Applications of Electromagnetic Phenomena in Electrical and Mechanical Systems
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INSPECTION OF THE PCB DEFECTS BY USING ECT TECHNIQUE WITH GMR SENSOR

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Abstract

Defect inspection on bare printed circuit boards (PCBs) by eddy-current testing (ECT) probe composed of a planar meander type exciting coil and a giant magneto-resistance (GMR) sensor is proposed in this paper. ECT inspection is an interesting approach for defect detection of the bare PCBs because this approach is a non-contact method and able to perform testing of conductivity by eddy-current. GMR sensor is an interesting magnetic sensor because it provides both high sensitivity over board range of frequency and high spatial resolution. The sensor is therefore very useful for detecting of small magnetic field variation occurred at small defects on bare PCBs based on ECT technique. The construction of ECT probe with GMR sensor for PCB inspection and the inspection results are described in this paper. Experimental results show that the proposed probe is able to inspect conductor disconnections with PCB conductor width less than 100 μm and imperfections on PCB track width and thickness.

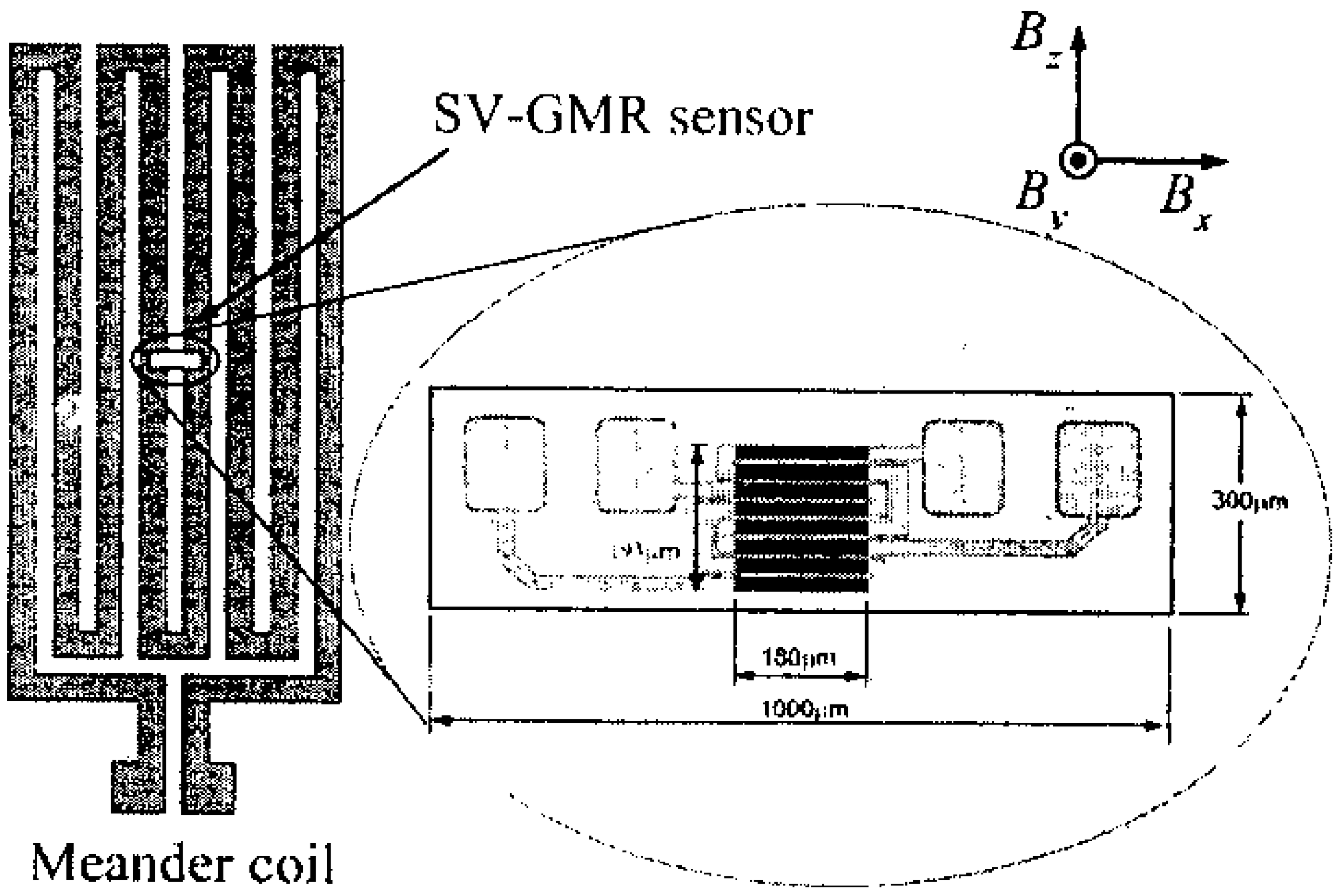
1. INTRODUCTION

Eddy-current testing (ECT) technique is a well known method of non-destructive testings that is, usually, applied to evaluate the material flaws without changing or altering of testing material. The advantage of ECT technique is sensitivity to material conductivity which depends on many variables such as material thickness, crack, and etc. Generally ECT technique is used as crack detection in piping systems of nuclear power plants and as imperfect welding spot detection on aircrafts. Printed circuit board (PCB) inspection is a new application of ECT technique that has been proposed [1, 2, 3, and 4].

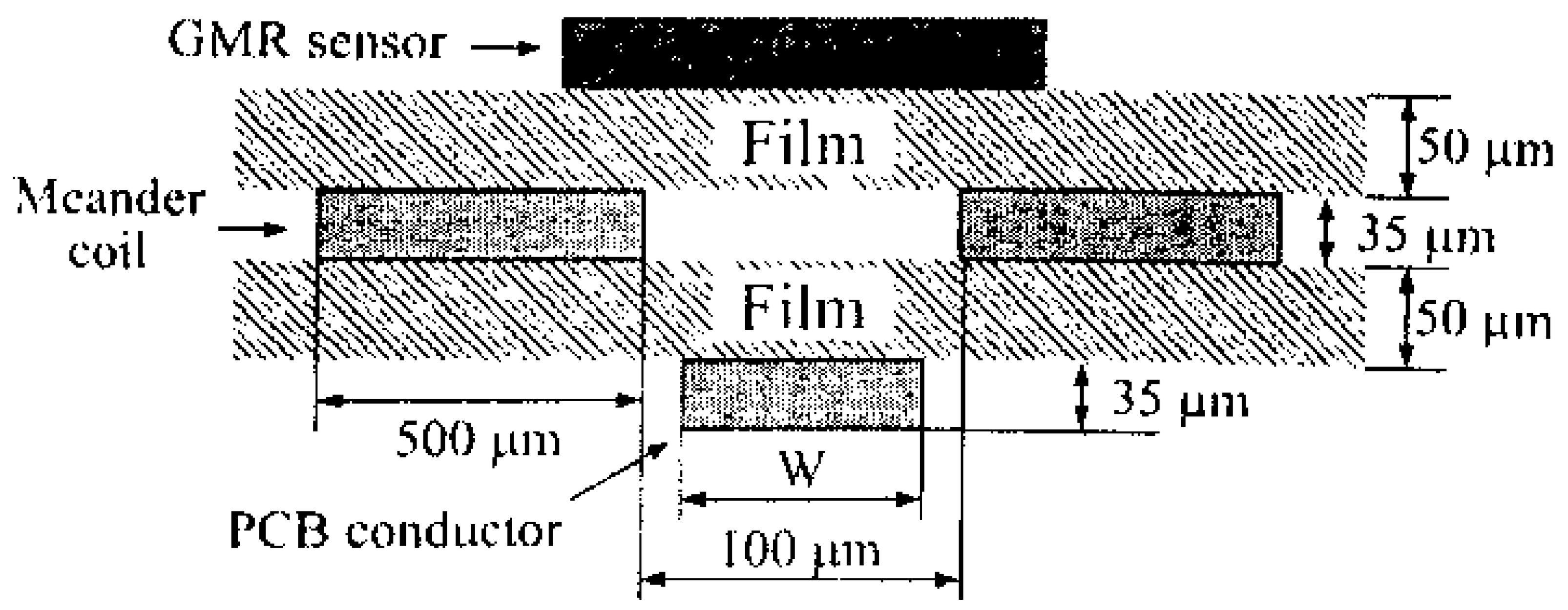
Several techniques have been used to inspect the bare PCBs. For example, the optical method is well known for the PCB inspection system because this method is a non-contact method and do not need high precision position control system. This method is limited to inspect only on the outer surface of the bare PCBs. Therefore, invisible conductor disconnection and short circuit on the PCB conductor can not be examined. Moreover, the thickness defects of PCB conductor can also not be inspected. Another technique is the conductive tester by pin probes that can inspect both visible and invisible conductor disconnections and short circuits. Nevertheless, bare PCBs will obtain the mechanical stress from contact actions and the non-uniformity on PCB track width and thickness can not be examined. Moreover, the conductive tester by pin probes method needs high precision position control system for the inspection.

