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INSPECTION OF BARE PRINTED CIRCUIT BOARD USING PLANAR TYPE ECT PROBE

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ABSTRACT. The eddy-current testing technique gives a new skill for inspection of bare printed circuit board (PCB). The combination of the high-sensitive micro eddy-current testing (ECT) probe and the image processing technique enables us to inspect defect (disconnection, and chipping crack) on the trace of bare PCB. This paper deals with the structure of the probe and characteristics to apply the ECT approach to the inspection of high-density PCB. We proposed the ECT probes of the meander coil (transmitter) and Spin-Valve Giant Magnetoresistance sensor(receiver). The high frequency excitation up to 5 MHz enables us to detect the disconnection on the trace of less than 100 μm width and 35 μm thickness.

INTRODUCTION

The eddy-current testing (ECT) technique is applied to the evaluation of metal structure as nuclear equipment, aircraft, engine and others. For this purpose, we examine the crack, aging, and material properties on metal equipments. We will apply the ECT technique to the inspection of bare printed circuit as a new application [1-2]. Actually failed patterns on the trace of bare printed circuit as example, disconnection, short circuit, and chipping defect are checked on in-site production.

There are briefly two kinds of inspections of bare printed circuit board (PCB). One of them is the image scanner by charge-coupled device (CCD) camera. It is most well-known and world-wide used in the process of PCB production. But after the surface is coated to protect printed circuit, it is difficult to inspect defect. And this approach checks the image pattern of trace and do not test conduction actually. Another is the conductive tester which is also useful device. This approach gives some mechanical stress on the trace by contact action. And the inspection time depends on the speed of actuator to move probe. For a future PCB inspection, we need to detect different kinds of imperfections such as disconnections, chipping defects, non-uniformity in thickness, and short-circuit, on the trace of PCB without contact operation.

The ECT technique makes attractive to inspect defect on the conductors of bare PCB because of the following advantages.

- (1) The inspection operation is non-contact, then there is no mechanical stress and precise position setting mechanism.
- (2) The data of resistance condition can be measured. Therefore, not only disconnection but also imperfection of on the conductor of PCB can be detected.
- (3) The ECT probe has simple structure of the probe and the multi-sensor can be fabricated.

(4) The ECT sensor has the high sensitivity for surface properties.

The actual inspection system consists of two parts, the data acquisition by ECT technique and the identification of defect by image processing [3]. In this paper we deal with only the previous part, the eddy-current testing technique for the inspection of PCB. The structure of the ECT probe for PCB inspection and its characteristics are discussed. We examined the feasibility of high-density PCB inspection with conductor less than $100\text{ }\mu\text{m}$ width.

ECT PROBE FOR PCB INSPECTION

We fabricated two types of probes for the inspection of PCB. The previous one is of inductive type. Fig. 1 shows the basic structure and configuration of one of ECT probes. The long meander coil is transmitter (exciter) and carries a high frequency alternating current up to 5 MHz. The pick-up coil is of solenoid type and is placed on the top of the exciting coil between its two conductors. The multiple solenoid pick-up coils are used to increase the resolution and enhance the sensitivity. Fig. 2 shows the detailed dimensions of the probe and the PCB conductor. The width of the meander conductor is $500\text{ }\mu\text{m}$. The winding of the sensing coil is wound on a glass-fiber form of $150\text{ }\mu\text{m}$ in diameter. The lift-off height is kept at $50\text{ }\mu\text{m}$. The probe is simple in structure but the miniaturization of the solenoid coil has some difficulty. The size of the probe is related with the resolution of inspection.

