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Imaging of magnetically recorded data using a novel scanning magnetic microscope

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Abstract

In this paper we report new results obtained using a novel scanning magnetic microscope. In particular, we demonstrate the use of this system to reveal, in two dimensions and at high resolution, the information recorded on a standard ferric magnetic tape. Results are presented for an audio frequency signal, individual bits of data and a credit card 'bar-code' pattern. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Scanning microscopy; Magnetic materials; Imaging; Magnetic recording

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1. Introduction

Analysis of material properties in the micron to submicron regime is clearly of great importance in the development of new and improved magnetic recording media. As a part of our sensor programme at Sussex we have created a non-contact (sample to surface spacing 1 μm) scanning magnetic microscope, as previously reported [1], which currently is capable of imaging magnetic systems at the micron level. Previously, this system has been used to image magnetic domains in alloys, structures fabricated in thin film samples a few hundred nanometres thick and currency bills printed using magnetic inks [2]. In our previous work we were not concerned with magnetic materials containing recorded information but with the local, mesoscopic, properties of these materials. For many of the previous applications we have been recording the contrast between the non-magnetic substrate and the magnetic material. In this paper we report on new results which demonstrate that our scanning microscope system can be used to reveal, in two dimensions and at high resolution, the magnetic orientation information corresponding to signals recorded onto standard magnetic tape.

2. Microscope system

The microscope is based on a fine gap magnetic circuit derived from standard video head technology. The sense head used in this microscope was produced by mechanical polishing to reduce the dimensions of the head gap to approximately 1 μm in both width and length. The modified structure created by this machining process formed the measurement tip of the sense head. This procedure had the effect of reducing the effective inductance of the head, which in turn, required us to find a satisfactory method for monitoring the correspondingly small inductance changes (typically maximum $\Delta L \sim 30$ nH). In this head it is just these small inductance changes which are created when the sense head is scanned over the surface of a magnetic sample (typical dwell time ~ 200 ms/point). One solution is to incorporate the sense head into a gyrator circuit and resonate this at audio frequency (typically 5 kHz). The gyrator is an active circuit which transforms the small (< 1 μH) inductance of the head into a larger effective capacitive reactance. This effective capacitance is then connected in parallel with a passive inductor to form a resonant circuit.

