

## PCB Conductor Dimension and Alignment Inspection Using an ECT Probe with an SV-GMR Sensor

K. Chomsuwan, S. Yamada, M. Iwahara, H. Wakiwaka\*, and S. Shoji\*\*  
 Kanazawa University, 2-40-20 Kodatsuno, Kanazawa, Ishikawa 920-8667, Japan  
 \* Shinshu University, 4-17-1 Wakasato, Nagano 380-8553, Japan  
 \*\* TDK Corporation, 543, Saku, Nagano 380-8555, Japan

Inspection of bare printed circuit boards (PCBs) consists of evaluating not only imperfections in the PCB conductor but also PCB conductor dimensions and alignment. An eddy-current testing (ECT) probe consisting of a spin-valve giant magneto-resistance (SV-GMR) device was used as a magnetic sensor, with a planar meander coil as an exciter, and applied to PCB conductor dimension and alignment inspection. High-frequency (18MHz) excitation was used to inspect a PCB conductor, with thickness of less than 10  $\mu\text{m}$ , and a high-resolution scan pitch of 20  $\mu\text{m}$  enabled the examination of high-density PCBs. The characteristics and configuration of the proposed ECT probe are presented in this paper. Inspection examples of a high-density PCB with a 100  $\mu\text{m}$  PCB conductor width and gap verify that the proposed ECT probe yields accurate results.

**Key words:** spin-valve giant magneto-resistance, eddy-current, printed circuit board, dimension, alignment, inspection

### 1. Introduction

PCB inspection was divided into two parts. The first is inspection of electric circuit consisted of PCB conductor disconnection and short circuit. The second is PCB conductor dimension and alignment inspection. These also includes partial defect on PCB conductor. Conductive tester by pin probe is a traditional technique that usually used to inspect defect on PCB conductor. This technique is able to inspect only electric circuit failure on PCBs. Moreover, PCBs obtains mechanical stress from contact action. Optical method by CCD camera is well known and world wide use for PCB inspection. This method is a non-contact method and inspects the PCB pattern. It means that inspection of PCB conductor dimension and alignment can be achieved well. However, after the PCB surface was coated, optical method is very difficult to inspect defect (invisible defect) on PCB conductor such as conductor disconnection, partial defect, and etc.

ECT technique for inspection of defect on PCB conductor was proposed and provide good inspection results<sup>1), 2)</sup>. Not only defect on PCB conductor but also PCB conductor dimension and alignment is able to be inspected by ECT probe. In this paper, ECT probe structure, inspection principle, and simulation analysis are proposed. Moreover, absolute measurement error of PCB

dimension and especially example of high-density PCB inspection are also proposed.

### 2. System configuration

The proposed ECT probe consists of planar meander coil as an exciter and SV-GMR device as a magnetic sensor. The SV-GMR sensor is mounted on planar meander coil to detect magnetic field only in z-direction, as shown in Fig. 1(a). The advantage of SV-GMR sensor denotes that it is useful to apply it for this purpose<sup>3)</sup>. For example, SV-GMR has high spatial resolution because of the small size, high sensitivity to low magnetic field over board range of frequency, low noise, and etc. The exciter conductor size is 200  $\mu\text{m}$  width, 35  $\mu\text{m}$  thick and 50  $\mu\text{m}$  pitch as shown in Fig. 1 (b). The distance from the PCB surface to the SV-GMR sensor surface is around 135  $\mu\text{m}$ . This includes the films needed to isolate the meander coil, PCB conductor, and SV-GMR sensor. The SV-GMR sensor that has effective area of 180  $\mu\text{m} \times 193 \mu\text{m}$  was used in the experiment. A normal resistance of the SV-GMR sensor is 627  $\Omega$ . Sensing axis,  $B_z$ , sensitivity of the SV-GMR sensor to the magnetic flux density in linear