ECT technique is an interesting method for bare PCB inspection because this is a non-contact method and able to inspect not only conductor disconnections and short circuits but also partial defects on PCB track width and thickness. Moreover, the construction of PCB inspection system by mean of ECT technique is not complicated and expensive. Image processing techniques such as wavelet-base processing technique were developed to eliminate noise and to enhance the signals for defect identification easily [4]. However, image processing techniques will not be successful if the sensor is unable to detect the signal at the defect points. Figure of eight, multiple solenoid coils, and solenoid coil were developed to improve the spatial resolution and sensitivity of magnetic sensor in order to obtain the larger and clearer signal at defect points [1, 2, and 3]. However, these sensors are inductive sensors and its output signals are proportional to the rate of change of the magnetic field. Moreover, the reduction of inductive sensor size to increase the spatial resolution is very difficult.

In recent year, several kinds of magnetic sensors such as Hall, giant magneto-resistance (GMR), Squid, and etc. have been successful in ECT for applying to non-destructive testing to detect material cracks [5]. Especially, the GMR sensor is very interesting because it provides a good performance versus its cost. GMR sensor has high sensitivity over board range of frequency and high spatial resolution because of small dimension. Moreover, it is inexpensive and able to operate at room temperature. From the features above, the applications of GMR sensor to PCB inspection based on ECT technique will provide the good inspection signals that can identify the defect points easily. Therefore, new application of GMR sensor as a magnetic sensor of the ECT probe for PCB inspection is proposed in this paper. The probe construction and the inspection signals with different defect types are discussed. Furthermore, the inspection results of PCB model are verified that the proposed probe can examine the defects on PCBs.



(a) Top view of ECT probe for PCB inspection and GMR sensor.



(b) Cross section of ECT probe to represent dimension

Fig. 1 Configuration of the proposed ECT probe

2. THE PROPOSED ECT PROBE

The configuration of the proposed ECT probe consisted of a meander coil that functions as an exciting coil and a GMR sensor is shown in fig. 1. The high frequency alternating current, 1-10 MHz, is fed into the meander coil. Then eddy-current is generated in the PCB conductor due to high frequency excitation. The GMR sensor that has effective area of 180 μm × 193 μm is mounted on the meander coil as shown in fig. 1(a).

Fig. 1(b) shows the dimension of the probe. The meander conductor is 500 μm width and 35 μm thick and the meander conductor pitch is 100 μm. The distance from the PCB surface to GMR sensor surface is around 135 μm. This includes the films needed to isolate the meander coil, PCB conductor, and the GMR sensor.