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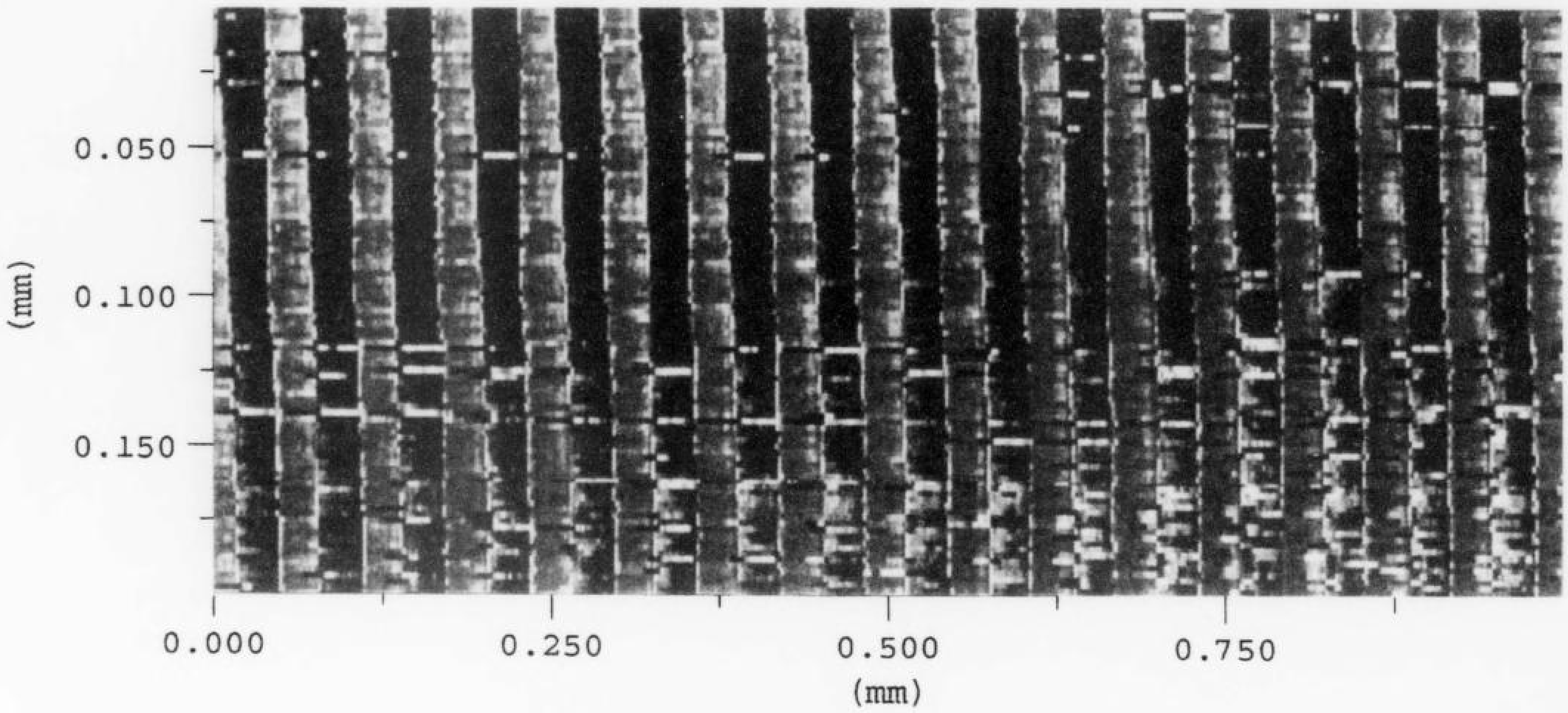

Fig. 1. Grey-scale image of 3 kHz square wave recorded onto a standard ferric recording tape.