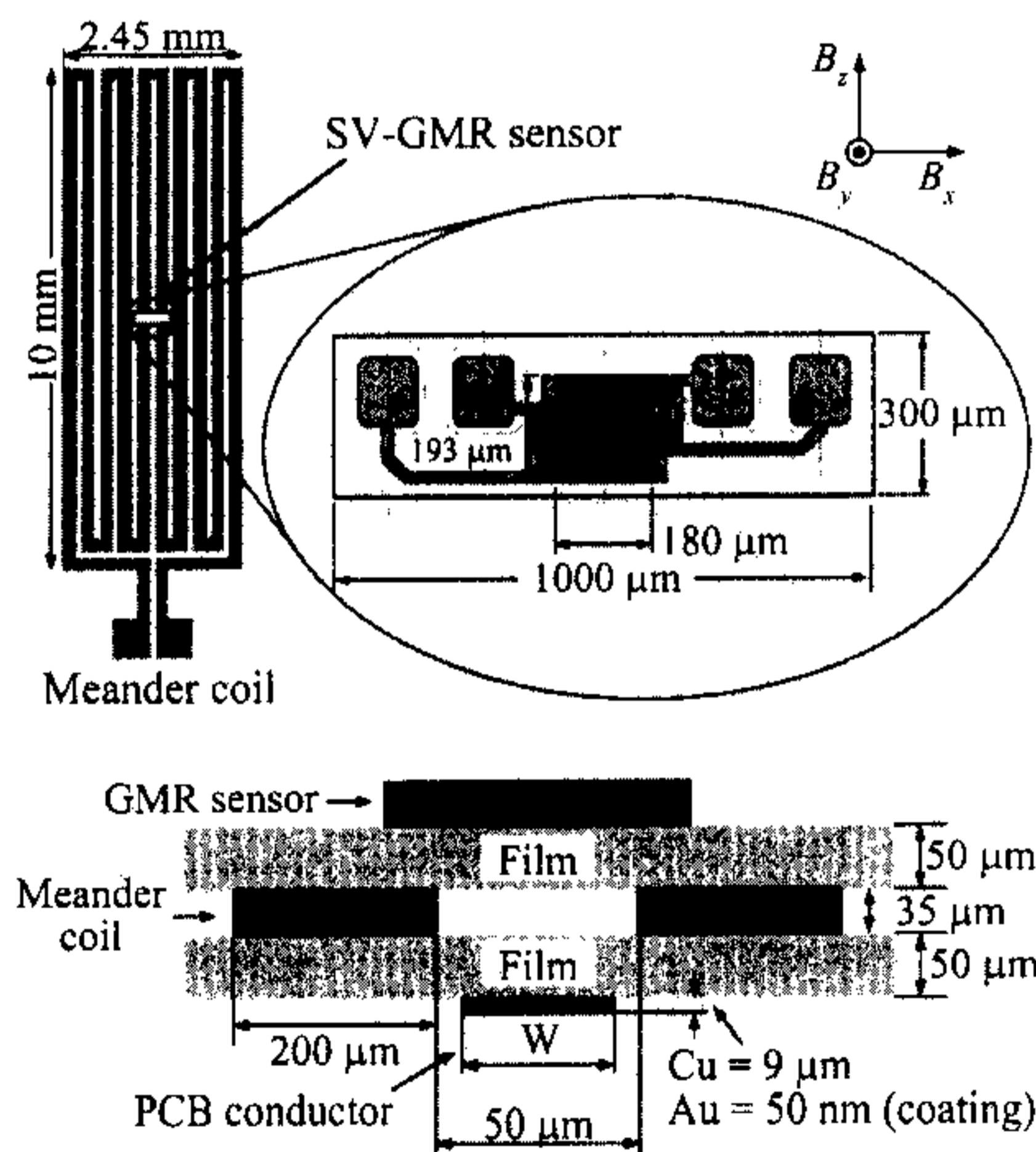


Fig. 1 Top-view (top) and cross-sectional (bottom) structure of the proposed ECT probe.

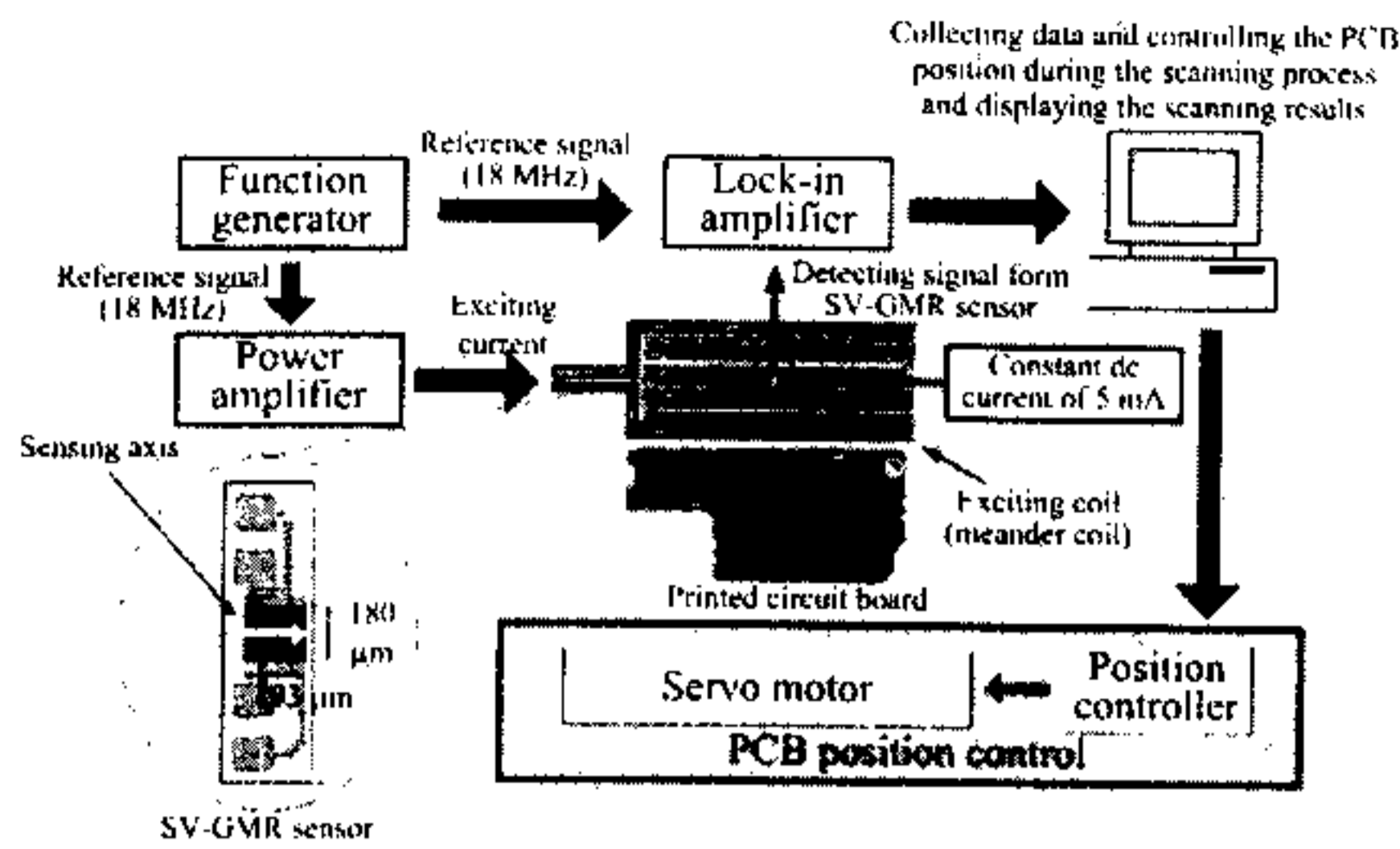


Fig. 2 Configuration of the proposed system.