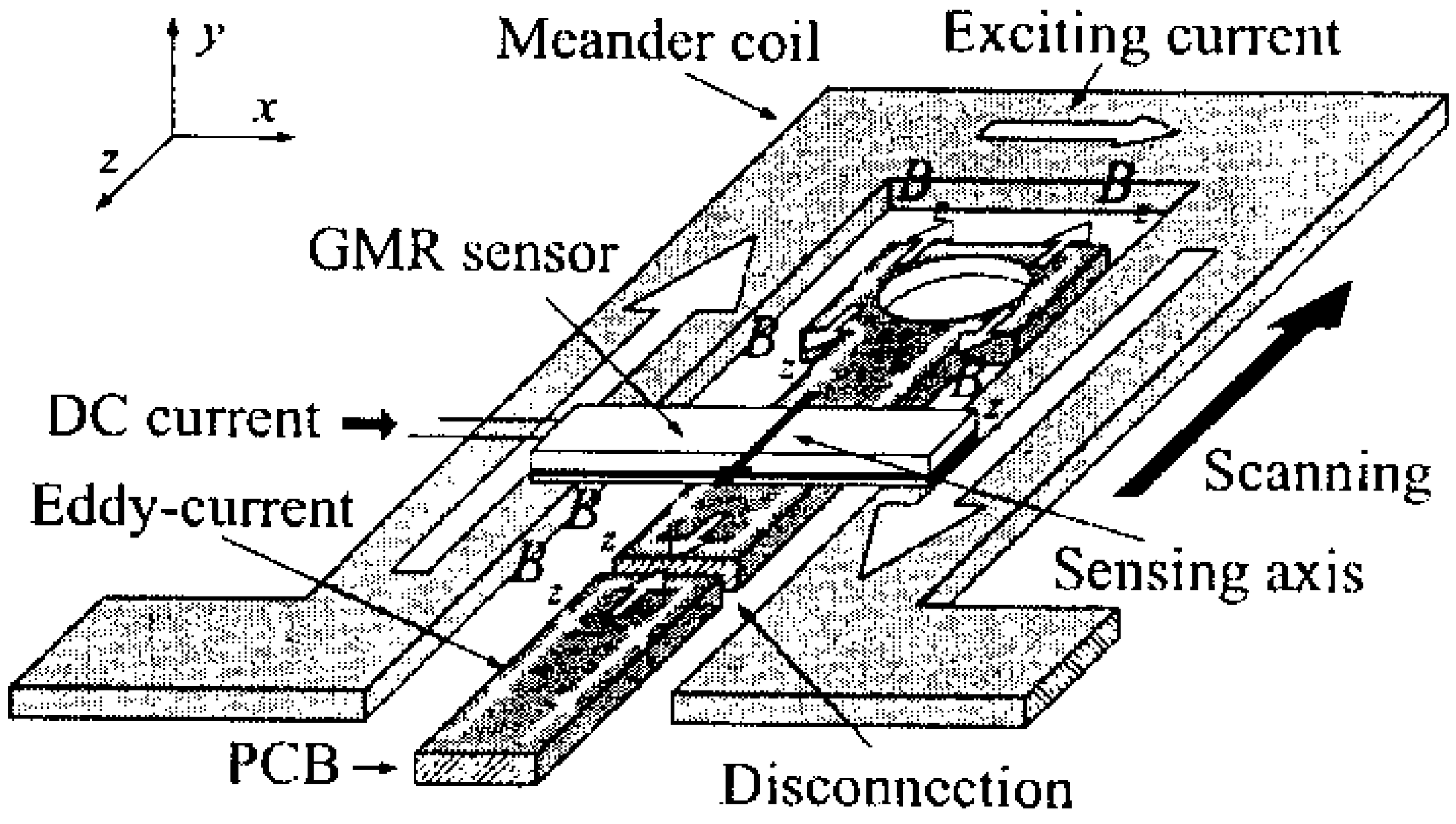


Fig. 2 Basic principles of the proposed ECT probe

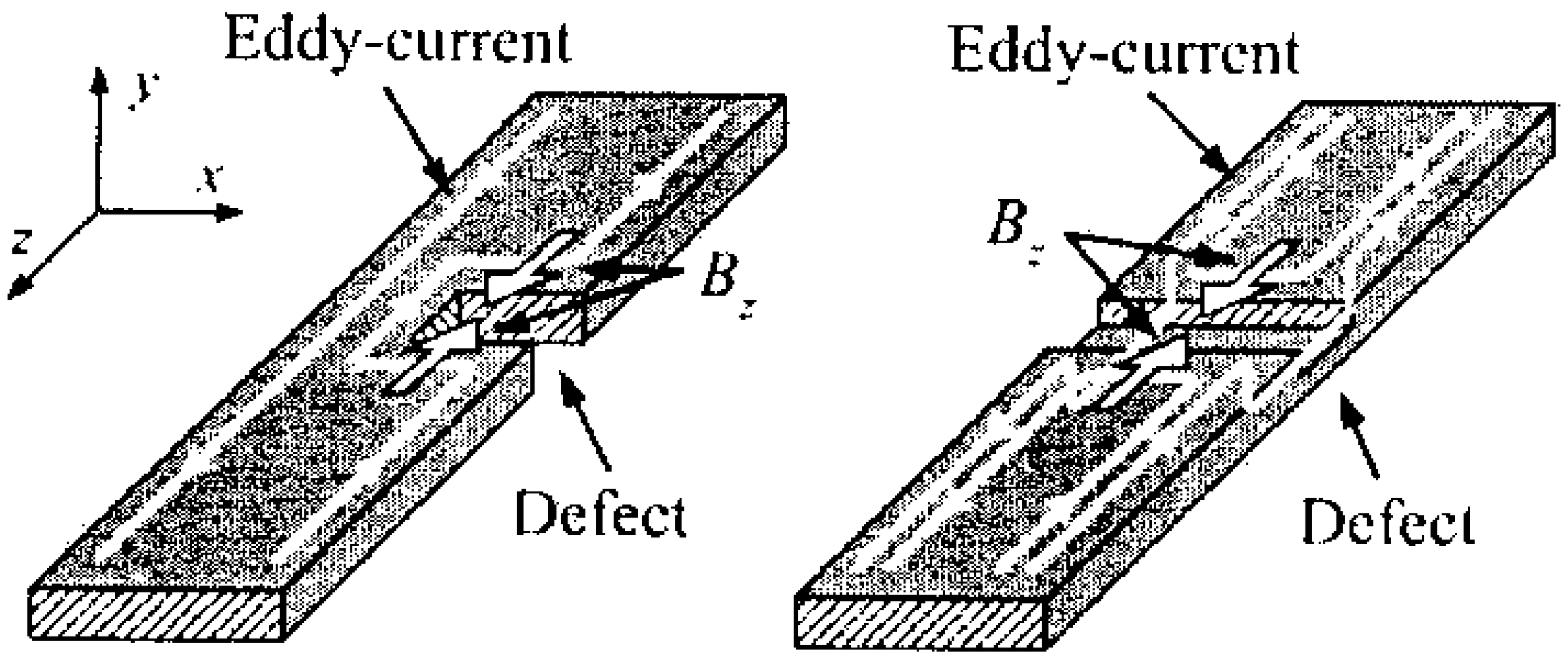


Fig. 3 Eddy-current paths of partial defects on PCB

3. PRINCIPLE

Fig. 2 shows the basic principles of the proposed ECT probe for PCB inspection. Usually, exciting current flows in the z-axis and also generates magnetic flux density in the x- and y-axis namely the normal component. Cause by high frequency excitation, the eddy-current is generated in PCB conductor in the z-axis. The eddy-current paths will flow in the x-axis when the conductor disconnection or soldering point is detected. Therefore, the magnetic flux density in the z-axis namely the tangential component is generated. For defect detection, the magnetic sensor is mounted on the meander coil to detect only the tangential component.

Fig. 3 shows the eddy-current generated in PCB conductor in case of the occurrence of some partial defects on PCB track width and thickness. At the partial defects, small eddy-current flows in the x-axis and also generates the magnetic flux density B_z. Although, the magnetic flux density B_z is not much when the partial defects are detected, the output signal variation from SV-GMR sensor is significant enough to identify that partial defects.

4. SV-GMR CHARACTERISTIC

Fig. 4 shows the configuration of the GMR characteristic tester system using Helmholtz coil technique. A normal resistance of GMR sensor used in this experiment was 627 Ω. As shown in Fig. 5(a), the applied magnetic field ranged from -4 to 4mT was applied to test the characteristics of the GMR sensor in its sensing axis. The GMR sensor has the maximum MR ratio and the sensitivity to the magnetic flux density range from -0.6 to 1 mT around 10.37 % and 6 %/mT respectively. Moreover, the GMR sensor also provides low hysteresis loop. The AC characteristics at each of GMR sensor axis was tested with the magnetic flux density in range from -0.2 to 0.2 mT, as shown in Fig. 5(b), which is sensing magnetic flux density range of GMR sensor for the purposed of PCB inspection base on ECT technique. The GMR sensor is still has sensitivity around 6 %/mT to the magnetic flux density in the z-direction whereas the x- and y-direction has less than