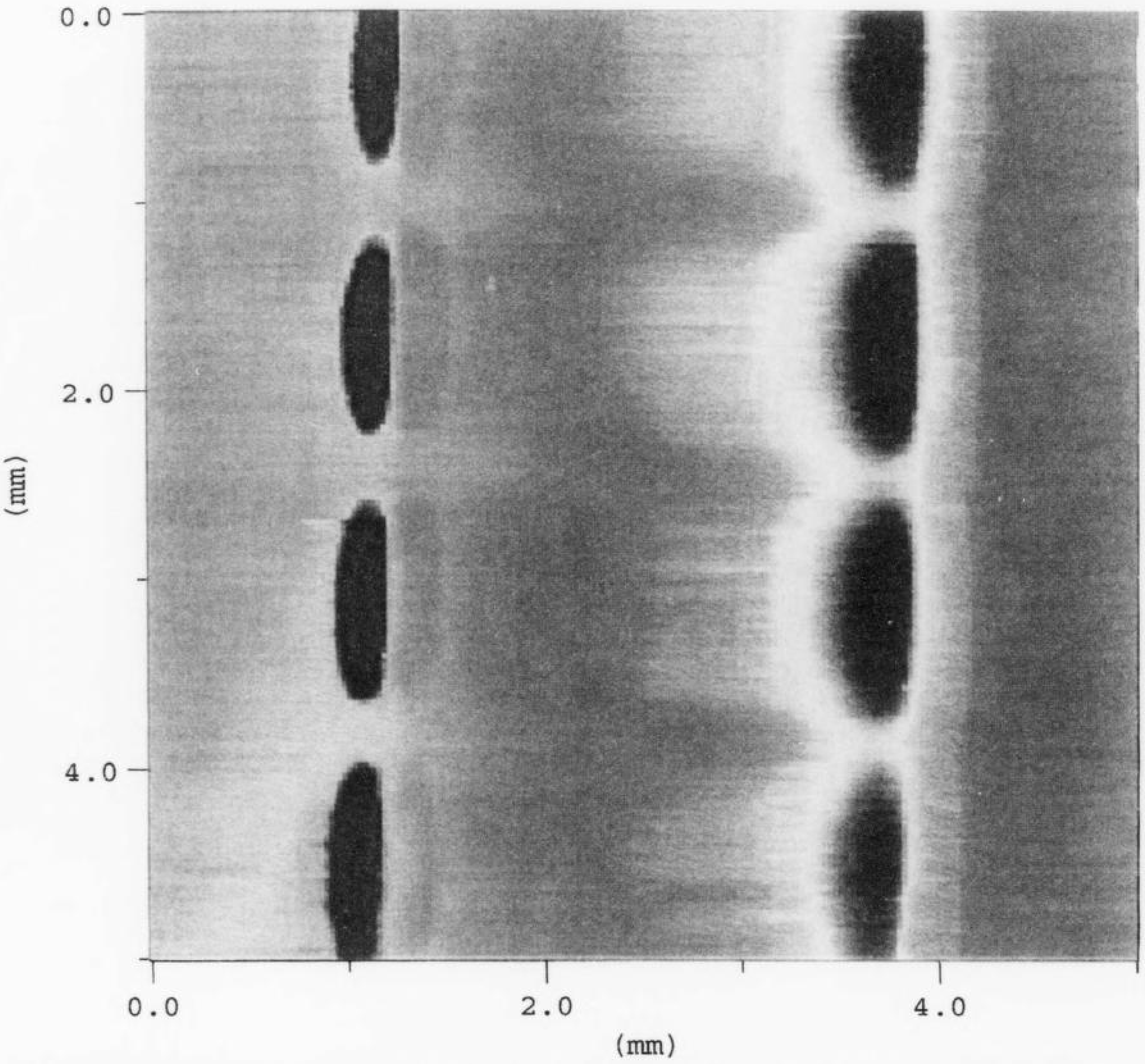

Fig. 2. Grey-scale image showing individual bits of information recorded onto a computer data tape.

Passing a magnetic sample close to the head will cause the effective inductance of the head to change due to flux coupling between the two. In operation a fixed frequency drive current is fed to the resonant circuit from a signal generator and the amplitude and phase of the resulting voltage across the parallel resonant circuit provides the output. A change in the inductance of the head will cause a corresponding change in the resonant frequency of the gyrator circuit and result in a phase shift in the output voltage with respect to the input current. This is the method we used to obtain the results reported in this paper. To obtain the best (i.e. highest signal-to-noise) results the quality factor (Q) of this coupled resonant system (i.e. the sense head plus the magnetic material being scanned) could be adjusted externally. In order to achieve this a field effect transistor was used as a voltage variable resistor to control the level of positive feedback within the gyrator circuit. In practice, Q factors were adjusted to deal with samples which had varying magnetic properties. This allowed a range of phase shifts to be observed, for a fixed drive frequency, as the sample was scanned. The sense head, gyrator, resonant circuit and associated feed components all operated with small signal levels and were therefore housed in a compact shielded box to minimise any noise pickup from the surrounding environment. The remainder of the signal processing electronics were built into a rack system and connected to the sense head by a shielded cable. Control of the scanning table, as well as the acquisition of the data, were carried out using a National Instruments LabView [3] virtual instrument written for this microscope.

3. Measurements

The sample was mounted on a computer controlled X, Y, Z stage which typically was operated in an X–Y raster scan mode with the probe at fixed height (Z) above the sample comparable with the step size. An external synthesised oscillator was used to provide a stable drive current at the resonant frequency of the gyrator. In this system it was arranged that the output voltage amplitude varied linearly with the phase difference between the input current and the output voltage. This linear response, is strictly speaking, only true for small changes in phase (which is the case here) and it is this which we plot as a function of position over the sample. In this work the data collected is displayed as a grey-scale image with the density representing the magnitude of the phase change. In Fig. 1 we show the output voltage as a grey-scale image for a 3 kHz square wave recorded on a standard ferric audio tape. Clearly, we can see the reversal in the orientation of the magnetic material caused by the encoded information. Additional work is required to ascertain the origin of the more detailed structure within this figure. Fig. 2 is a grey-scale image of individual bits of information as recorded onto a computer data tape. The 'bar-code' pattern to be found on credit cards is shown in Fig. 3. In