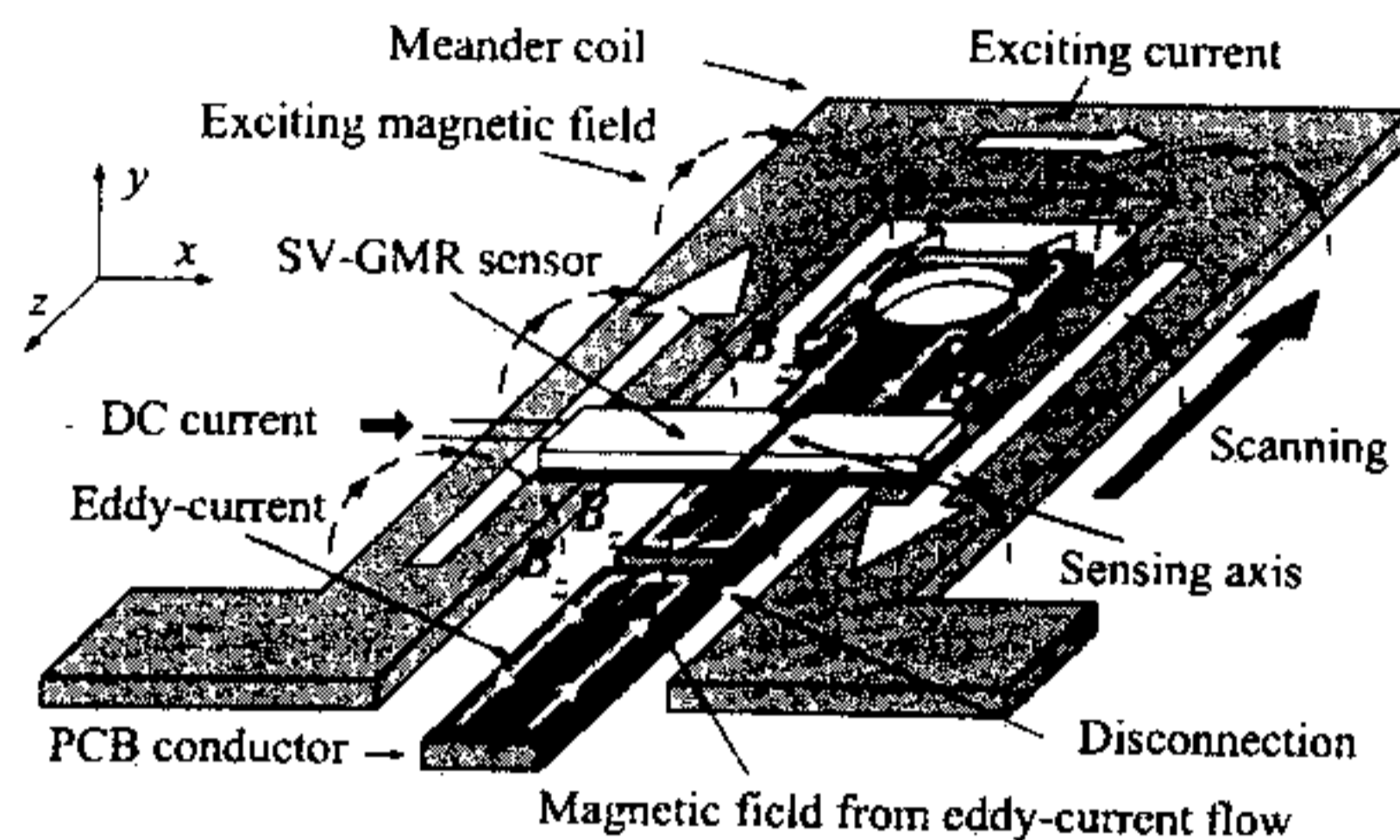


Fig. 3 Basic principle of ECT technique for inspection of bare PCBs.

region is around 6 %/mT whereas the sensitivity in other axes are lower than 1 %/mT.

Configuration of the proposed system is shown in Fig. 2. The high-frequency excitation, 18 MHz, was fed to the planar meander coil to generate eddy-current flow in PCB conductor. DC bias current of 5 mA was fed to the SV-GMR sensor. Lock-in amplifier and personal computer was used as data acquisition and post processing system by image processing technique.

### 3. Detection of PCB conductor boundary

#### 3.1 Principle of ECT technique for PCB inspection

Basic principle of ECT technique for PCB inspection is shown in Fig. 3. Usually, exciting current flows in the z-axis and also generates magnetic field density in the x- and y-axis. Since high frequency excitation current was fed to exciting coil, the eddy-currents are generated in PCB conductor and, usually, flow in the z-axis. The eddy current paths will flow in the x-axis when the PCB conductor boundary that is perpendicular to scanning direction is detected. Therefore, the magnetic field density in the z-axis is generated. For detection of PCB conductor boundary that is perpendicular to scanning direction, the magnetic sensor is mounted on the planar meander coil to detect only the magnetic field density in the z-axis.

#### 3.2 Simulation analysis

The simulation results when the probe scanned over both along and across PCB conductor are shown in Fig. 4 and 5 respectively. High-frequency excitation of 18 MHz