Another is meander coil/giant magnetoresistance (GMR) sensor type ECT probe. We use meander coil as transmitter, and GMR as receiver as shown in Fig. 2. The element is

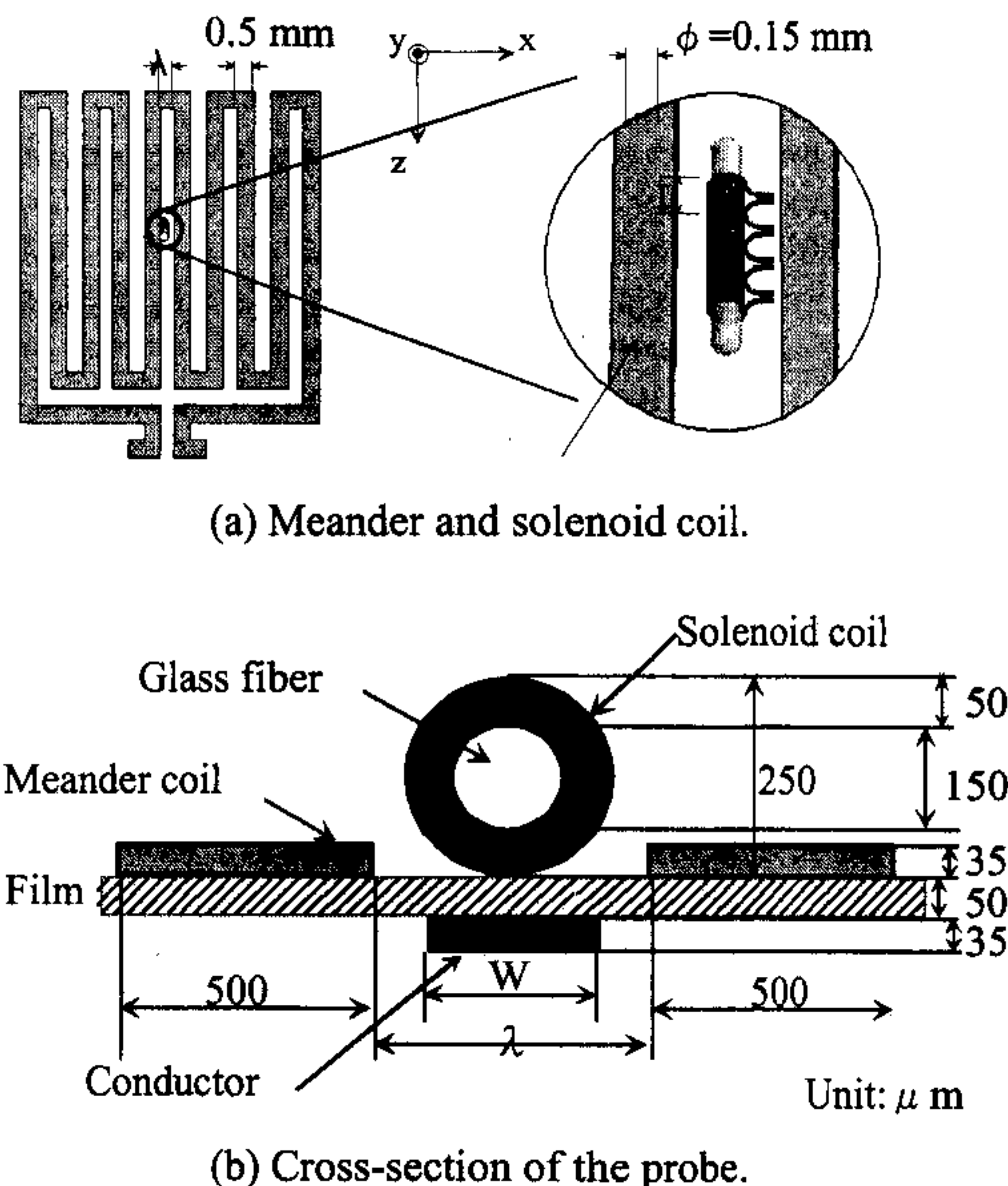


FIGURE 1. Inductive type ECT probe.

