Experimental study on ternary recording possibility in Heat Assisted Magnetic Recording

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Ternary recording possibility in Heat Assisted Magnetic Recording (HAMR) [1] is studied in this prsentation. By heating the medium without applying a magnetic field in HAMR, an AC erase-like magnetization state is formed on the medium. By regarding this erase state as a new signal level of "0", ternary recording is expected to be realized in HAMR. By using prototype HAMR Hard Disk Drive (HDD), waveform observation and overwrite capability evaluation are performed as an initial feasibility study.

***Index Terms* — HAMR, magnetic recording, ternary recording**

I. Introduction

In conventional magnetic recording, direction of the magnetization on the recording medium has been used for storing information. Upward magnetization means "+1" and downward one means "-1", for example in perpendicular magnetic recording. Writing process switches these two states by applying a magnetic field corresponding to "+1" / "-1" from write head.

In HAMR, higher coercivity material is used in recording layer in the medium. Therefore, not only applying a magnetic field but heating the medium is necessary to lower effective coercivity in writing process. On the other hand, by heating the medium without applying a magnetic field, an AC erase-like magnetization state will be formed on the medium. This AC erase-like state can be regarded as a new signal level of "0" in addition to conventional signal level "+1" and "-1". This means that "ternary recording" is expected to be realized in HAMR.

Some experiments using prototype HAMR HDD were performed as an initial feasility study.

II. Experiment setup/flow

- Prototype HAMR HDD, 1head, 1location
- Datarate: 2087Mbps
- Measurement flow:
  1. To write specific pattern (*) onto specific location as an old data with normal HAMR condition.
  2. To read at the location and to get waveform of condition #1.
  3. To over-write the same location with special condition, which is heating the medium without applying a magnetic field (**).
  4. To read at the location and to get waveform of condition #3.
  5. Waveform analysis (#2 and #4)

*: 1T - 16T tone pattern and 127-bit Pseudo Random Bit Sequence (PRBS) pattern are used.
**: set write current to minimum(2mA) of the preamp spec.

III. Results and Considerations

A. Waveform observation:

Figure 1 shows waveform from "16T pattern writing" and "Heating only". As shown in this figure, "+1" and "-1" level can be seen in "16T pattern writing" portion in bottom lefthand side. In bottom righthand side of the figure, it is observed that "Heating only" forms signal level "0".

We'd like to evaluate overwrite capability of "Heating" as next step.

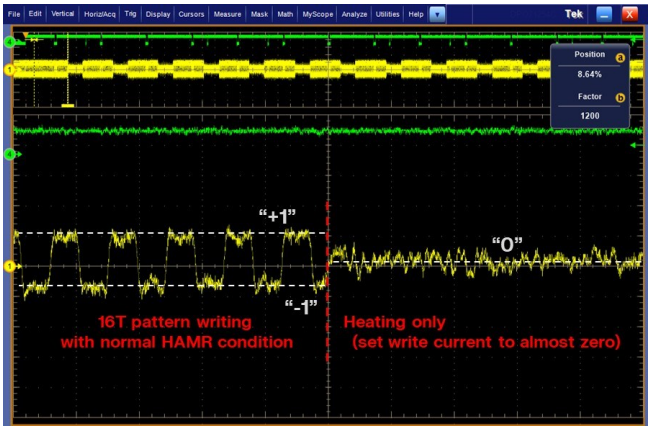

Fig. 1. Waveform (screen capture of digital oscilloscope)
Bottom lefthand side: 16T pattern writing with normal HAMR condition. Bottom righthand side: Heating only.

B. Overwrite capability:

As described in section II, we took waveforms from two situations. One is just after writing specific pattern (#1 and #2). The other is just after heating the same location (#3 and #4). By analyzing and comparing these two waveforms, we can know how much the heating can erase original pattern (~old data), which is overwrite capability of the heating.

i. Periodic tone pattern case:

Figure 2 is the chart for explanation on overwrite capability evaluation. In this case, periodic tone pattern is used as an old data. Top and middle of the figure is waveform of 16T tone pattern and after heating respectively. Bottom is frequency domain plot of each waveform.

The Difference between two plots (orange and blue) around "Normalized frequency" = 1 in horizontal axis means the overwrite capability of this example. Taking similar data for not only 16T pattern case, but 12T, 8T, 6T, 4T, 3T, 2T and 1T pattern cases, then plot these intensity data on the graph with the horizontal axis as tone pattern length is Figure 3.

As seen in Figure 3, overwrite capability is about 60~100dB in range of 1T to 16T. This means that by heating, the intensity of the old data has decreased to $1/10^6 \sim 1/10^{10}$ in signal power.