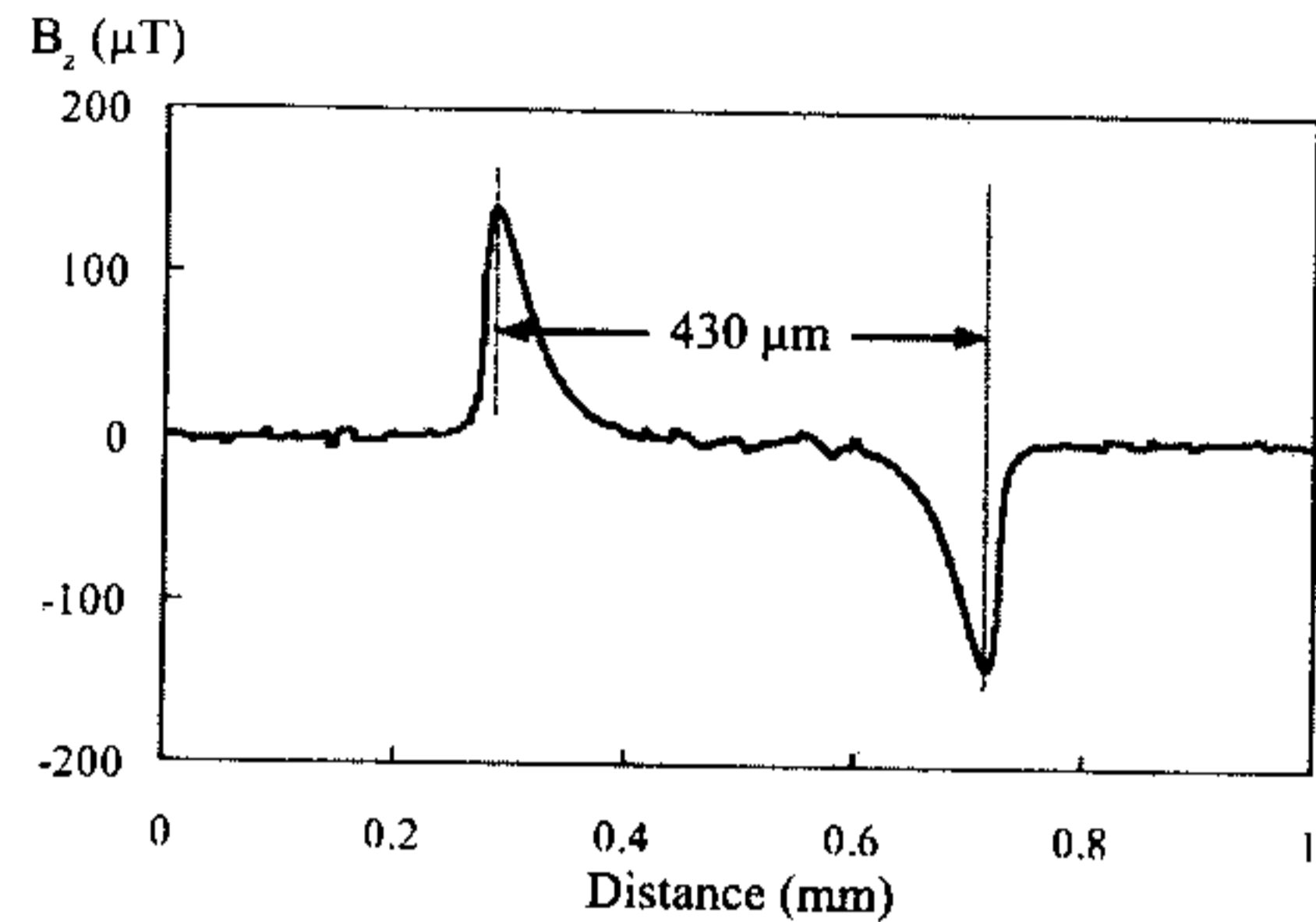
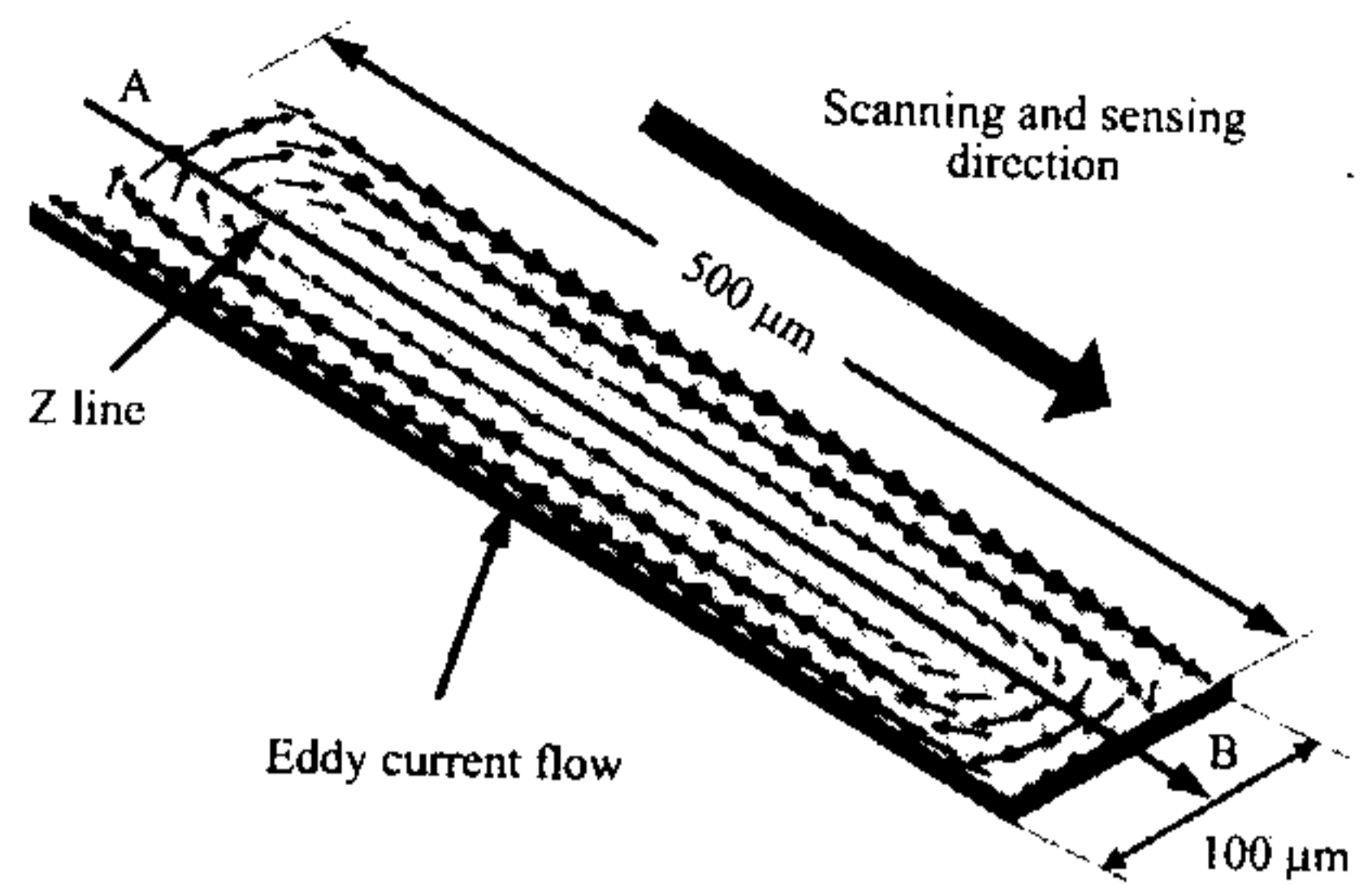