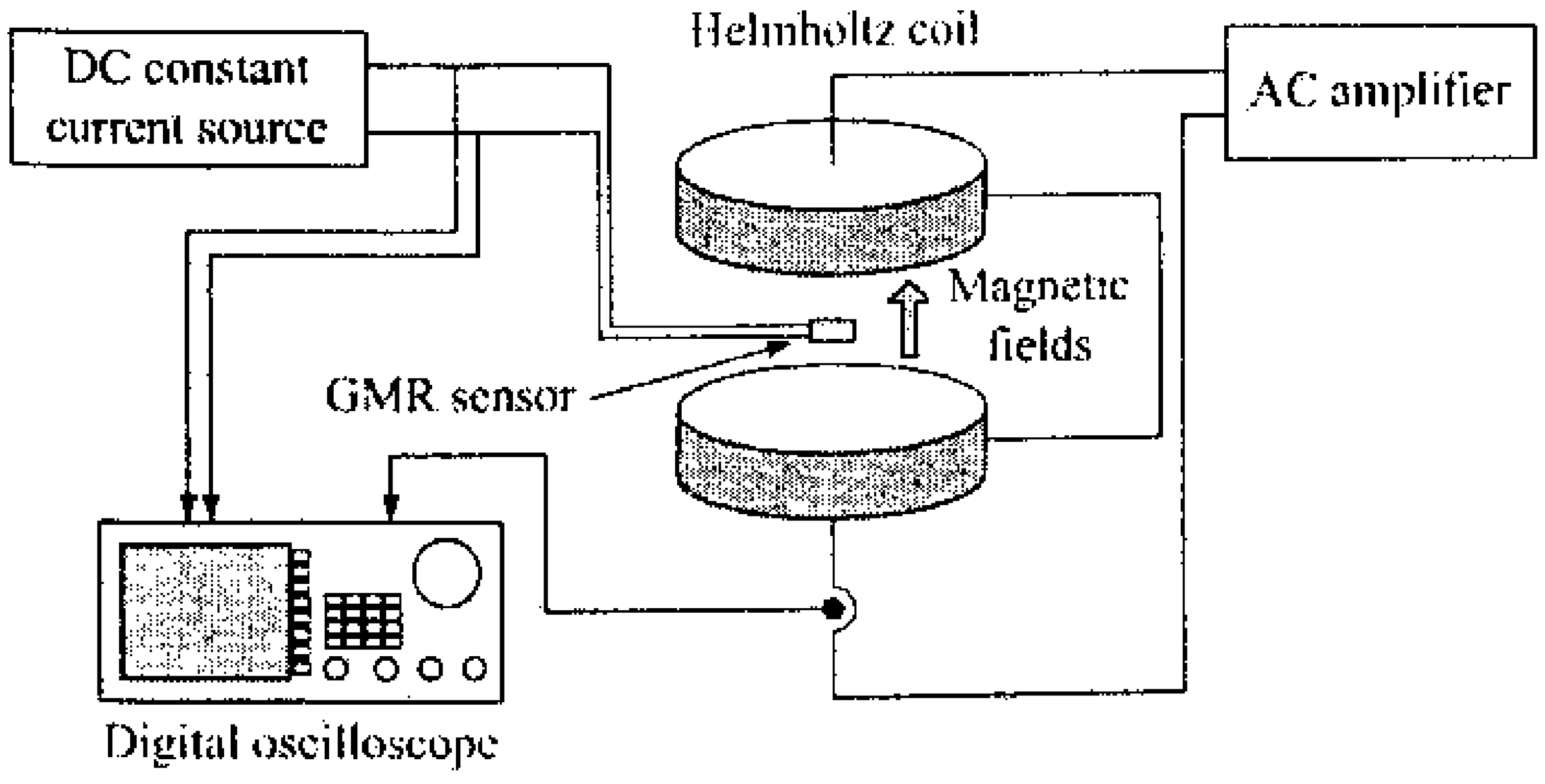
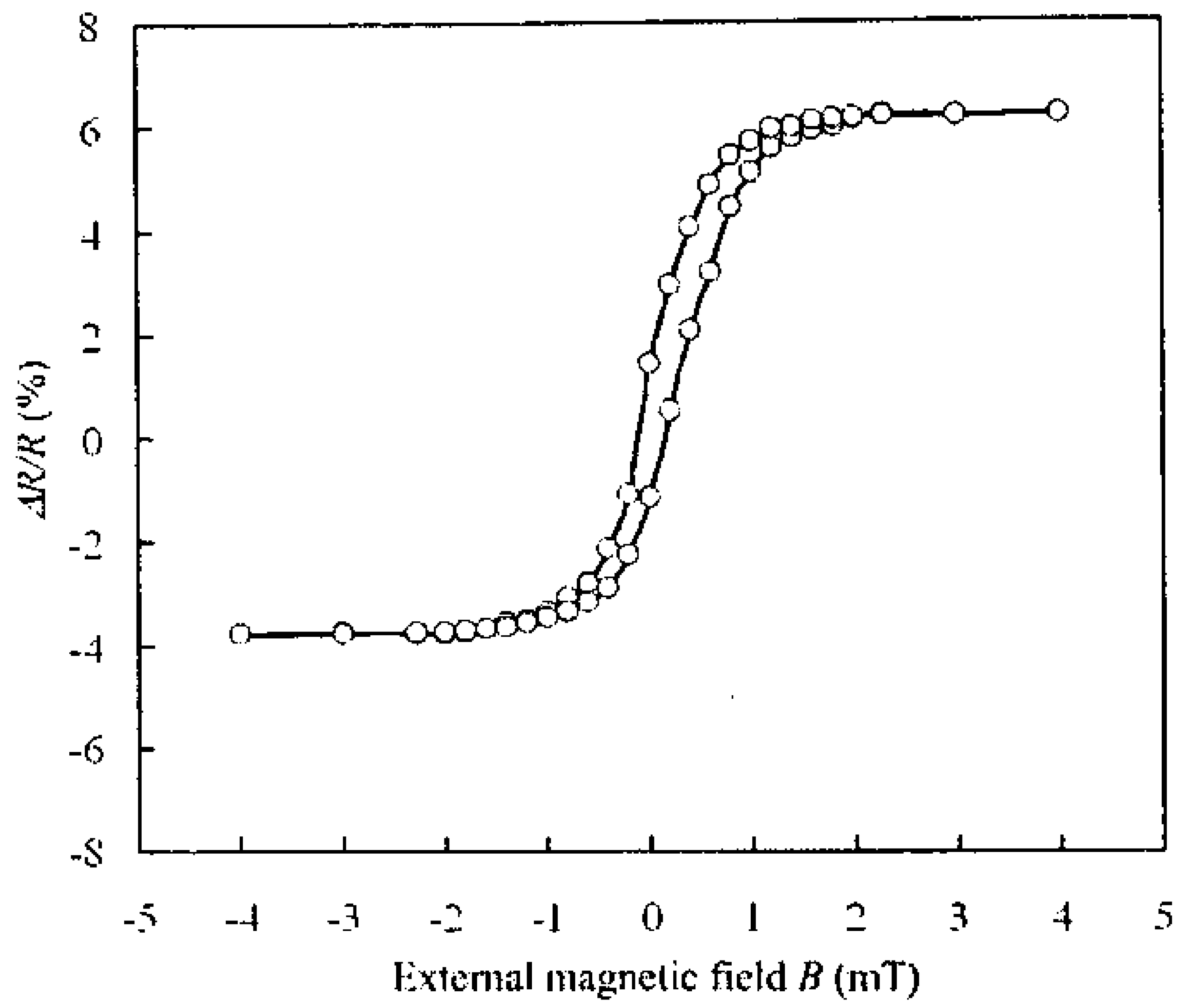
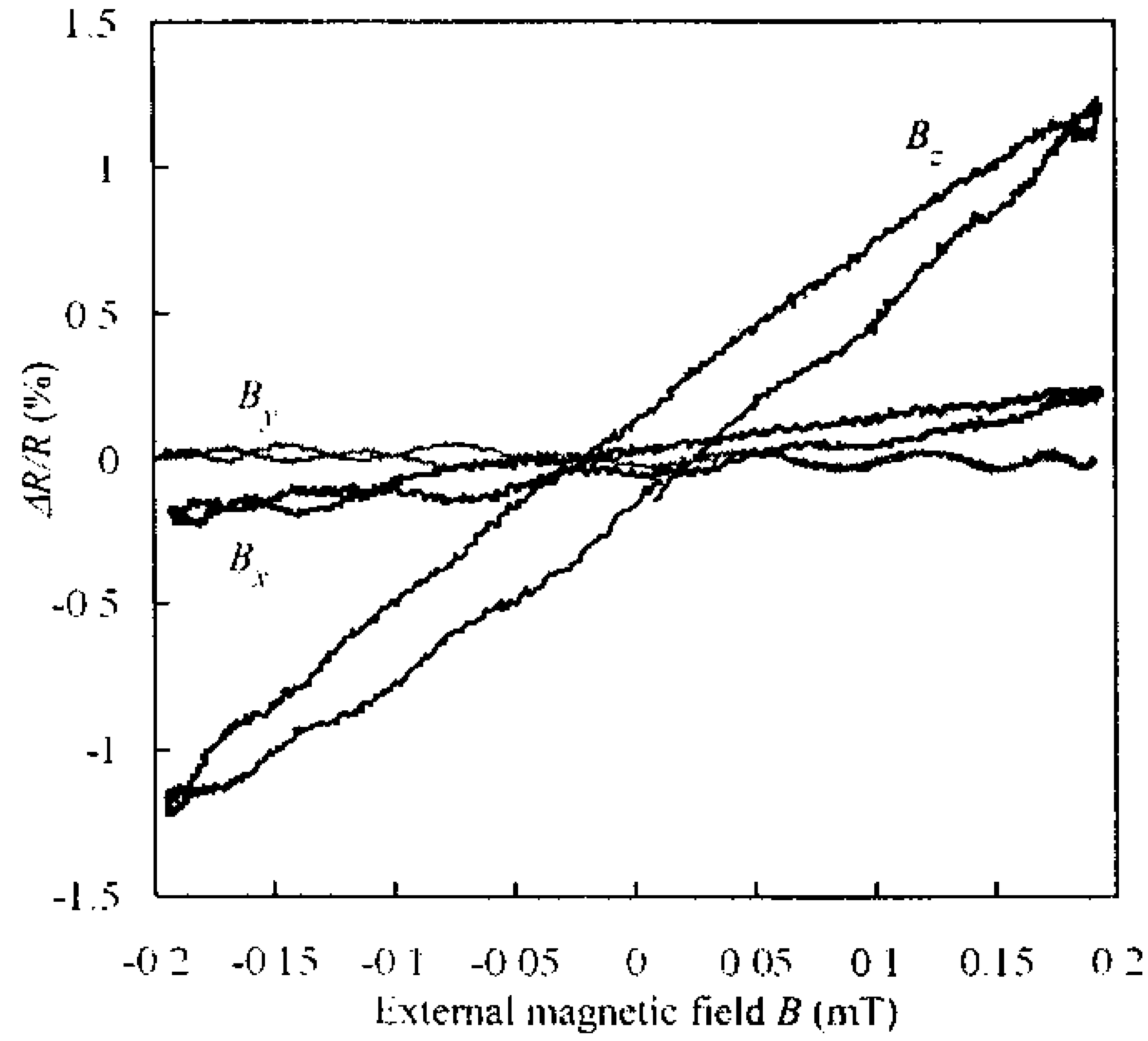


Fig. 4 Configuration of GMR characteristic tester system



(a) SV-GMR sensor characteristics in its sensing axis.



(b) SV-GMR sensor characteristics at each of direction at frequency of 100 kHz.

Fig. 5 Characteristics of SV-GMR sensor.

1 %/mT of sensitivity. From these features, the GMR sensor was mounted on the meander coil, as shown in Fig 1(a), to detect only the tangential component B_z that, usually, occurred at the defect and soldering points as mentioned above.

5. INSPECTION OF PCB MODEL

5.1 System configuration

Fig. 6 shows the configuration of the PCB inspection system based on ECT technique. Sinusoidal current of 250 mA at frequency of 5 MHz was fed to the meander coil and DC current of 5 mA was fed to the GMR sensor. The lock-in amplifier was used to measure voltage drop across GMR sensor. Scanning pitch was set at 0.05 mm. Personal computer was used to control the position of bare PCBs and to collect data from lock-in amplifier. Numerical gradient technique was applied to eliminate offset and to enhance signals at defect points for easier defect identification.