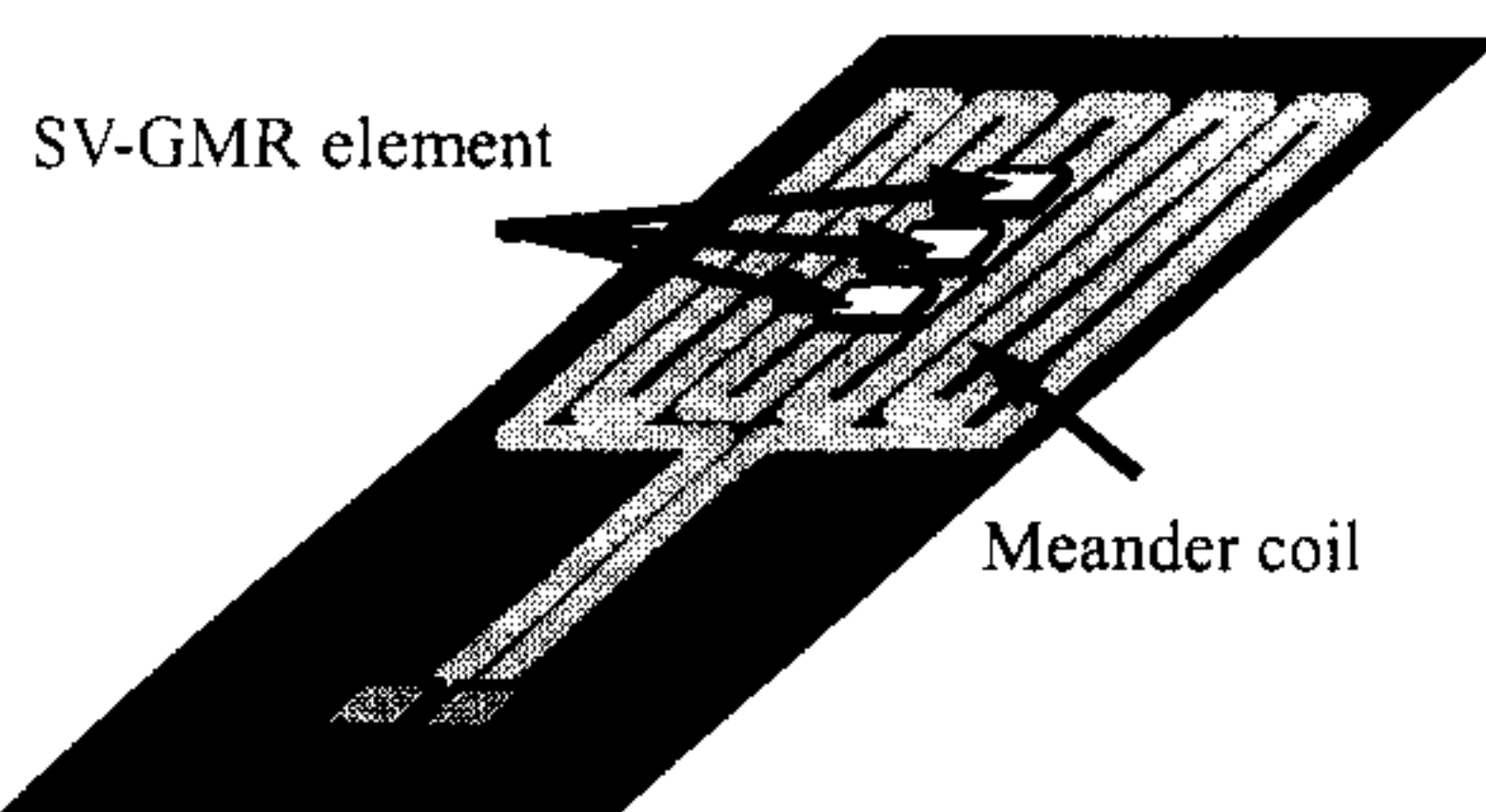


FIGURE 2. Meander coil/GMR type ECT probe.

