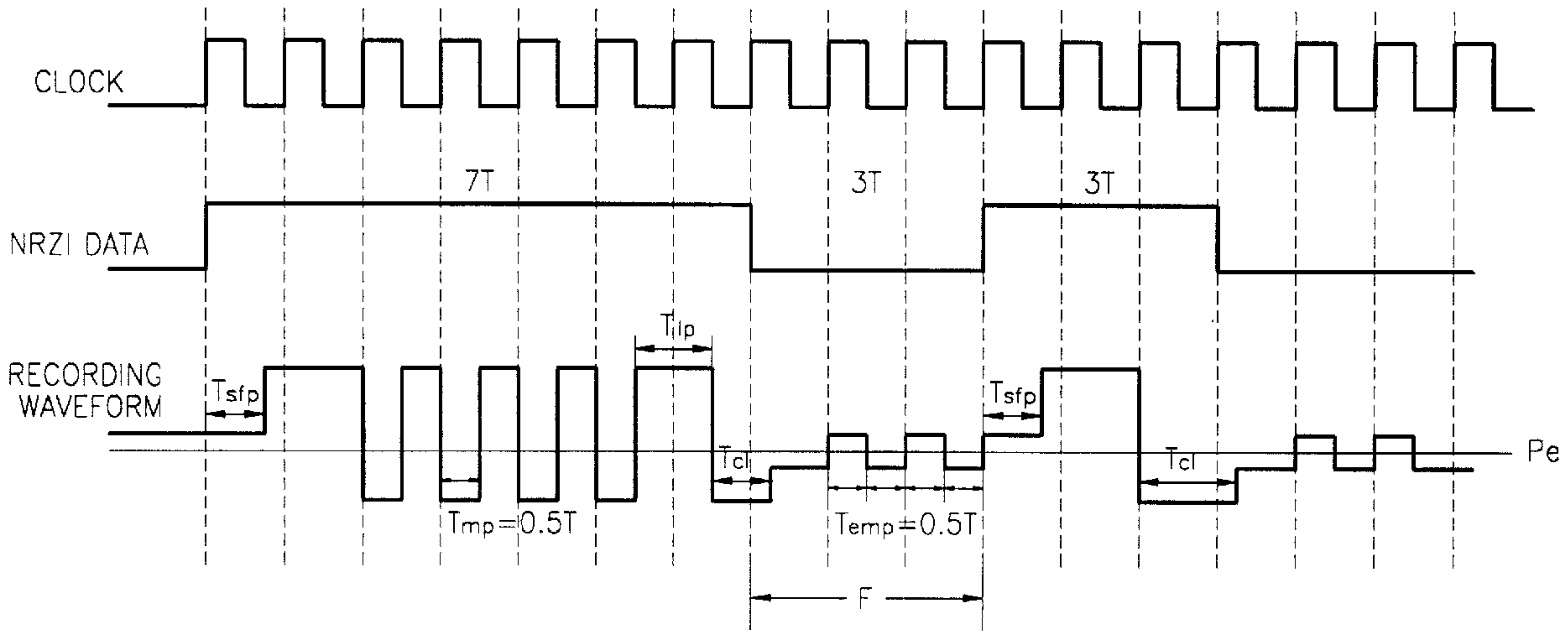

START
GENERATE NRZI DATA
1801
GENERATE RECORDING WAVEFORM HAVING ERASE PATTERN INCLUDING UNIT PULSE SEQUENCE THAT IS REPEATED TWO TIMES FOR PREDETERMINED PERIOD
1802
FORM MARK OR SPACE TO RECORD NRZI DATA USING GENERATED RECORDING WAVEFORM
1803
END

FIG. 22B


START
GENERATE NRZI DATA AND OBTAIN ERASE POWER INFORMATION
2201
GENERATE RECORDING WAVEFORM HAVING ERASE PATTERN BASED ON ERASE POWER INFORMATION
2202
FORM MARK OR SPACE TO RECORD NRZI DATA USING GENERATED RECORDING WAVEFORM
2203
END



CLOCK
NRZI DATA
RECORDING WAVEFORM
7T
3T
3T
Tsfp
Tsfp
Tilp
Tcl
Tcl
Tmp=0.5T
Temp=0.5T
Pe
F