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Electromagnetic Field Induced Degradation of Magnetic Recording Heads in a GTEM Cell

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Abstract- A Gigahertz Transverse Electromagnetic Mode (GTEM) Cell was used to apply a controlled RF electric field to magnetic recording assemblies. The resistance and magnetic properties of the giant magnetoresistive (GMR) and tunneling MR (TMR) sensors were measured before and after exposure to the electric field. No degradation in GMR sensor properties was observed for pulsed field strengths up to 40V/m for the standard assembly configuration. However, severe resistance and magnetic damage was observed when an additional 7cm long wire was attached to the input of the GMR sensor. It is concluded that it is important to understand and measure the radiated immunity failure level for extremely ESD sensitive devices like magnetic recording assemblies.

I. Introduction

It is well known that the giant magnetoresistive (GMR) sensor used in today's magnetic recording heads can be severely damaged by extremely small current transients on the order of 10mA [1,2]. In spite of their extreme ESD sensitivity, the magnetic recording industry has developed techniques to handle and assemble millions of GMR heads without a significant, continuous ESD-related yield loss.

However, it is less known and understood that GMR heads can also be damaged indirectly by high frequency electromagnetic fields. One source of field is the spark associated with an ESD event, which can induce a significant current transient through the GMR sensor *indirectly* [3,4,5]. It is therefore of critical importance to study and understand the damage mechanism due to electromagnetic interference (EMI), since it can lead to yield losses if ignored. This high frequency field damage mechanism spans the specialized disciplines of electrostatic discharge (ESD) and electromagnetic compatibility (EMC).

One method for testing the EMI immunity of a device is to use a GigaHertz TEM (GTEM) Cell [6]. Figure 1 shows a schematic representation and photo of a GTEM Cell, which is used to provide a uniform electromagnetic field in a specified

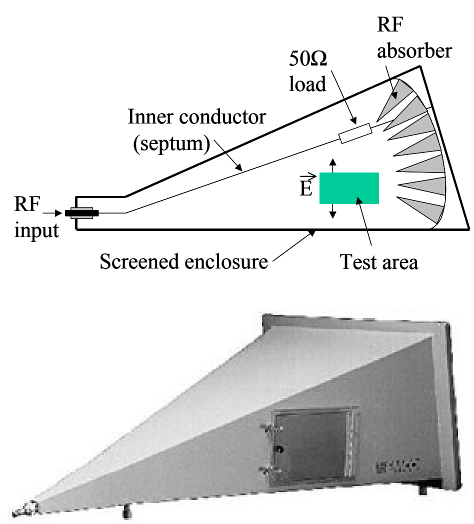

Fig. 1.(top) Schematic representation of a GTEM cell. (bottom): Photo of the 1.7m long GTEM cell, showing opening door in the side for inserting the device under test.

volume inside a pyramid-like structure that has properties of a far field. The GTEM cell provides for a controlled, high frequency electric field in a closed metal box that is shielded from any external interference.

The GTEM Cell is well known as a radiated emission measurement tool and is, essentially, a TEM cell that has been altered to extend the usable frequency range. This is achieved by replacing one port of a two-port TEM cell with a wideband, non-tapered, hybrid discrete resistor/wave absorber termination. The GTEM Cell also has an internal conductive plate or "septum". The GTEM Cell is accepted for EMC testing in lieu of far-field measurements by various international regulation bodies. The level of the RF signal that is fed into the GTEM Cell determines the field strength developed within the test volume of the cell.

The purpose of this work was to study the effect of electric fields on the behavior of the GMR head on a typcial assemblies and to determine under what conditions an electric field can damage state-of-the art GMR sensors.

II. Experimental

An ETS-Lindgren Model 5402 GTEM cell with an overall length of 1.7m and a test area that measured 16.7 cm x 12.5 cm was used in this study. The frequency range was 300kHz to 2.9GHz for the radiated immunity testing done in this study.

Magnetic recording assemblies with either giant magnetoresistive (GMR) or tunneling MR (TMR) heads at an areal density design point ranging from 40 to 60 Gb/in^2 were used in this study. The GMR (TMR) sensors had a direct charged device model ESD failure level of 3V (1V) [2]. An Integral Solutions International 2001 QST tester was used to measure the resistance and magnetic properties of the recording head before and after exposure to the electromagnetic field in the GTEM Cell.