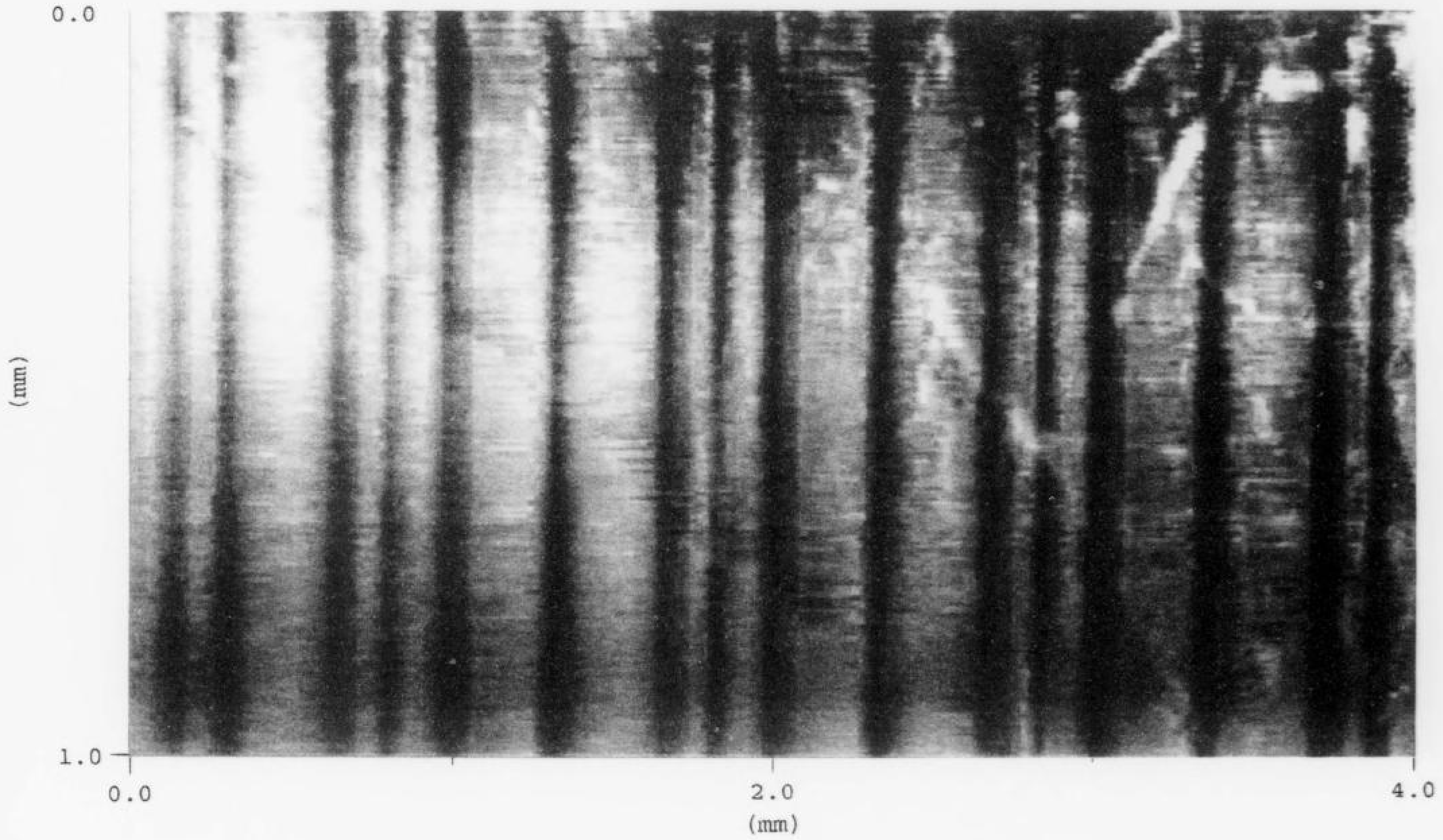

Fig. 3. Grey-scale image of 'bar-code' of a typical credit card.

all the above measurements no special sample preparation was necessary other than the requirement that the sample was flat and planar with respect to the X–Y table. The magnetic field levels which exist at the sense head are low enough to ensure that this is a non destructive magnetic measurement with no modifications occurring to the recorded data.