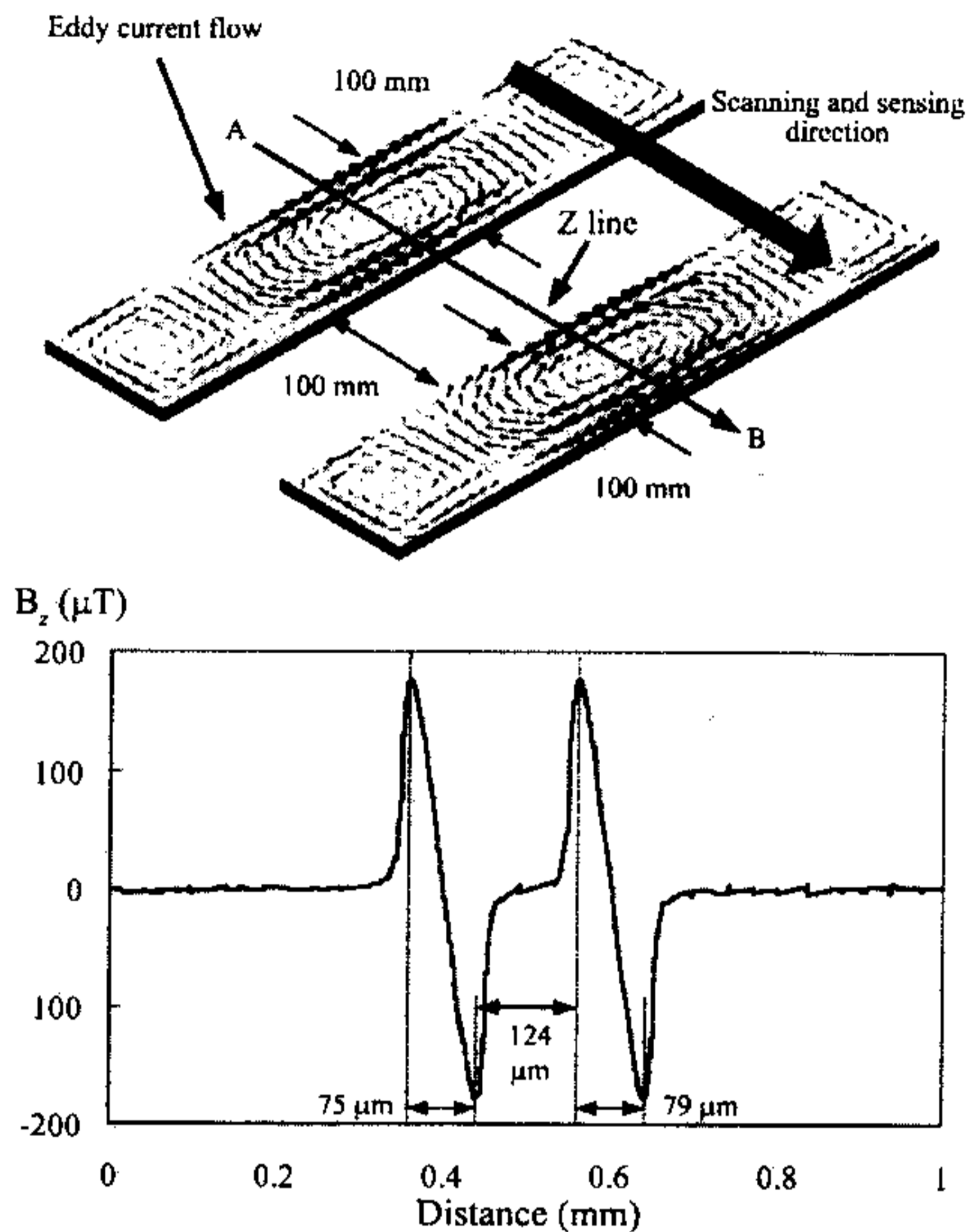
Fig. 4 Eddy current flow (top) and magnetic field density over a PCB conductor in the sensing direction on the Z line from A to B (bottom) when the probe scans along the PCB conductor.

was set for this simulation and initial mesh sizes over PCB conductor area were also set to be smaller than 10 μm. As shown in the simulation results, eddy-currents distribute near PCB conductor boundary. Therefore, peak values of magnetic field density in sensing direction occur near PCB conductor boundaries that are perpendicular to scanning direction. This characteristic indicates that both length and width of PCB conductor are specified by considering the peak values of magnetic field density with measurement error less than 70 μm and 30 μm for measurement of PCB conductor length and width respectively. For precise measurement, exciting frequency should be higher than the frequency in simulation to generate eddy-currents flowing as close as possible to the PCB conductor boundary. Therefore, peak values of magnetic field density in sensing axis will occur very close to PCB conductor boundary that is perpendicular to scanning direction.