Two types of magnetic recording assemblies were studied: head gimbal assemblies (HGA) and head arm assemblies (HAA). The HGA consisted of a GMR head on a suspension with a single "long-tail" interconnect. Figure 2 shows an HGA mounted on insulating blocks inside the GTEM Cell test area, along with a Credence Technologies CTC-111 E-field sensor.

The HAA is an assembly with one HGA , preamplifier and connector. Figure 3 shows an example of an HAA in the test chamber.

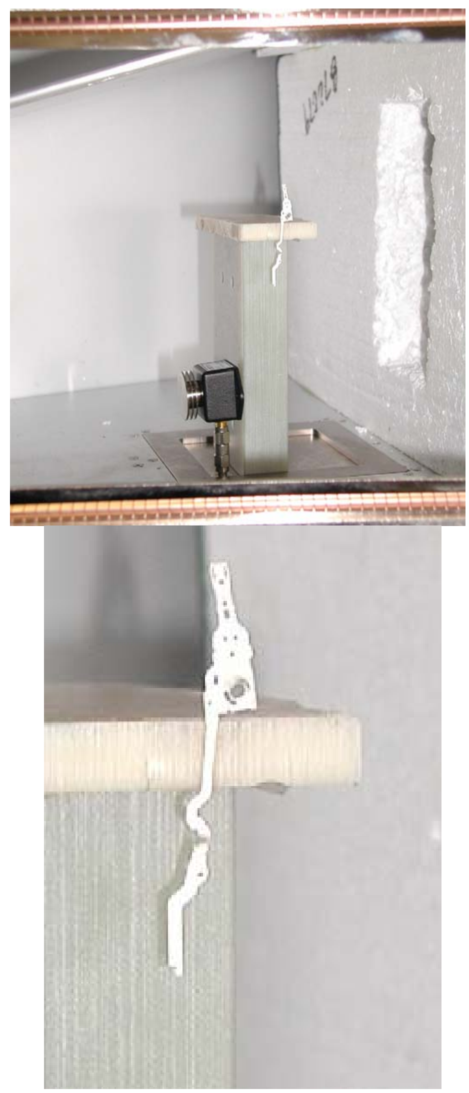

Fig. 2 HGA on insulating pedestal inside the GTEM Cell.

Fig. 3. HAA on pedestal inside GTEM Cell. Field sensor is shown to left of HAA.

Three types of voltage waveforms were applied to the input of the GTEM Cell: swept (300kHz to 2.9GHz) continuous sinusoidal, repetitive square pulses, and a single voltage transient generated from an RC discharge. The tracking generator in an Agilent HP8595A spectrum analyzer was connected to an RF Amplifier (Mini-Circuits ZFL-2500VH) to generate the continuous swept field. For transient fields, a Philips pulse generator (PM5770) was used to produce 10ns-long voltage pulses spaced 5μs apart. Finally, a simple charged 150pF capacitor was discharged into the 50Ω GTEM input to produce even higher fields of a transient nature.

In some tests, an HGA with an additional 7 cm-long monopole antenna was connected to one input of the recording head. Fig. 4 shows the HGA on a board with a vertical wire attached, along with the E-field sensor. The additional wire simulated the real-word situation of a resistance measurement, where the ohm meter wires form an additional antenna connected to the device input.

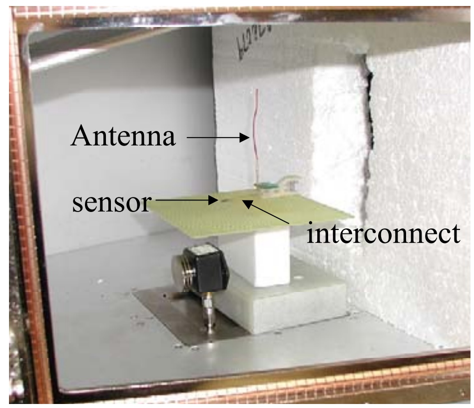

Fig. 4. HGA on plate with vertical wire "monopole antenna" connected to the GMR input.