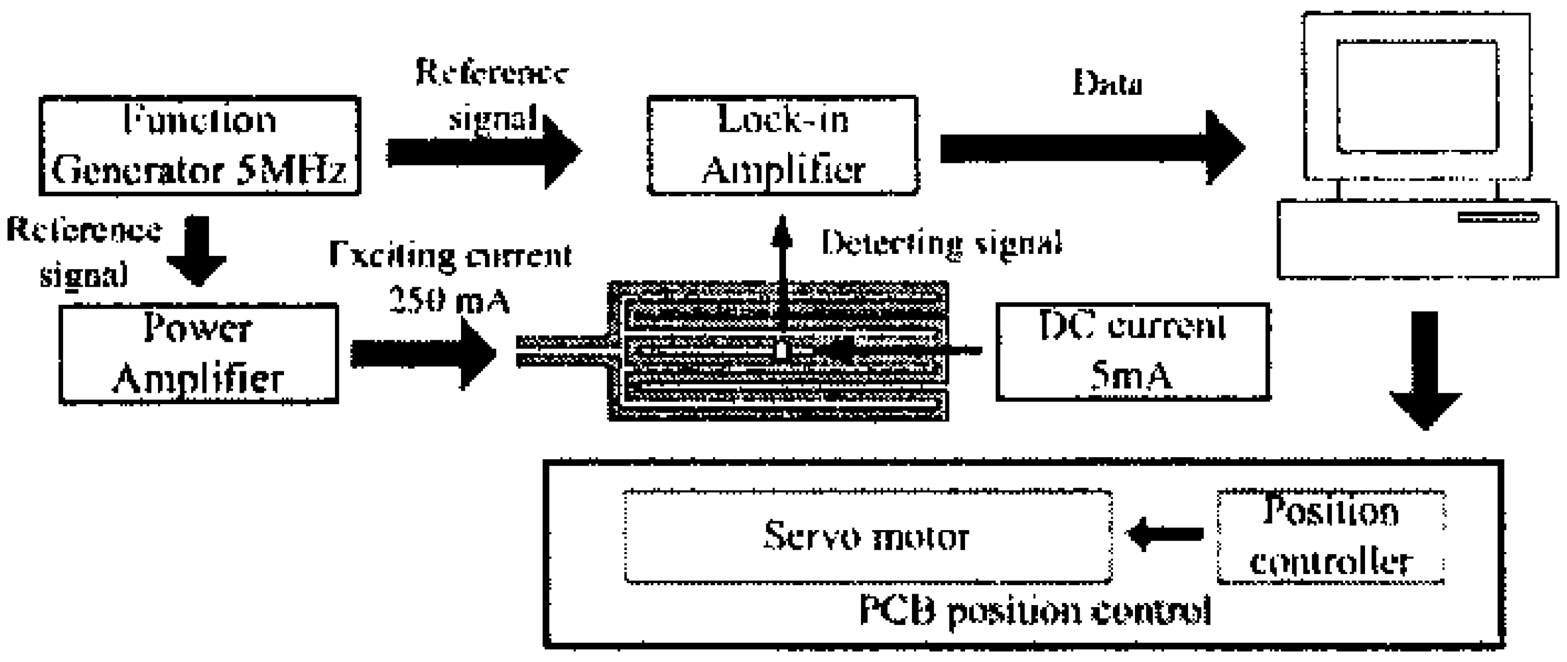
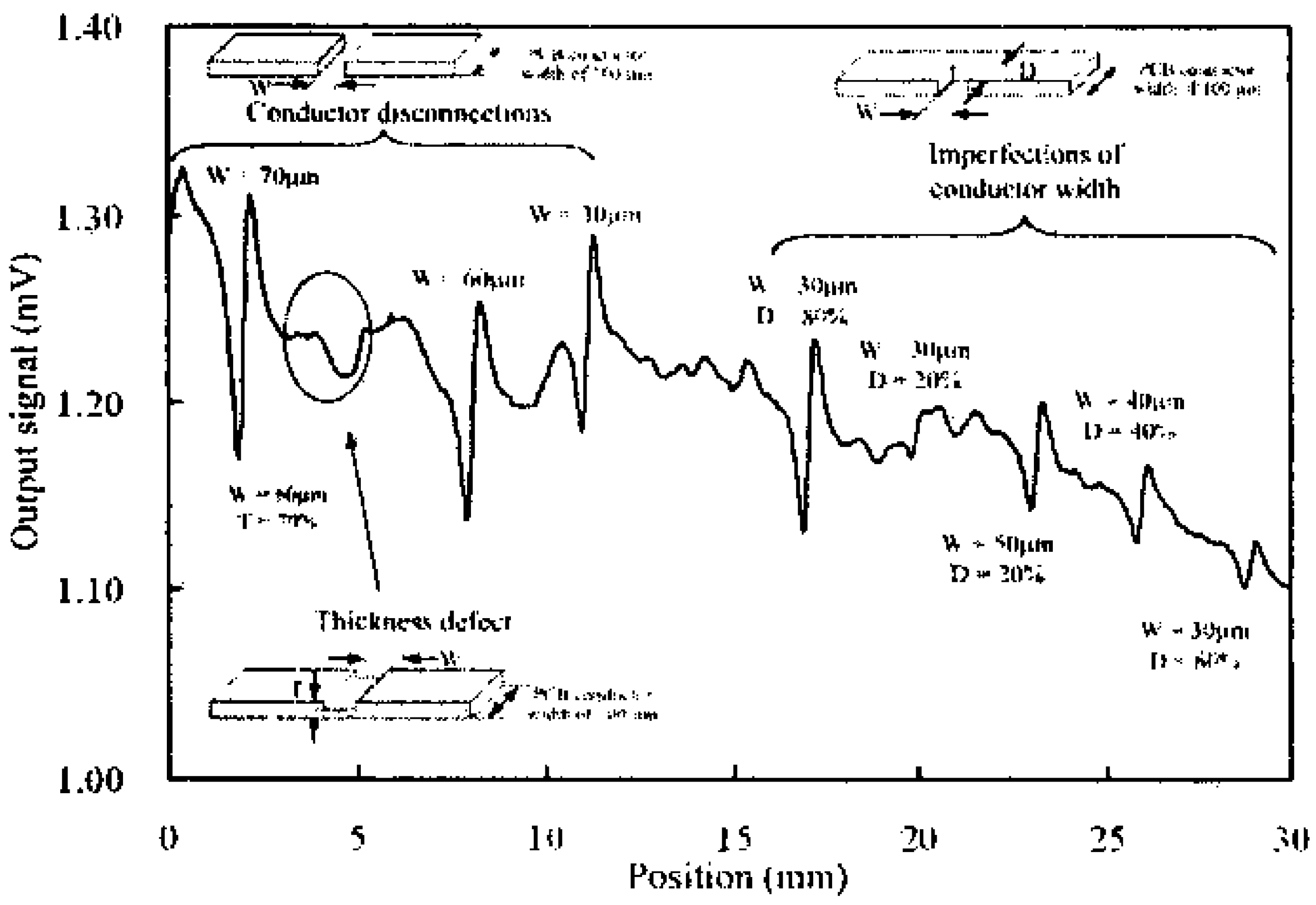
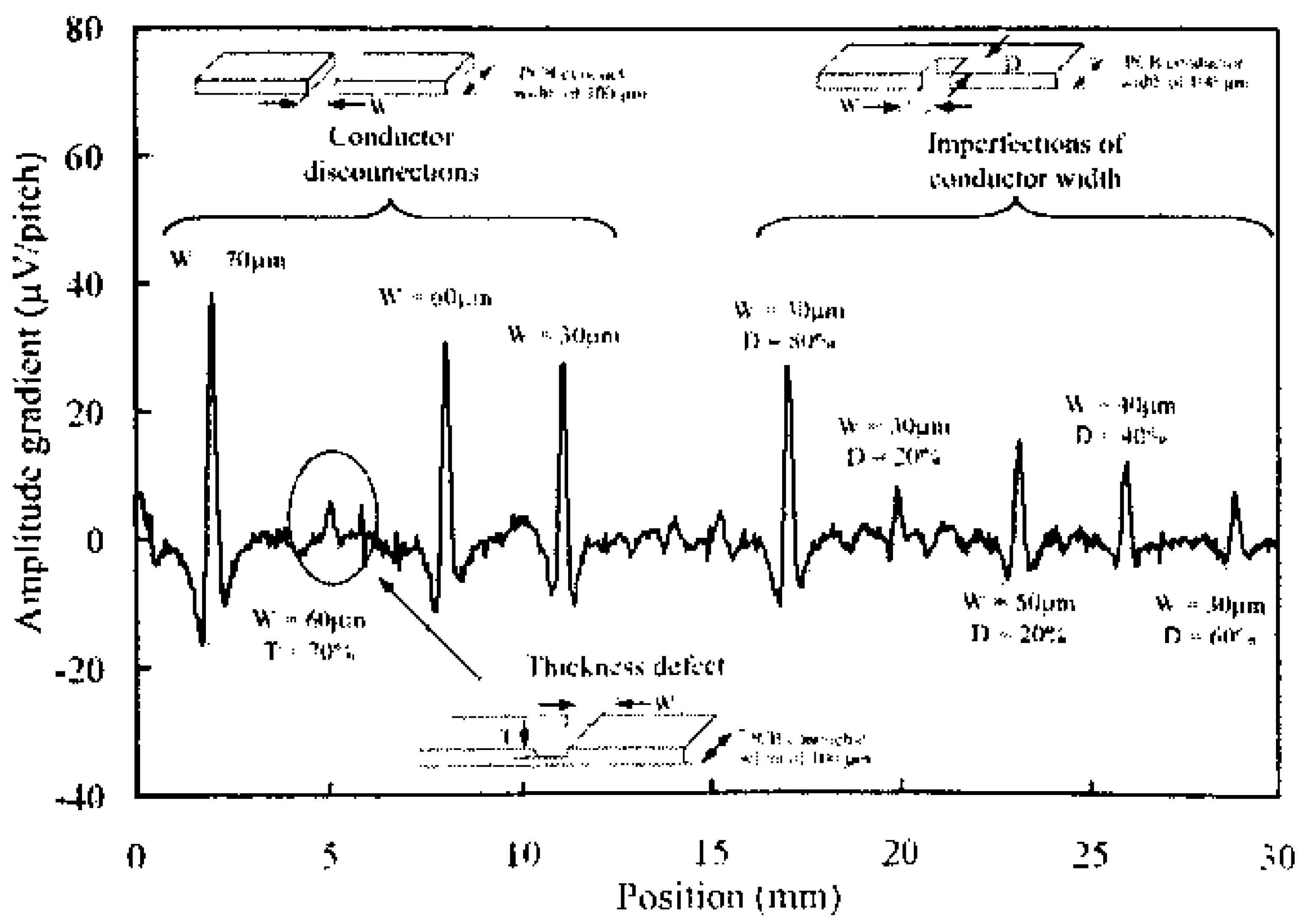


