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RESTORING AN IBM RAMAC 350 AND RECOVERING THE ORIGINALLY RECORDED DATA

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IBM loaned the mechanical hardware of a RAMAC 350 (the first disk drive), shown to the left, to The Magnetic Disk Heritage Center, then located at Santa Clara University. The goal was to restore this drive to an operational status so it could serve as a historical "icon" reflecting the birth and beginnings of magnetic disk storage. We report the results of a preservation effort in which we have successfully read, digitized, and decoded all of the pre-existing recorded information. This demonstrates, without extrapolation and after 40-50 years, the continued functionality of all of the motors and the integrity of the disk coating, the magnetic heads, the spacing mechanisms, and the recorded information.

The first two years involved two senior design projects to establish the feasibility of a restoration. The first project demonstrated that the access mechanisms could be controlled with a microprocessor and solid state electronics. As received, the 50 disks in the stack were all heavily coated with dust and other debris. An *in situ* cleaning process was developed that preserved the oxide coating on all 100 surfaces. The pneumatic system was refurbished to load the heads to the nominal spacing of about 25-50µm. This allowed the second project to demonstrate that the recorded data could be read back and that the heads could still write to the disk.

The MDHC then relocated to the Computer History Museum and continued with volunteers. One initial focus was to preserve the recorded contents of the 50 disks.

The readback waveforms from all 10,200 tracks were captured with a digital storage oscilloscope. The 50,854 formatted records were decoded with a software peak detector, and there were no errors that could be attributed to data decay (the other 146 sectors had not been recorded with formatted data). Two records had errors: one appeared to be due to poor overwrite; the other had two invalid characters (with the correct parity). Based on the contents, some of the records must have been recorded in October 1965 or later.

Figure 1 shows the readback waveforms from the OD track (-01) and the ID track (100). The peak-to-rms signal-to-noise ratios for these waveforms are about 30dB at the OD and 24dB at the ID. Since the estimated bandwidth of the preamplifier is about 10 MHz, reducing the bandwidth to 1MHz increases the SNR by about 10dB.

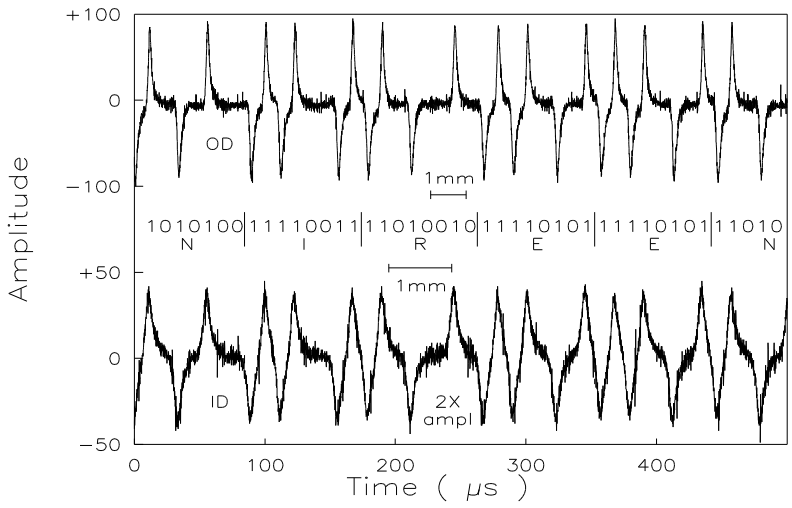

Figure 1. Readback waveforms from tracks -01 and +100, showing the same data patterns. The ID waveform has been magnified 2X for clarity. Also shown is the detected transition pattern, the decoded characters, and scales indicating 1mm. The decoded test is read from right to left.

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The data were recorded at a PW_{50}/T of less than 1.0 (commensurate with contemporary signal processing capabilities), and there was no significant intersymbol interference even at the innermost tracks. The error rate was estimated by extrapolating timing and amplitude margins based on the 4000 data bits per track. The projected error rate for the OD tracks was less than 10^{-40}, dominated by missing or extra bits, and the error rate due to shifted bits was extrapolated to be less than 10^{-80}.

The isolated pulses were asymmetric, with the rise times on the leading edge obviously shorter than the fall times. This asymmetry is consistent with the perpendicular component in the recorded magnetization. A small amplitude asymmetry of about 5% may be a readback effect due to some residual magnetization in the yoke.

The pole tip dimensions of two heads were measured by optical microscopy. The read/write element was skewed about 5˚ with a width of 460μm, pole lengths of 52μm, and a gap length of 35μm. The corresponding dimensions for the erase element are <1˚, 780μm, 500μm, and 38μm. The nominal head-medium spacing was about 25-50μm.

The disks were spin coated with an epoxy-based paint, with a nominal thickness of about 50μm. One disk was tested with modern techniques. The magnetic recording medium is composed of randomly oriented γ-Fe_2O_3 particles, not obviously acicular, with a coercivity of 263-266 Oe. The remanent magnetization was 37 memu/cm^2 at the ID and 45 memu/cm^2 at the OD. The K_uV/kT from AGM measurements was more than 200.