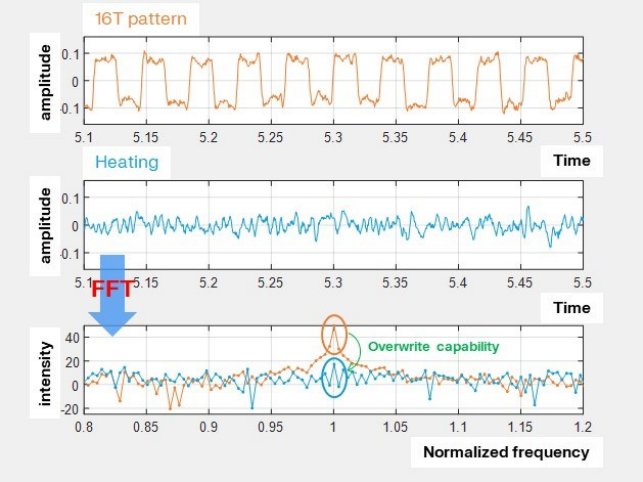

Fig. 2. Explanation of overwrite capability evaluation,
Top: Waveform from periodic 16T pattern, Middle: Waveform from after heating, Bottom: Frequency domain plot of the waveforms above.

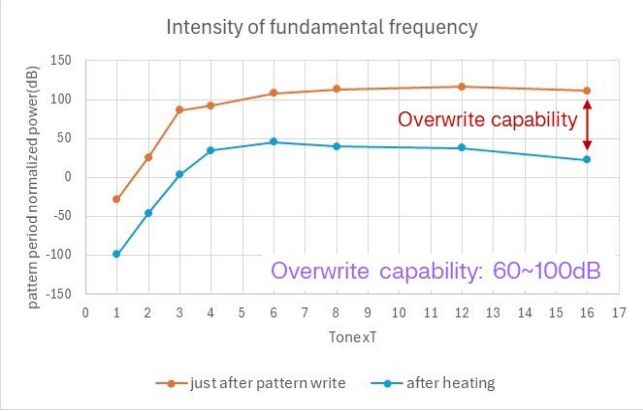

Fig. 3. Overwrite capability result

ii. Periodic 127-bit PRBS pattern case:

Figure 4 shows overwrite capability evaluation in another way. In this case, periodic 127-bit PRBS pattern is used as an old data. Top and middle of the figure is waveform of periodic 127-bit PRBS pattern and after heating respectively. Bottom is auto-correlation plot of each waveform.

As seen in auto-correlation plots, there are periodic peaks observed in orange plot which is from 127-bit PRBS pattern case. On the other hand, no periodic peak is observed in blue plot coming from after heating. That means by heating, periodic property in the old data has been erased enough.

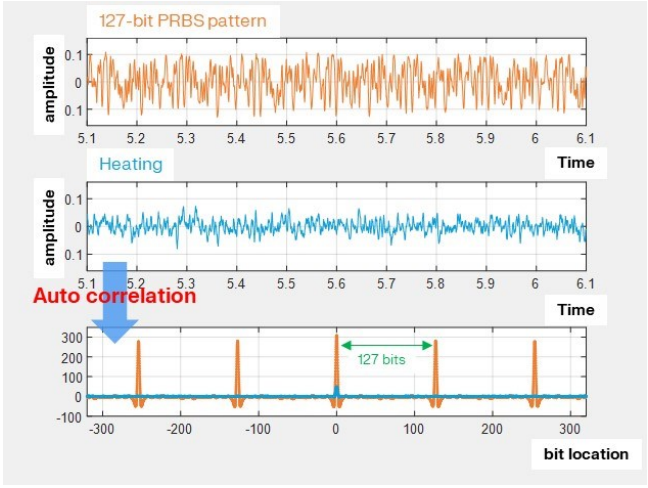

Fig. 4. Overwrite capability evaluation by 127-bit PRBS pattern,
Top: Waveform from periodic 127-bit PRBS pattern, Middle: Waveform from after heating, Bottom: Auto-correlation plot of the waveforms above.

IV. Conclusion

Some experiments have been performed to realize ternary recording in HAMR as an initial feasibility study. And, it has been experimentally confirmed that …

i. "Heating" can create new signal level "0" in addition to conventional signal level "+1" and "-1".
ii. "Heating" can overwrite an old data enough.

References

[1] R. E. Rottmayer et al., "Heat-Assisted Magnetic Recording," in IEEE Transactions on Magnetics, vol. 42, no. 10, pp. 2417-2421, Oct. 2006.