Fig. 6 Configuration of PCB inspection system based on ECT technique.



(a) Detecting signal obtained from GMR sensor by scanning along the PCB conductor model.



(b) Gradient signal calculated from the detecting signal in Fig. 7(a).

Fig. 7 Detecting and gradient signals obtained from scanning over the PCB conductor model.

5.2 Inspection signal

The probe was scanned along the PCB conductor with disconnections and partial defects. The PCB conductor width and thickness is 100 and 35 μm respectively. Fig. 7(a) shows the actual signals obtained from the GMR sensor and Fig. 7(b) shows the amplitude gradient signal calculated from the actual signal in Fig. 7(a). The signals at the defect points have similar pattern but different magnitude. The amplitude gradient magnitude at the defect points depends on the defect size and type. From Fig. 7(b), the thickness defect is the defect type that provides the lowest magnitude as mentioned above.

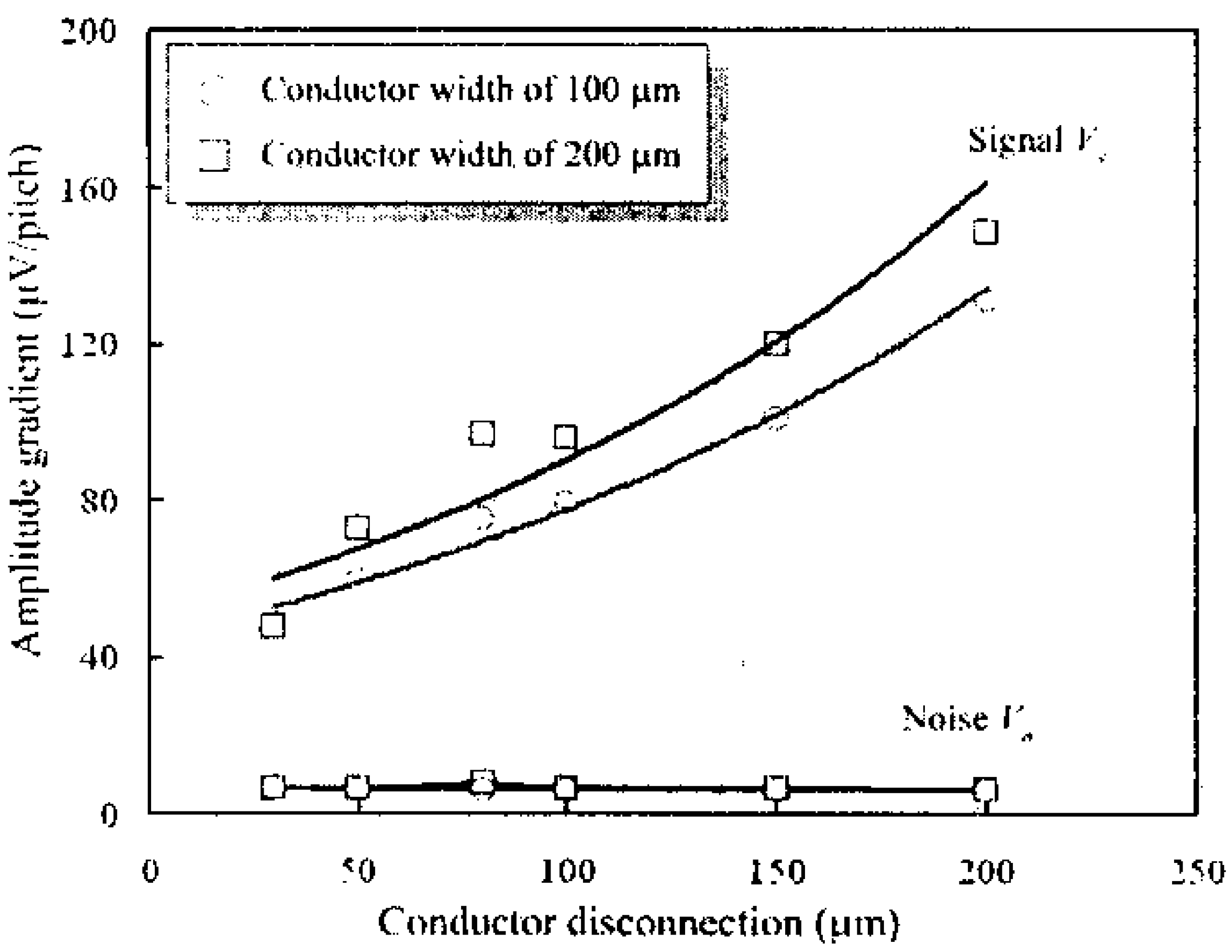


Fig. 8 Signal and noise versus conductor disconnections.