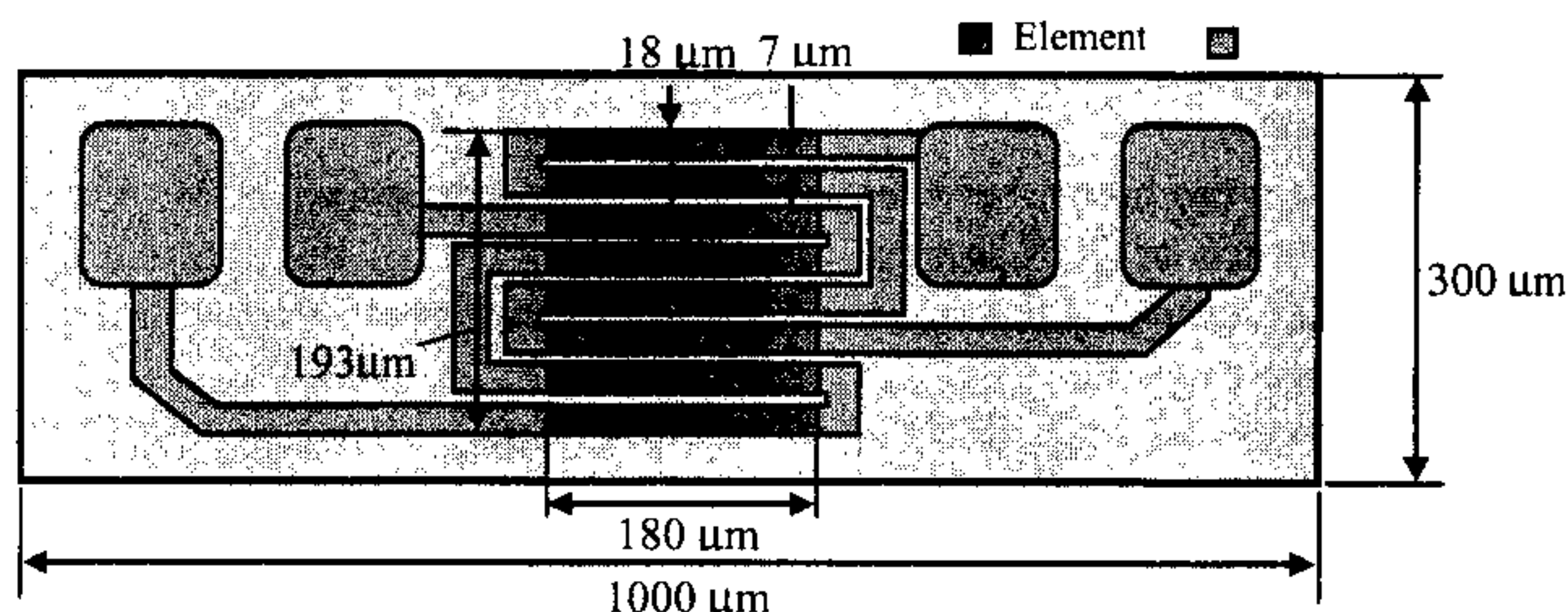
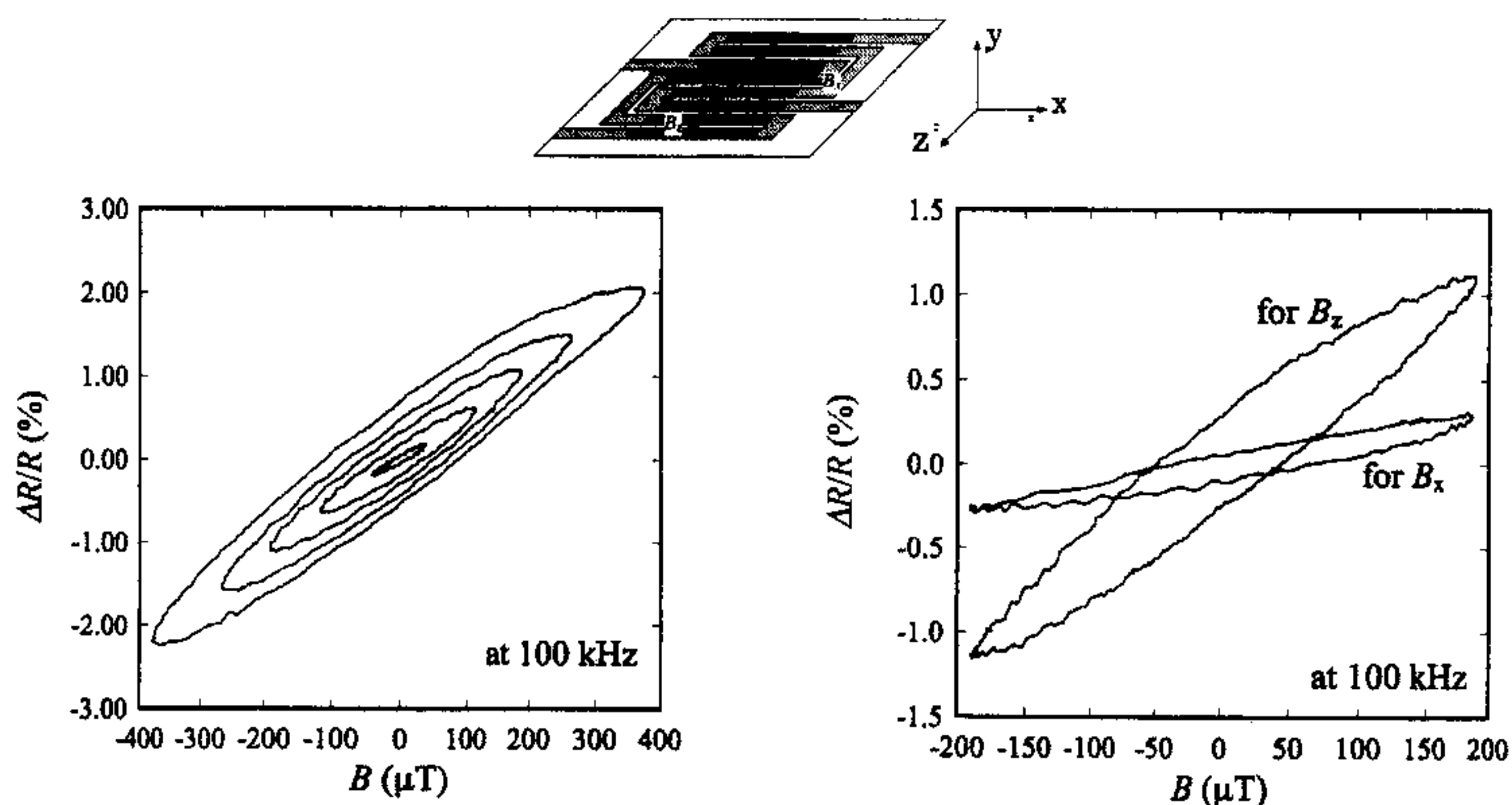