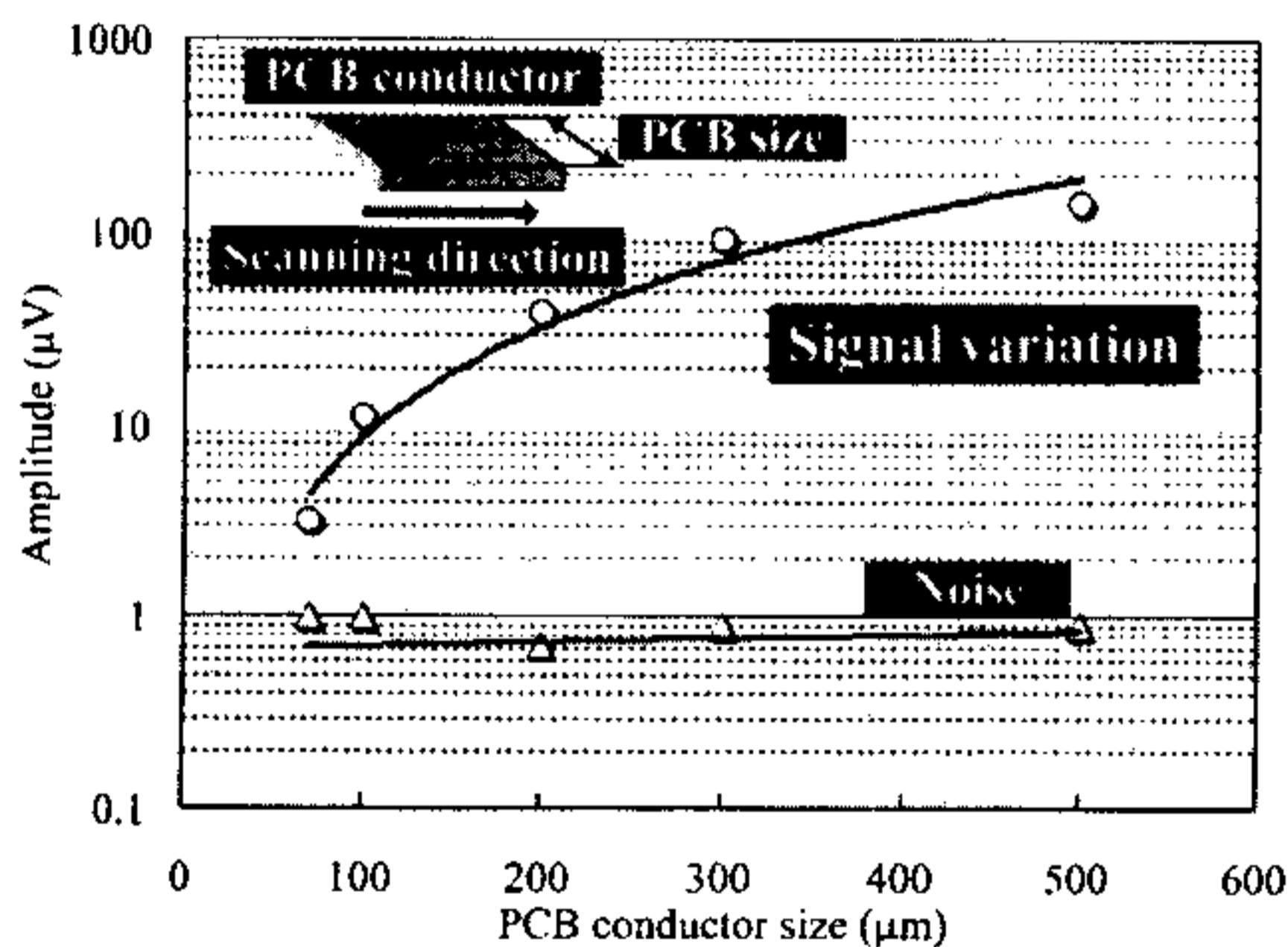
### 4. Inspection results

#### 4.1 Inspection signal

PCB conductor with 9 μm Cu thick coated by 50 nm Au was used as model in the experiment. Usually, ECT signals obtained from scanning over bare PCBs contain undesired components such as noise especially. Fig. 6 shows signal variation and noise at the PCB conductor boundary when the probe scanned along PCB conductor with different conductor widths. Amplitude of the signal at the PCB conductor boundary is proportional to PCB



**Fig. 5** Eddy current flow (top) and magnetic field density over a PCB conductor in the sensing direction on the Z line from A to B (bottom) when the probe scans across the PCB conductor.