4. Conclusions

The scanning magnetic microscope has been applied successfully to the imaging of recorded data on magnetic media and three experimental examples have been provided to illustrate the principle of operation. We consider that this technique will prove to be a powerful diagnostic tool and is capable of operating over a wide range of length scales (millimetre to submicron) and sense head to sample distances. Information about the detailed local magnetic properties of materials may also be obtained using this microscope system. For example, the B–H curve may be measured by placing the sample inside a Helmholtz pair and recording the response of the head/sample as a function of position and applied static magnetic field. In addition, by configuring the gyrator to be a self oscillating system it is possible to look at eddy current losses locally within a conducting sample. Future work will include an accurate estimation of the magnetic field levels applied to the sample and calibration of the instrument to allow quantitative measurements to be made.

References

[1] G. Howells, R.J. Prance, T.D. Clark, C. Watkins, C. Vittoria, J.M.M. Mat. 155 (1996) 55–56.
[2] G. Howells, R.J. Prance, T.D. Clark, H. Prance, Meas. Sci. Tech. 8 (1997) 734–737.
[3] LabView virtual instrumentation software, National Instruments U.K. Corp., 21 Kingfisher Court, Hambridge Road, Newbury, RG14 5SJ.

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Two-dimensional measurements and presentation of media recording properties

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Abstract

A system for measuring the head output voltage across the surface of a video tape is introduced. The two dimentional distribution is shown by means of a contour plot. Typical results are shown and discussed.

Keywords: Two-dimensional distribution; Optimum head current; Contour plot

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1. Introduction

Media recording properties, namely signal output, signal to noise ratio, dropout rate [1], 50% pulse width etc., are usually characterized by one value for the whole media. This may be sufficient for commercial matters but from the production and research points of view it is desirable to know the two-dimensional distributions of the parameters across the surface of the media, which can tell something substantial about the production process, the physical properties of the media and the recording system as well.

2. Equipment and preparation of media

Fig. 1 shows the block diagram of the measuring system for tape media. It is designed to measure tape media as well as disc media, but for disc media some minor modifications are necessary. The system is build up of five subunits. The envelope detector (1) converts the amplified head signal into a DC–voltage. This voltage follows the peak amplitude according to the setting of the time constant τ. The optimal setting of τ was found to be 100 μs for all measurements presented in this paper. The A/D convertion unit (2) converts the DC–voltage into a binary value which is stored in the memory unit (3). The trigger unit (4) is driven by the head drum pulse signal. Each slope of this signal starts a burst of 20 sampling pulses with a time period of 1 ms. Each pulse starts the A/D conversion process. The results are stored in the memory. Finally the memory is read out via a RS232 serial interface (5) into a personal computer by using ASCII format.

The tapes are recorded by applying a 5 MHz signal to the head amplifier of commercial available PAL VHS-tape deck. The selected amplitudes are 170–310 mV in steps of 20 mV. Each amplitude is recorded in a block of approximately 5 min. Various commercial HG-tapes are measured.

3. Experimental results

Before discussing the measured results it is necessary to make a few remarks about tape geometry and tape speed. Each block recorded with a fixed amplitude is replayed and measured for 8 s. This corresponds to 8 s/20 ms = 400 tracks. At each track there are 20 sampling points which give 8000 samples per measurement.