FIGURE 3. Spin-valve GMR sensor head pattern.

spin-valve GMR(SV-GMR) that has the pattern of sensor head as shown in Fig. 3. Two sensors are included on one chip. The size of one element is $18\ \mu\text{m}$ in width and $180\ \mu\text{m}$ in length.

Fig. 4 shows the fundamental characteristics of SV-GMR sensor for small signal. We measure the characteristics by using Helmholtz coil. As shown in Fig 4(a), about 0.61% change of resistance is obtained under the small signal of $100\ \mu\text{T}$. Fig. 4(b) shows the directional sensitivity. The z- and x-axis sensitivities become high. The y-axis, normal to the surface of GMR, sensitivity is very low, the curve is eliminated.



(a) Small-signal characteristics of B - $\Delta R/R$. (b) Characteristics of directional sensitivity.
FIGURE 4. Characteristics of SV-GMR sensor under small signal.

PRINCIPLE OF DETECTION AND CHARACTERISTICS

Fig. 5 shows the fundamental operating principle of the ECT probe. The exciting currents in the meander coil are flowing along the z-direction. Under normal operation without defect, the flux is flowing along the x and y-axis. Whenever there is a disconnection in the PCB conductor, the eddy currents change its path and that will results in the generation of z-axis component of flux density. The z-direction component of magnetic flux near the disconnection gives the important signal for detection. The solenoid coil picks up the z-component of flux in Fig. 5(c). The same phenomenon also occurs at not only different imperfections but also soldering point. The raw data in Fig. 5(c) has the signal of defects and the offset voltage due to noise, misalignment and unavoidable adjustments. Figure 5(d) shows a typical gradient data of the low signal. We can get the signal of disconnection and soldering point clearly.

Fig. 6 shows the layout between meander/GMR probe and PCB. The ECT probe is scanned along the trace of PCB pattern. The offset voltage by the main magnetic flux by excitation can be decreased by making a y direction of extremely low sensitivity as same as a perpendicular plane of PCB.