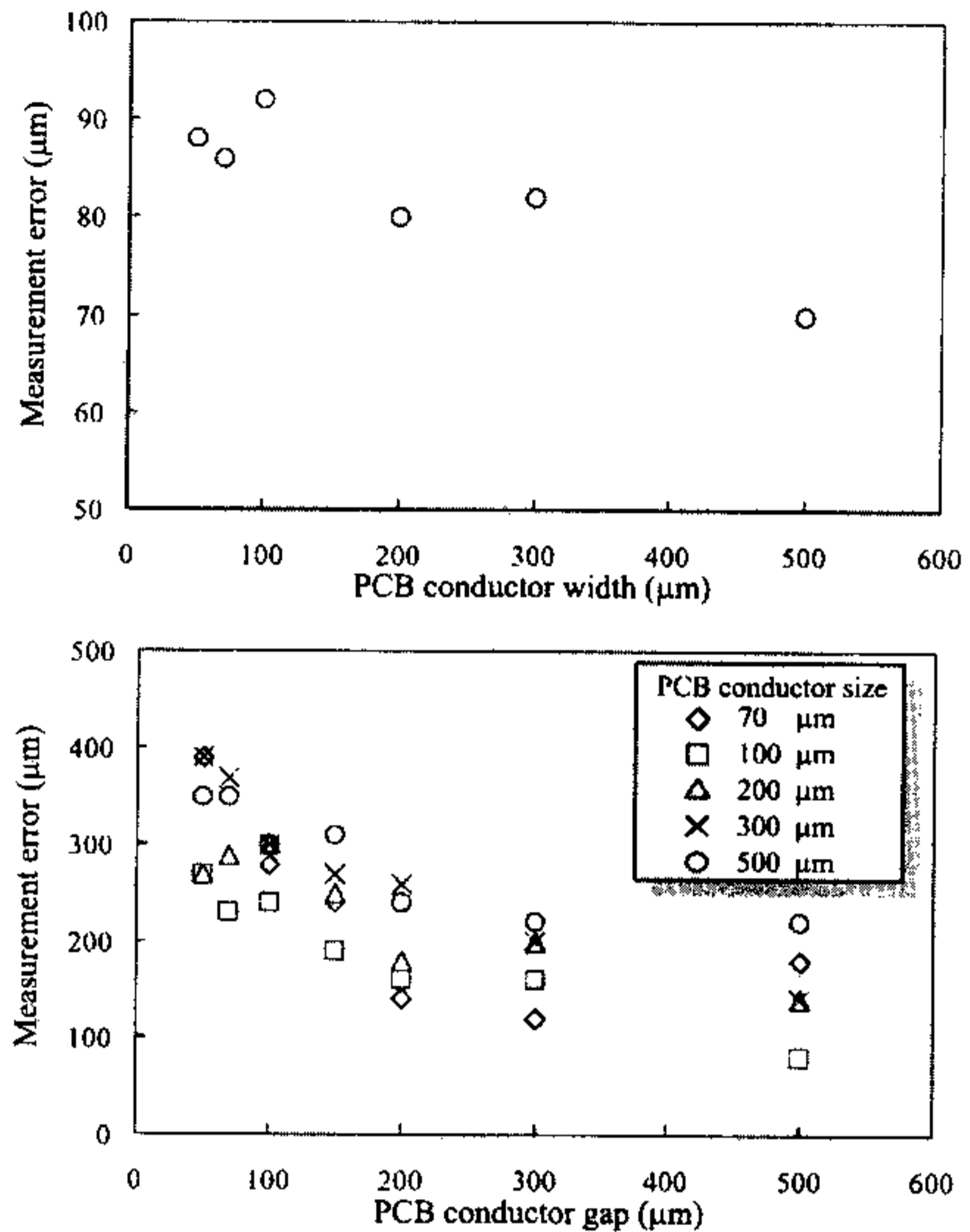


**Fig. 6** Signal variation and noise at the boundary of a PCB conductor according to the difference in its width.

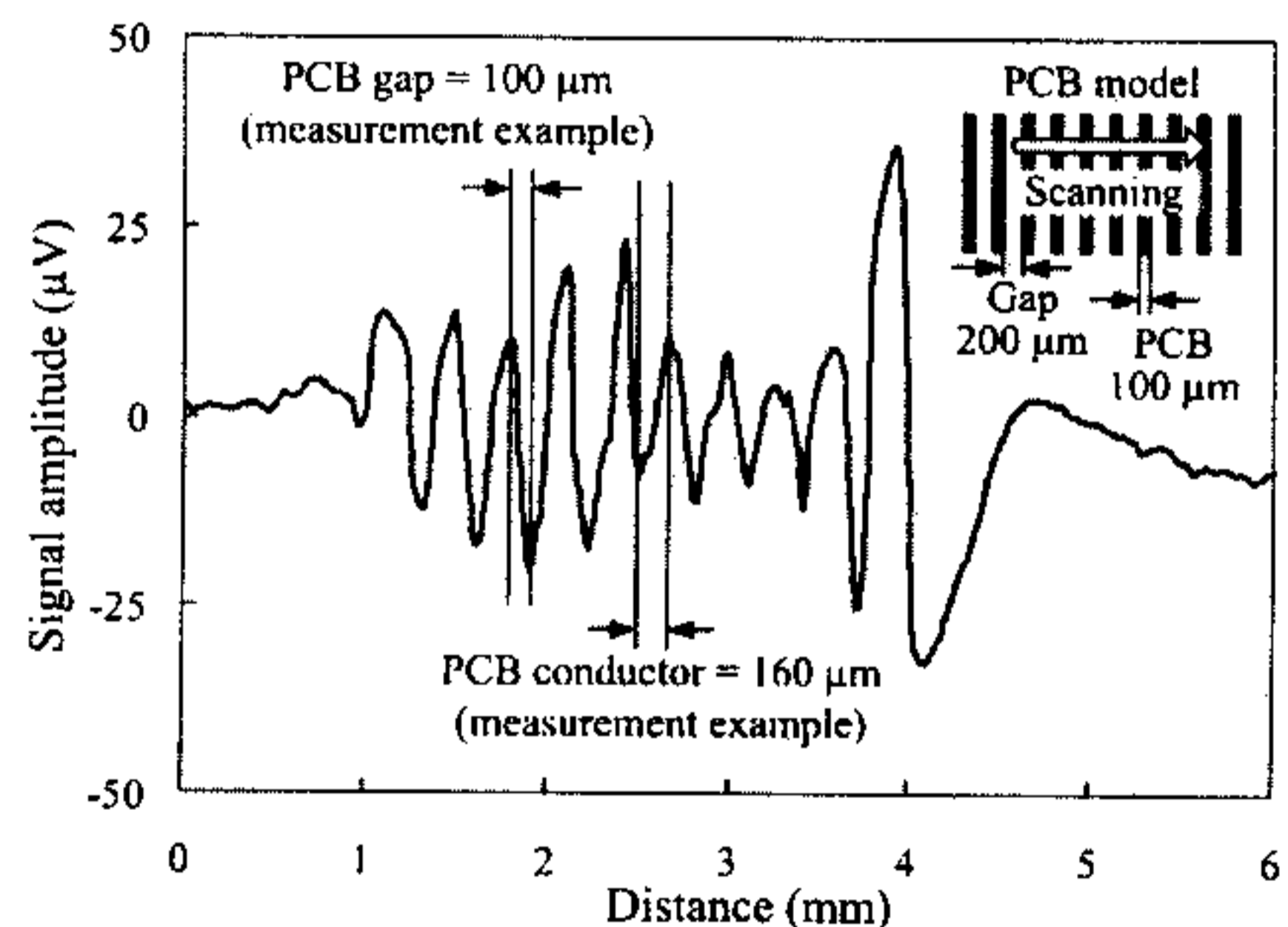
conductor width whereas the noise is constant, around 1  $\mu\text{V}$ . Signal to noise ratio is about 9 dB although the PCB conductor width is only 70  $\mu\text{m}$ .

#### 4.2 Inspection error

Absolute measurement errors when the probe has been applied to measuring PCB conductor width and disconnection length are shown in Fig. 7 (top) and (bottom) respectively. From these results, absolute measurement errors are lower than 100  $\mu\text{m}$  for measurement of PCB conductor width. In case of conductor disconnection and PCB conductor length