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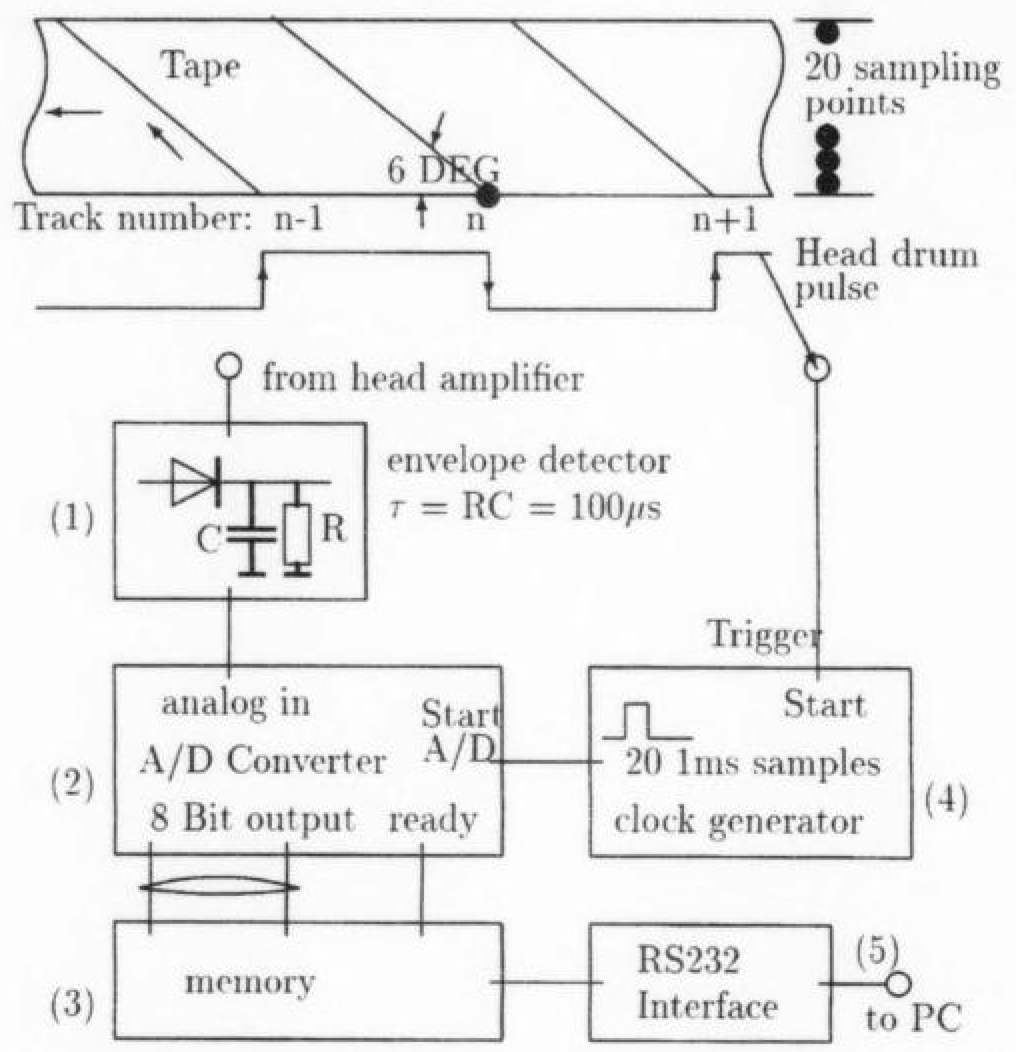

Fig. 1. Block diagram of the measuring equipment and tape geometry.