Fig. 7 shows the strip chart along the conductor by meander/GMR probe. The width of conductor is 200 μm and the thickness is 35 μm . The percent numbers indicate the size of damage. The number of 100% means perfect disconnection. The disconnection point

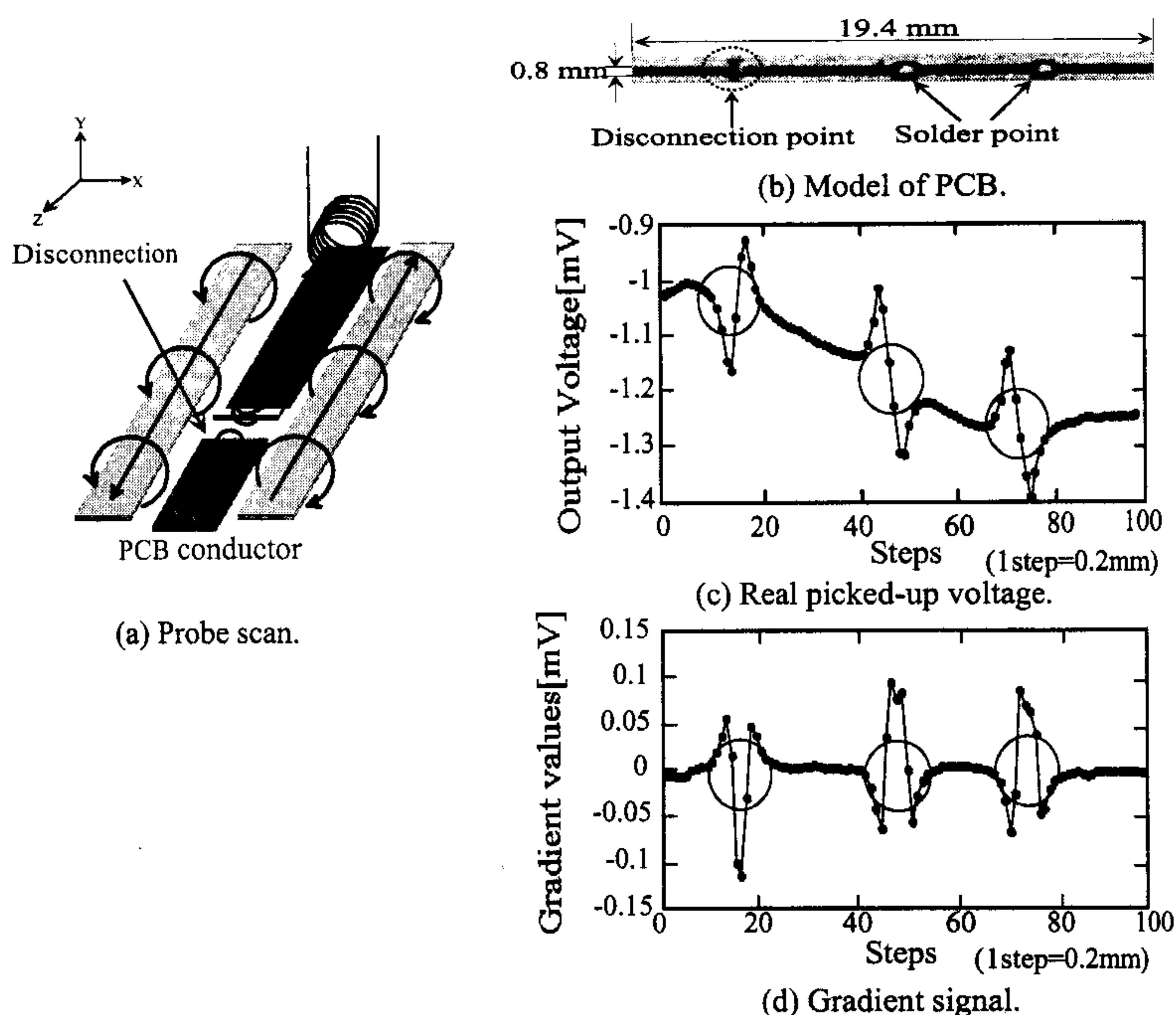


FIGURE 5. Fundamental principle of detection of defect.