III. Results

Figure 5 shows the resistance and amplitude for 5 GMR HGAs before and after exposure to swept and pulsed fields. The field strengths for the swept field and pulsed fields was 10 V/m and 40 V/m respectively. Note that there were no significant changes in the magnetic amplitude of the GMR sensors. For the resistance, after a 2Ω variation is taken in to account due to contact resistance in the fixture, there were also no significnt changes. The HGAs were tested in all three orientations with respect to the E-field direction.

Figure 6 shows the resistance and amplitude for 5 TMR HGAs before and after exposure to the same swept and pulsed fields used for the GMR heads. There were no significant changes in head properties after exposure to the E-field.

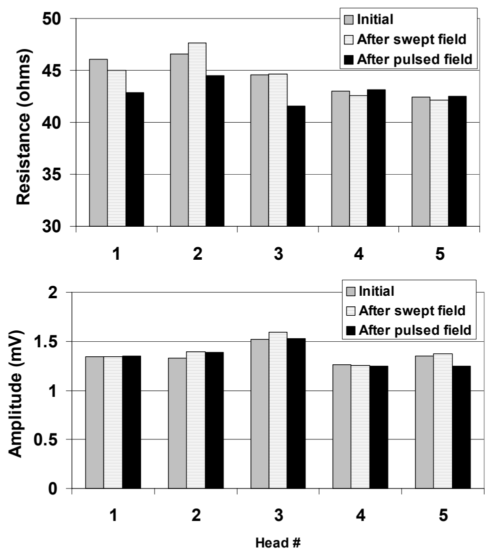

Fig 5. Resistance (top) and amplitude (bottom) for five GMR HGAs before and after exposure to swept and pulsed fields.

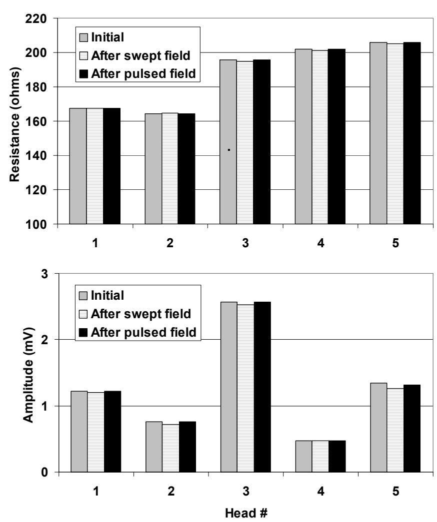

Fig. 6. Resistance (top) and amplitude (bottom) for 5 TMR HGAs before and after exposure to swept and pulsed fields.

To produce even stronger fields that were more closely related to the single, pulsed EMI from an ESD event, a 150 pF capacitor was charged and discharged into the input of the GTEM Cell. Figure 7 shows an example of the voltage waveform in the cell using the E-field reference antenna CTC-111. The field had a first peak duration of about 1ns and was over in about 5ns. Figure 8 shows

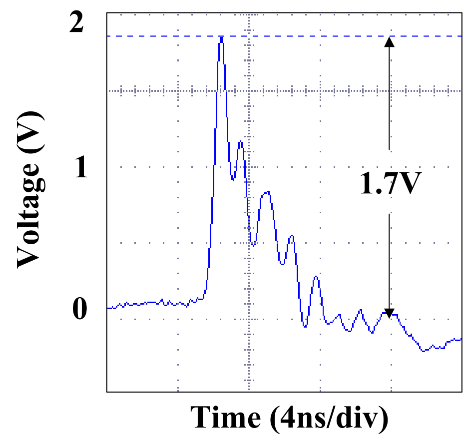

Fig. 7. Voltage waveform in GTEM cell for charged capacitor discharge at 500V.