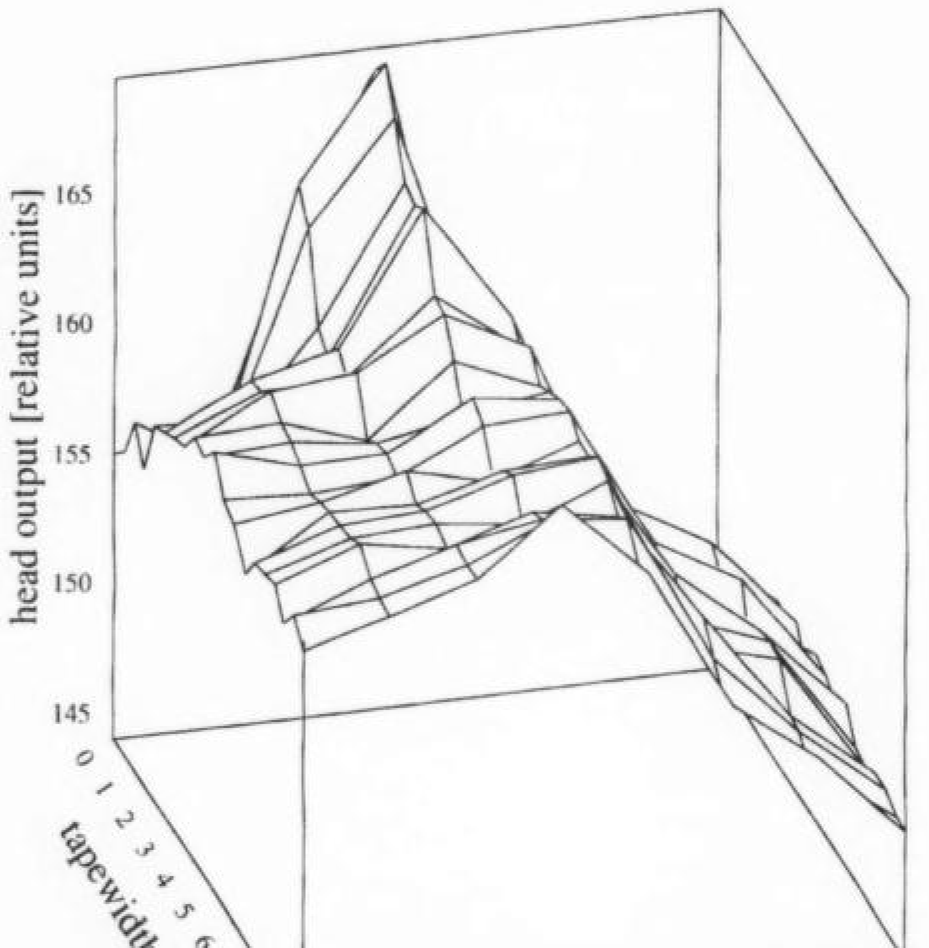

Fig. 2. Playback signal (head output) is shown as a function of tapewidth position and recording amplifier input voltage.

The total length of tape during the replay time of 8 s is (23.39 mm/s × 8 s = 187.12 mm (upper or lower edge of the tape). The 180° tape width is 10.07 mm. For calculating 'real world' coordinates of the measured points it is necessary to consider the video track angle of about 6 degrees. All the tape and speed data used in this paper base on the PAL VHS specification described in Ref. [2].

In Fig. 2 the head output signal for each of the 8 fixed amplitudes along the tape length axis is averaged and shown at each of the 20 sampling positions along the tape width. The result is a 3-dimensional graph which shows the change of output as a function of both, tape width position and recorded amplitude. Fig. 2 shows clearly that the optimum head current is a function of the tape position.

Fig. 3 shows the distribution of the head output across the tape surface. It is drawn by using the block data with 230 mV input voltage. The 'real world' coordinates used in this graph are calculated from measured data by using the video track angle. In order to get a one to one graph only a small part of the tape surface (10 mm × 20 mm) is shown in Fig. 3. The contour lines are marked in dB values where 0 dB is chosen to be equal to the maximum head output value within the area shown in the graph. The total change of head output voltage is 1 dB which is typical for all measurements within this area size. Another typical fact is that head output is changing more strongly in the direction of tape width (about 0.7 dB) than in the direction of tape length (about 0.2 dB).

Figs. 2 and 3 are created by using GLE 3.3 [3].