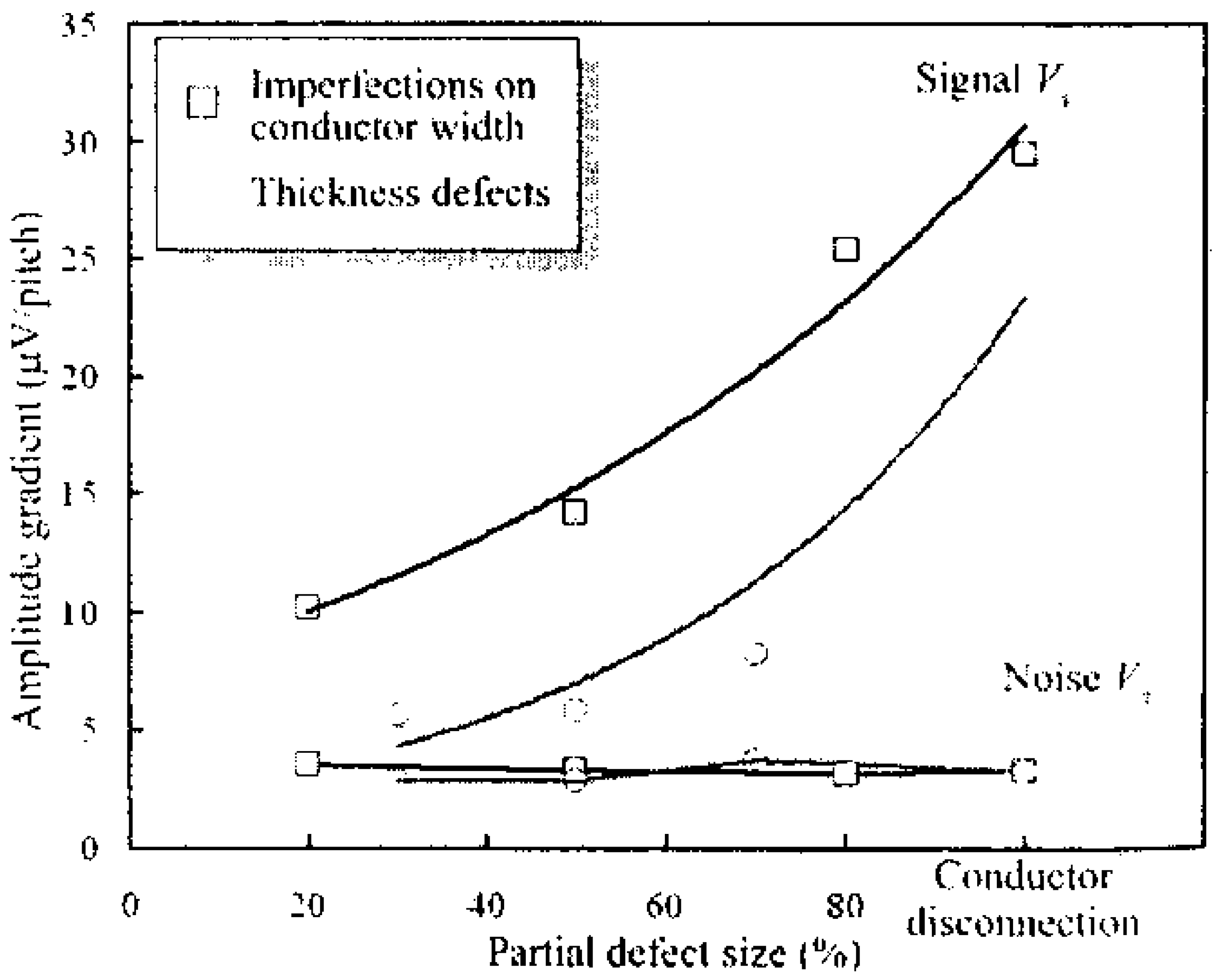


Fig. 9 Signal and noise versus partial defect sizes.

For conductor disconnections, the PCB conductor with track widths of 200 and 100 μm were inspected. The conductor disconnections of 200, 150, 100, 80, 50, and 30 μm were located on PCB conductor model. As shown in Fig. 8, the inspection signals at the defect points are more than 40 μV/pitch whereas noise signal has quit stable value with less than 10 μV/pitch. Actually, the bigger size of PCB conductor will provide the larger signal. Moreover, the signal magnitude at defect points will increase when the conductor disconnection is larger.

As shown in Fig. 9, imperfection on PCB conductor

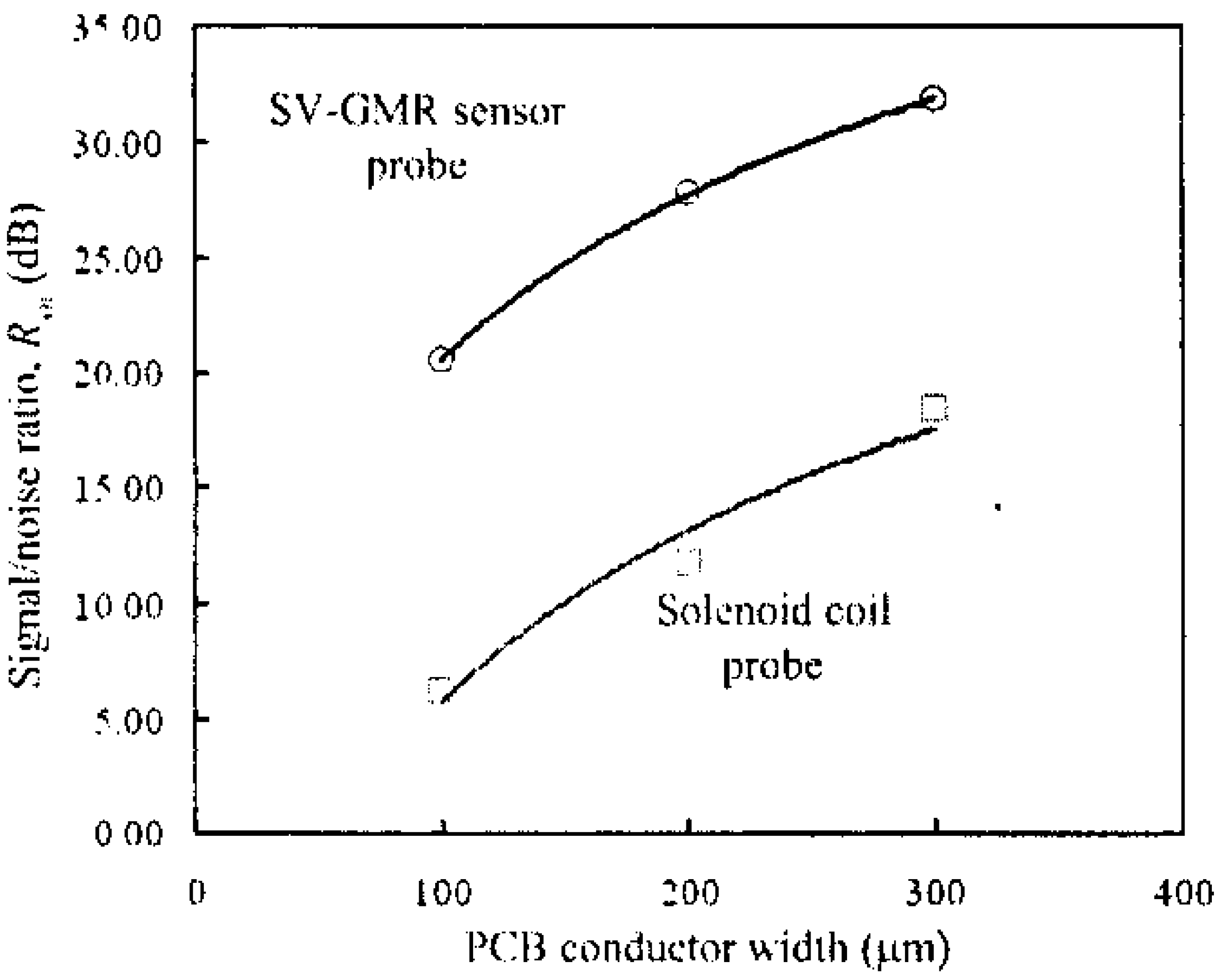


Fig. 10 Comparison of signal to noise ratio between the GMR sensor probe and solenoid coil probe.