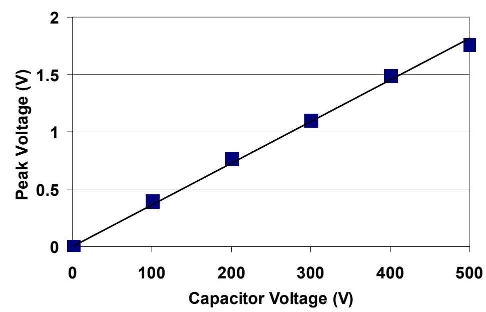

Fig. 8. Peak voltage of the discharge waveform shown in Fig. 7 vs. capacitor voltage

the peak voltage of the discharge waveform vs. capacitor voltage and shows a linear relationship with voltage.

GMR assemblies tested in the GTEM Cell using this transient field again showed no changes in resistance or amplitude. At this point, the 7-cm monopole "antenna" was then connected to one input of a GMR head and the testing was repeated.

While no changes were observed using the swept or pulsed fields even with the antenna, significant changes were observed when the stronger transient fields were applied. Figure 9 shows the resistance and amplitude of one GMR HGA (with the 7 cm wire antenna shown in Fig. 4) vs. capacitor voltage. Note the resistance increase and amplitude drop after the 500V capacitor was discharged into the GTEM input. These

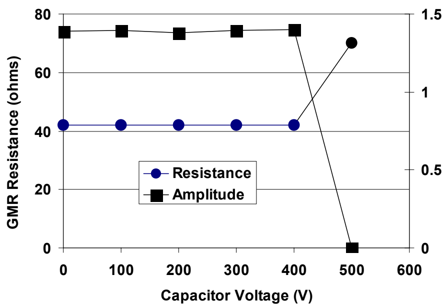

Fig. 9. Resistance and amplitude of one GMR HGA (with the 7cm wire) vs. capacitor voltage.

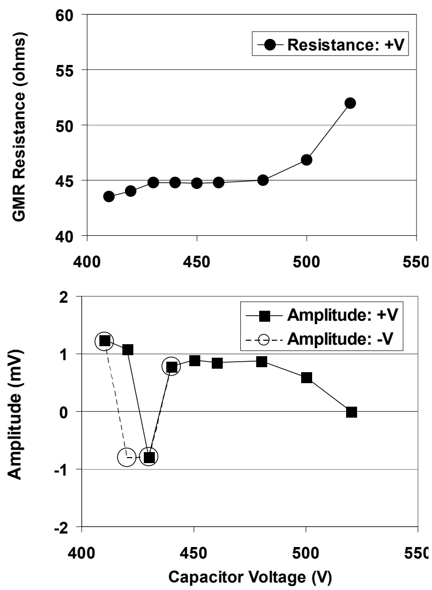

Fig. 10. Resistance (top) and amplitude (bottom) of a GMR head vs. capacitor voltage.

changes are consistent with GMR sensor melting and magnetic damage due to excessive current, as seen during CDM ESD testing.

Another head was tested using smaller voltage steps. Figure 10 shows the resistance (top) and amplitude (bottom) of the GMR sensor vs. capacitor voltage. The starting voltage was 400V, since the previous testing determined that the failure level was between 400V and 500V. Between 410V and 440V, the capacitor was charged to both postive and negative voltage. Note that after the –410V discharge, the amplitude of the GMR sensor *changed phase* and went "negative". This interesting and very important phenomenon was discovered during ESD testing of GMR heads and is due to pinned layer reversal within the sensor [7].

Figure 11 shows the amplitude vs magnetic field, or transfer curve, from the QST testing of this head before and after the –420V field pulse. One can clearly see that the slope, or phase, of the magnetic output of the GMR sensor has reversed and the peak-to-peak amplitude has been reduced. Thus, the GMR sensor has been damaged.

Two HAAs with a GMR HGA on them were also exposed to fields generated by the capacitor discharge. Table 1 shows the resistance and amplitude before and after 10 pulses of +500V and 10 pulses at –500V. There were so siginificant changes in head properties.

IV. Discussion

In the magnetic recording assemblies used in this study, the only changes in GMR head performance were found for the case of an additional, 7-cm monopole antenna connected to the GMR input on the HGA and only for the transient EMI case using the capacitor discharge.