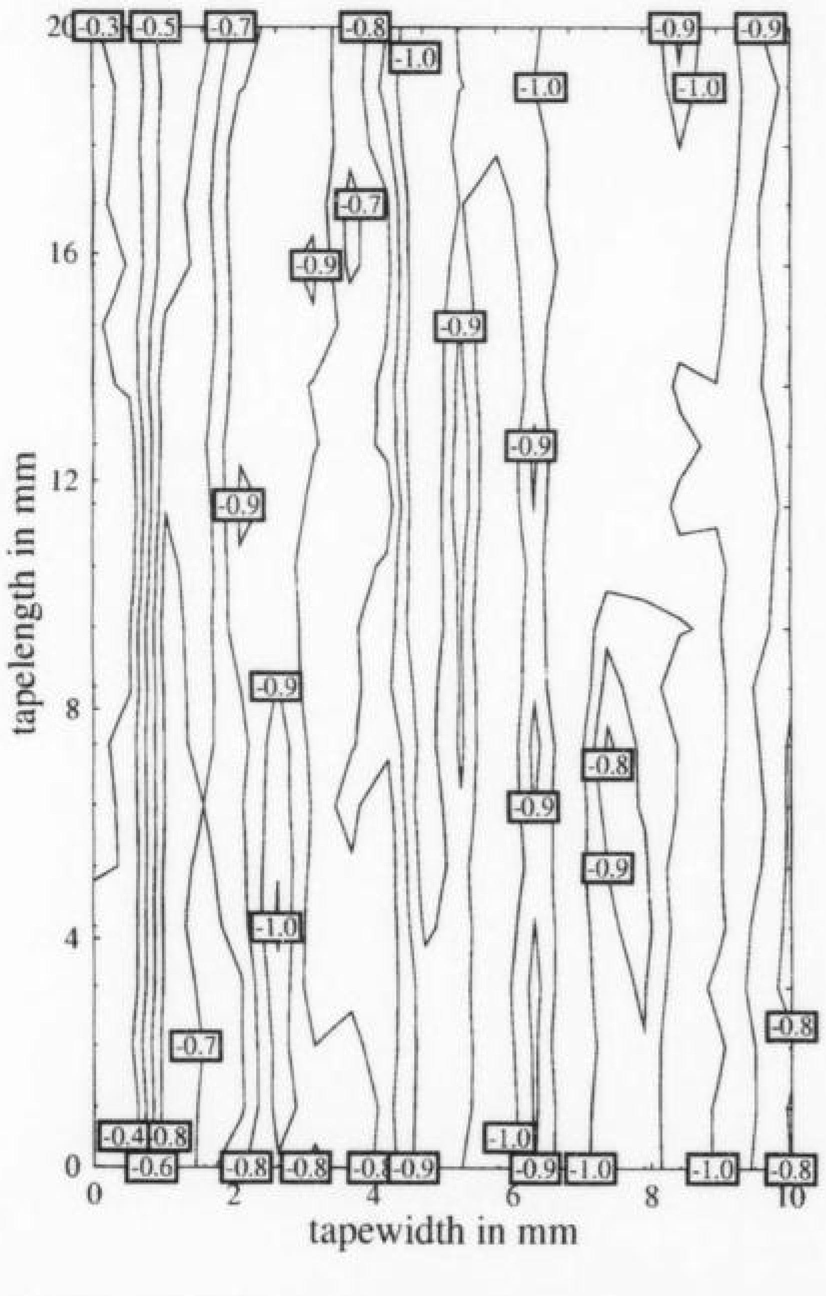

Fig. 3. Playback signal (head output) is shown as a function of tapelength and tapewidth position in 'real world' coordinates. Recording amplifier input voltage is 230 mV which is near the optimum recording current.

4. Conclusions

By measuring the head output across the tape surface at distinct points it is shown that the optimum head current setting depends on the position within the surface. Furthermore, it is shown that the head output variations along the tape width are bigger than along the tape length.

References

[1] R.H. Arnold, J. Magn. Soc. Japan 21 (Suppl. S2) (1997).
[2] ICE774 Documentation.
[3] Chris Pugmire, Graphics Language Editor, Version 3.3.