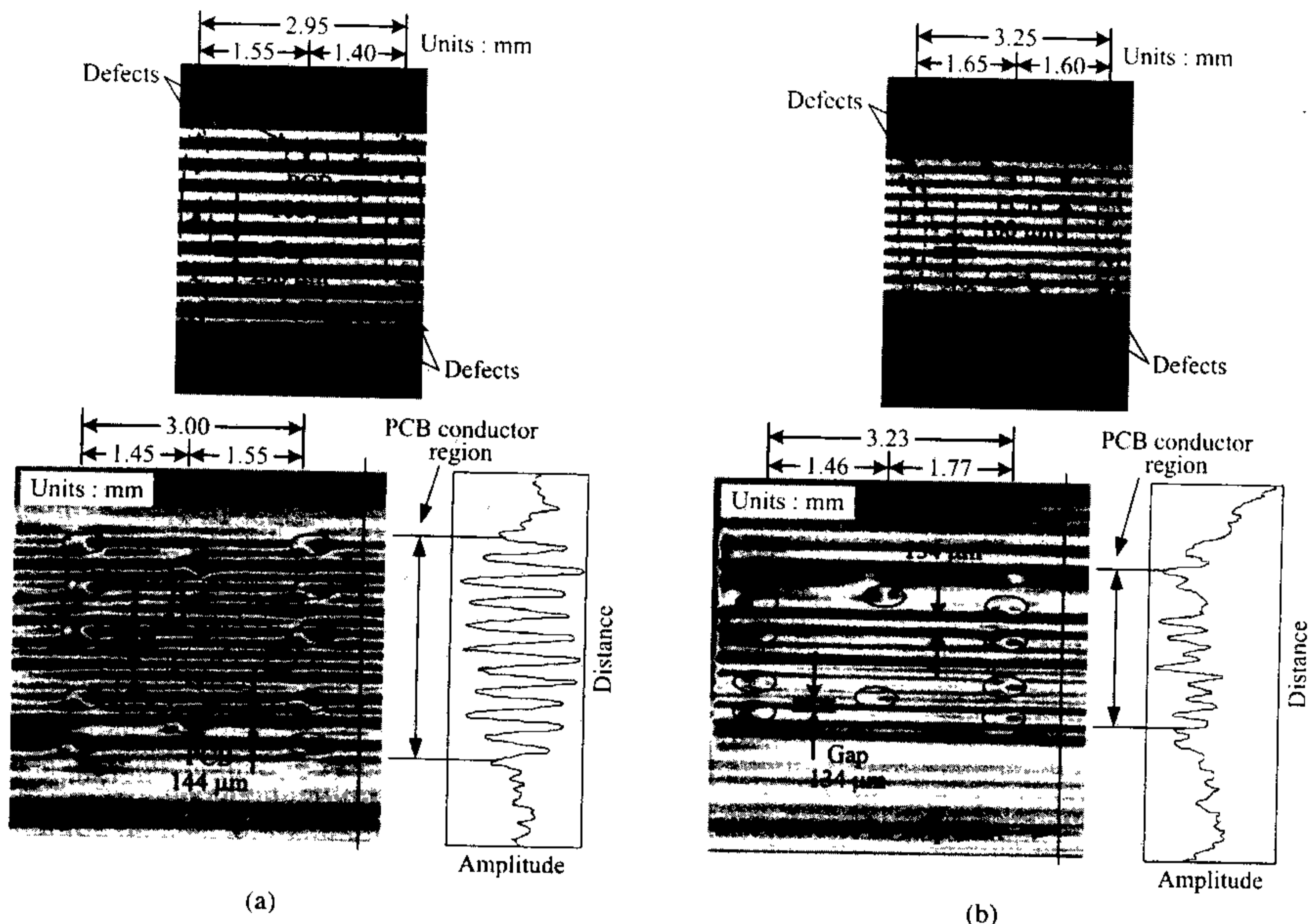


**Fig. 7** Absolute measurement errors obtain when the proposed probe is used to measure PCB conductor width (top) and disconnection length (bottom).



**Fig. 8** Example of PCB conductor width and gap measurement obtained by scanning across PCB model.

measurements, the absolute measurement errors are lower than 400  $\mu\text{m}$ . However, it is not over than 200  $\mu\text{m}$  when disconnection or gap between PCB conductors that are longer than 200  $\mu\text{m}$  is measured. Fig. 8 shows ECT signal without offset when the probe scanned across PCB conductor with 100  $\mu\text{m}$  width and 200  $\mu\text{m}$  gap. From the scanning result, the ECT signal indicates the width of PCB conductors nearly 200  $\mu\text{m}$  that is larger than actual width. This is because the SV-GMR dimension (around 200  $\mu\text{m}$ ) is larger than PCB conductor width (100  $\mu\text{m}$ ). Therefore, SV-GMR sensor dimension should be smaller than PCB conductor width to obtained accurate results.



**Fig. 9** High-density PCB pictures of a 100- $\mu\text{m}$ -wide PCB conductor (top) and its inspection results (bottom) with gaps 200  $\mu\text{m}$  (a) and 100  $\mu\text{m}$  (b). The strip charts obtained from line reference show the high signal variation occurring at the PCB conductor region.

#### 4.3 Example of high density PCB inspection

High-density PCB models with 100  $\mu\text{m}$  PCB conductor width was used as model in the experiment. The model was identified to two models as following:

- 100  $\mu\text{m}$  PCB conductor width with 200  $\mu\text{m}$  gap
- 100  $\mu\text{m}$  PCB conductor width with 100  $\mu\text{m}$  gap

The high-density PCB model pictures and its reconstruction 2-D image from ECT signal without offset are shown in Fig. 9. Conductor disconnection and partial defect were allocated on the conductor. 2-D Median filter was applied to eliminate noise before reconstruction of 2-D image. From the reconstruction 2-D image, the defect points on the conductor were identified clearly. The PCB conductors are able to be identified by considering the peak of ECT signal as shown in strip chart. Inspection of the larger gap model (Fig. 9a) provided not only clearer details and easier identification of PCB conductor size but also gap between conductors (with error less than 100  $\mu\text{m}$ ) than the smaller gap model (Fig. 9b). In addition, the distance between defect points, both the larger and smaller gap model, is also able to be specified accurately with error less than 200  $\mu\text{m}$ . However, image processing technique should be applied to improve the information.

#### 5. Conclusion

High-sensitivity ECT probe consisted of SV-GMR device as magnetic sensor and planar meander coil as

exciter was proposed in this paper to inspect PCB conductor dimension and alignment. Consideration the peak of magnetic field density that usually occurs at boundary of PCB conductor is useful for investigation the PCB dimension and alignment. The inspection results represented that the proposed ECT probe is able to examine the PCB conductor dimension and alignment with error around 200  $\mu\text{m}$ . In addition, small spatial resolution of SV-GMR sensor and high-resolution scan pitch provide the possibility of the proposed ECT probe to inspect the high-density PCB alignment with 100  $\mu\text{m}$  PCB conductor width and gap.

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