However, it is important to realize that, since EMI can have unpredictable effects, it should not be assumed that the result found for these assemblies can be extrapolated for all assemblies. This is because there are significant differences in physical and electronic design. Thus, each design must be measured. It is very likely that other magnetic recording assembly designs could have significantly lower or higher field damage levels due to physical or electronic design differences.

Another subject related to EMI influence on magnetic heads that warrants examination and study is induction of current transients into shunted heads and terminated head

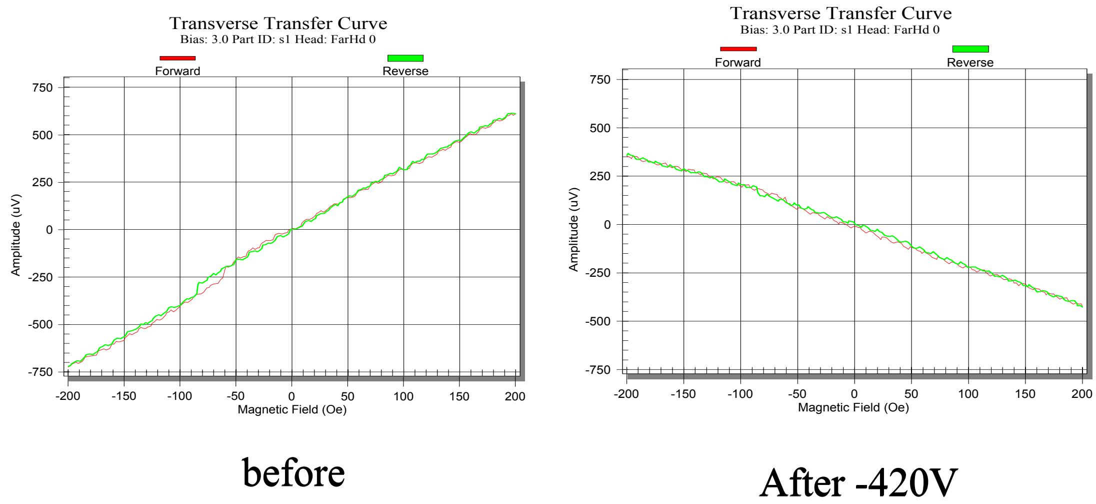

Fig. 11. QST amplitude vs. magnetic field curves for a GMR head before (left) and after (right) a negative 420V capacitor discharge to the GTEM cell input.

HAA #	Initial Resistance (Ω)	Final Resistance (Ω)	Initial Amplitude (mV)	Final Amplitude (mV)
1	49.8	49.8	2.88	2.89
2	46.7	46.6	2.63	2.66

Table 1. Resistance and amplitude of two HAAs before and after 10 pulses of +/- 500V capacitor discharges to the GTEM cell input.

assemblies caused by proximity to a ground plane with significant ground currents. This can occur when the assembly is simply lying on the grounded metal surface of a workbench or inside the tool whether directly or on an insulator. Ground return currents of wide spectrum, from DC to very high frequencies, are widely present in the industrial environment and create an accompanying magnetic field. This field, in turn, may create current via magnetic coupling in the closed loop of shunted head or terminated head assembly and inject current with the potential of exceeding head damage level.

Yet another situation that could expose magnetic recording assemblies to unexpectedly large electric and magnetic fields is *inside* a fully assembled hard disk drive due to a direct ESD event to the *outside* of the disk drive. This can occur during handling or ESD immunity testing. During this ESD Immunity test, which is described in the IEC 61000-4-2 standard, an ESD gun is used to “zap” the outside of the drive. At a gun voltage of 8kV in the contact mode the peak current that is injected onto the disk drive is about 30A! This large current can result in electric and magnetic fields inside the disk drive via apertures and/or conduction.

V. Conclusion

While the failure level due to current transients during ESD testing of extremely sensitive Class 0 devices is routinely measured and fully understood, the susceptibility of Class 0 devices to current transients caused by transient, high frequency fields has not been well studied.

It is concluded that it is important to measure the field sensitivity of assemblies with Class 0 devices, especially magnetic recording assemblies. Armed with this knowledge, one can begin to set specifications on the measured level of electromagnetic fields found in the production environment, during ESD immunity testing and handling of these components.

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