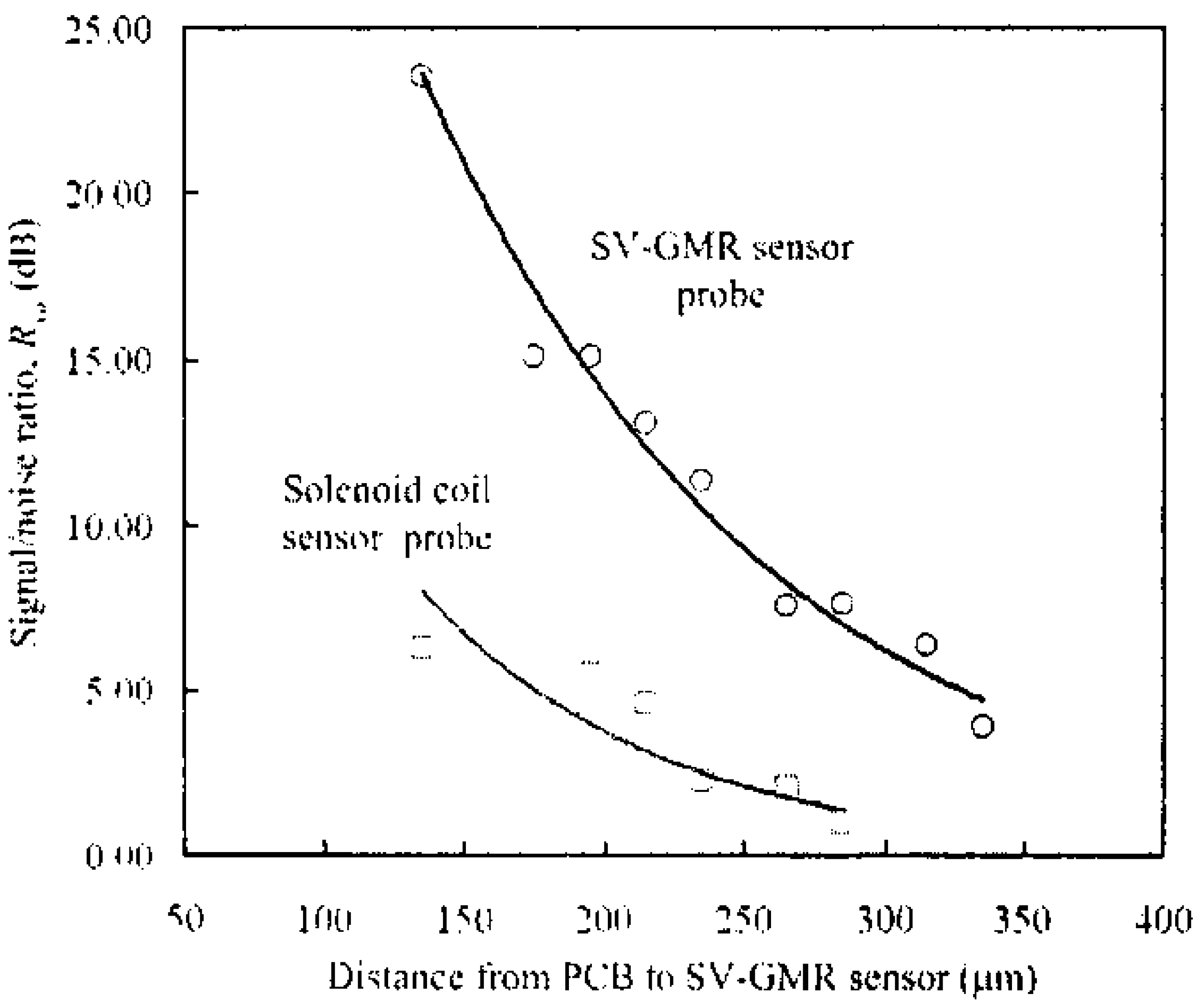


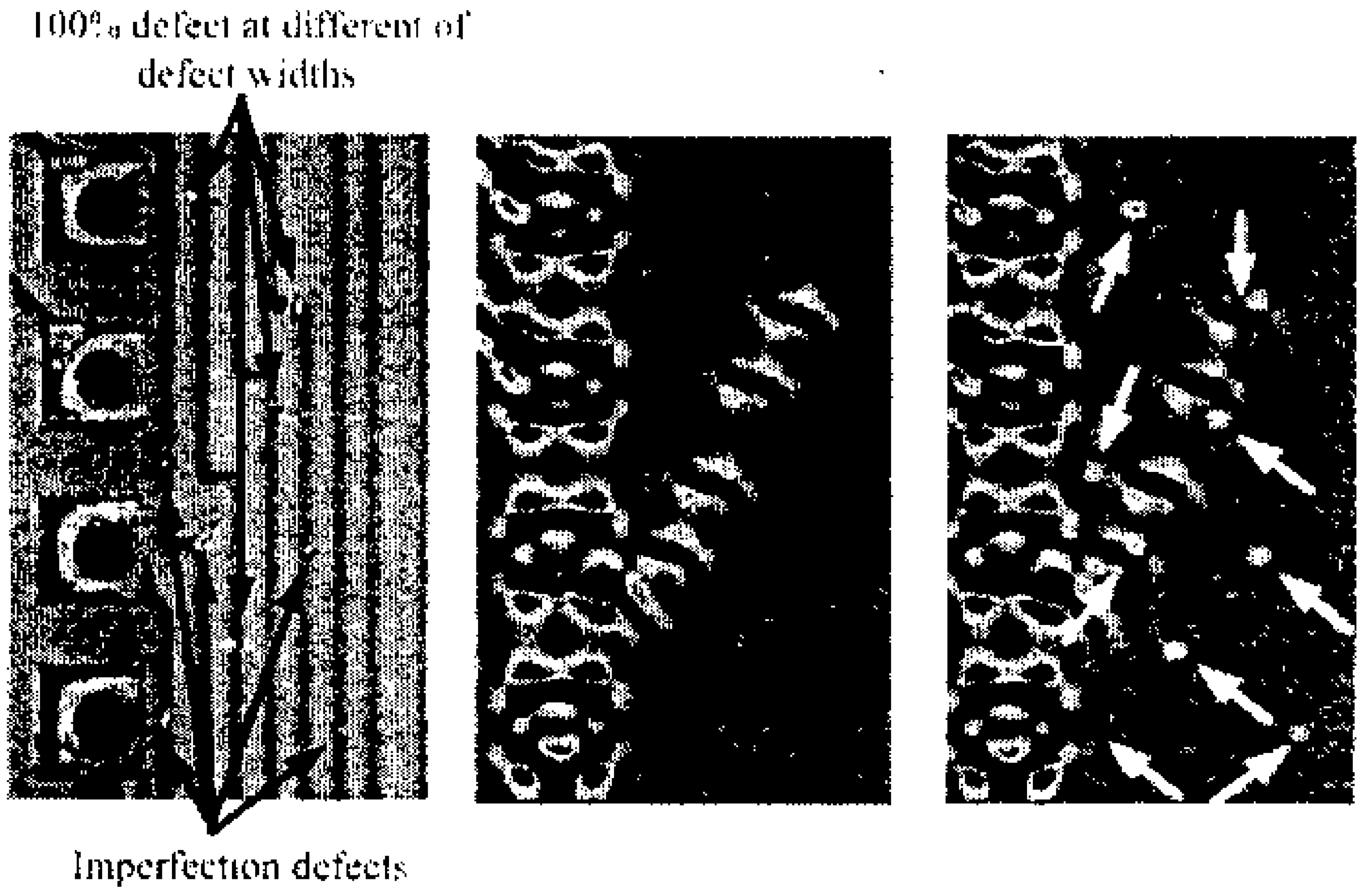
Fig. 11 Signal to noise ratio for various distances between the GMR sensor or solenoid coil and PCB model.

track width and thickness can be inspected by ECT probe with GMR sensor. The partial defects have a fixed width of 50 μm but have varied imperfection size. However, the signals obtained from partial defect inspection are usually lower than one from conductor disconnection inspection, the partial defect signals have significant enough for identification the defect points.

The utilization of GMR sensor for PCB inspection based on ECT technique provides higher signal to noise ratio than that of solenoid coil around 15 dB as shown in Fig. 10. This is because the GMR sensor has better spatial resolution than the solenoid coil. Furthermore, GMR sensor can be placed closer to PCB conductor than solenoid coil because of its construction. Therefore, the signals from GMR sensor will occur at more precise position. The ECT probe with GMR sensor is possible to apply to high-density PCB inspection with PCB conductor width less than 100 μm. Distance from the probe to PCB conductor is one of parameters that effects with the signal magnitude achieved from the sensor as shown in Fig. 10. For PCB inspection, the probe should be placed as close as possible to the bare PCBs to achieve the good inspection results.

5.3 Bare PCB model inspection

The bare PCB model as shown in Fig. 12(a) was used to demonstrate the inspection by the proposed probe. The model has a conductor width of 100 μm and thickness of 35 μm. Conductor disconnections with smallest size of 100 μm and partial defects consisting of imperfection on PCB track width and thickness were located on the bare PCB model. Some defect points on the model were located at the position that is close to corner of the PCB conductor. For these defect points, it is usually difficult to inspect by ECT probe with solenoid coil. Fig. 12(b) and Fig. 12(c) show 2-D image obtained from the defect



(a) Bare PCB model (b) 2-D non-defect image (c) 2-D defect image

Fig. 12 Bare PCB model and its inspection results bare PCB model in Fig. 12(a) and that obtained from non-defect bare PCB model similar to in Fig. 12(a) respectively. The defect identifications achieved by comparing these two images. From the inspection results, the ECT probe with GMR sensor is able to inspect all the defects occurred on the bare PCB model. However, the information achieved from this probe still needs applying of some image processing technique to enhance signals at defect points for easier defect identification.

6. CONCLUSION

Novel application of GMR sensor as a magnetic sensor of ECT probe for the defect inspection on bare PCBs was proposed. The inspection results verified that the proposed probe is very useful for PCB inspection. Both conductor disconnections and partial defects are inspected by the proposed probe. Moreover, the inspection signals from the proposed probe provide higher magnitude than that used solenoid coil as a magnetic sensor because of the GMR sensor features.

7. ACKNOWLEDGMENT

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