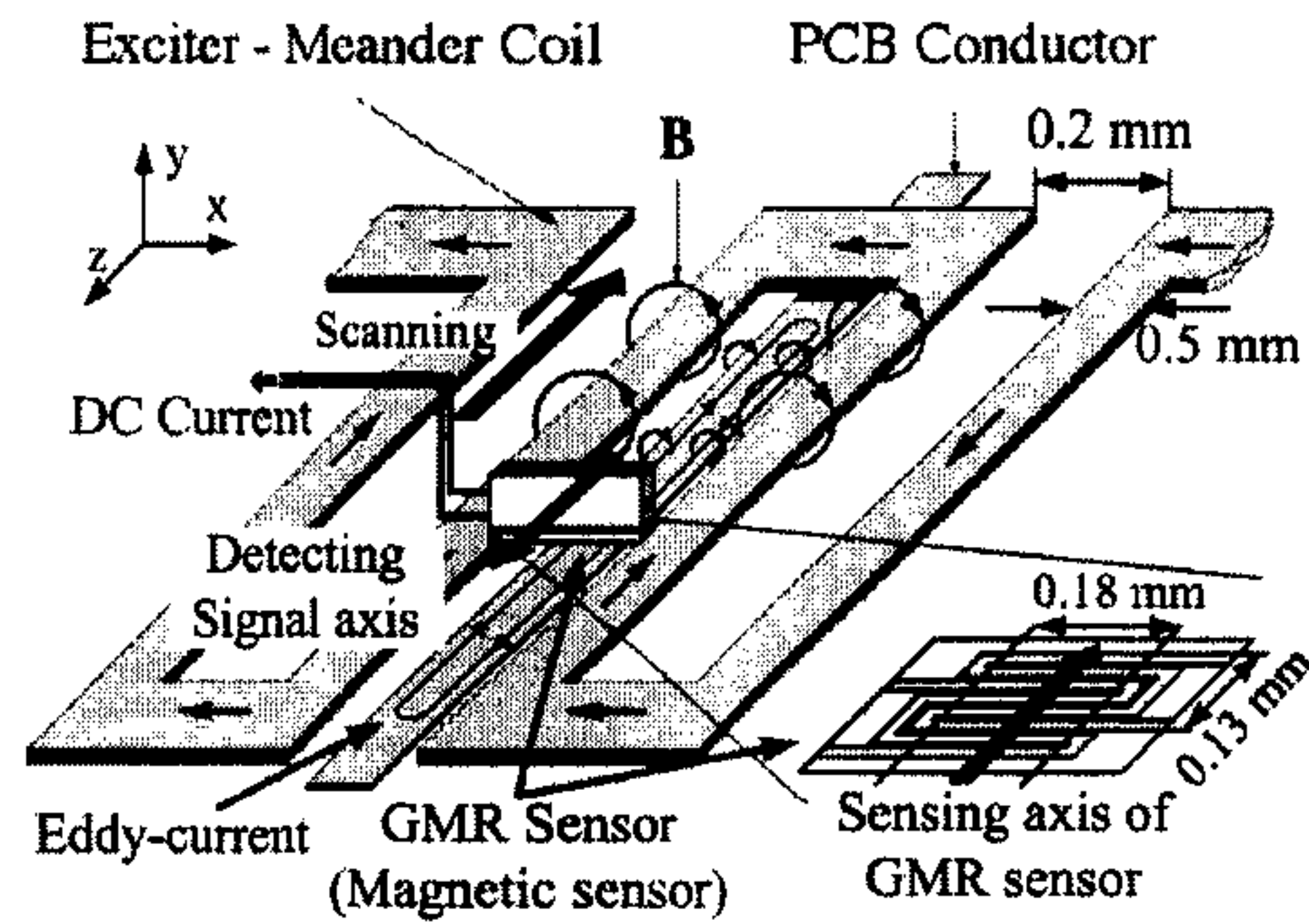


FIGURE 6. Meander/GMR type probe on PCB.

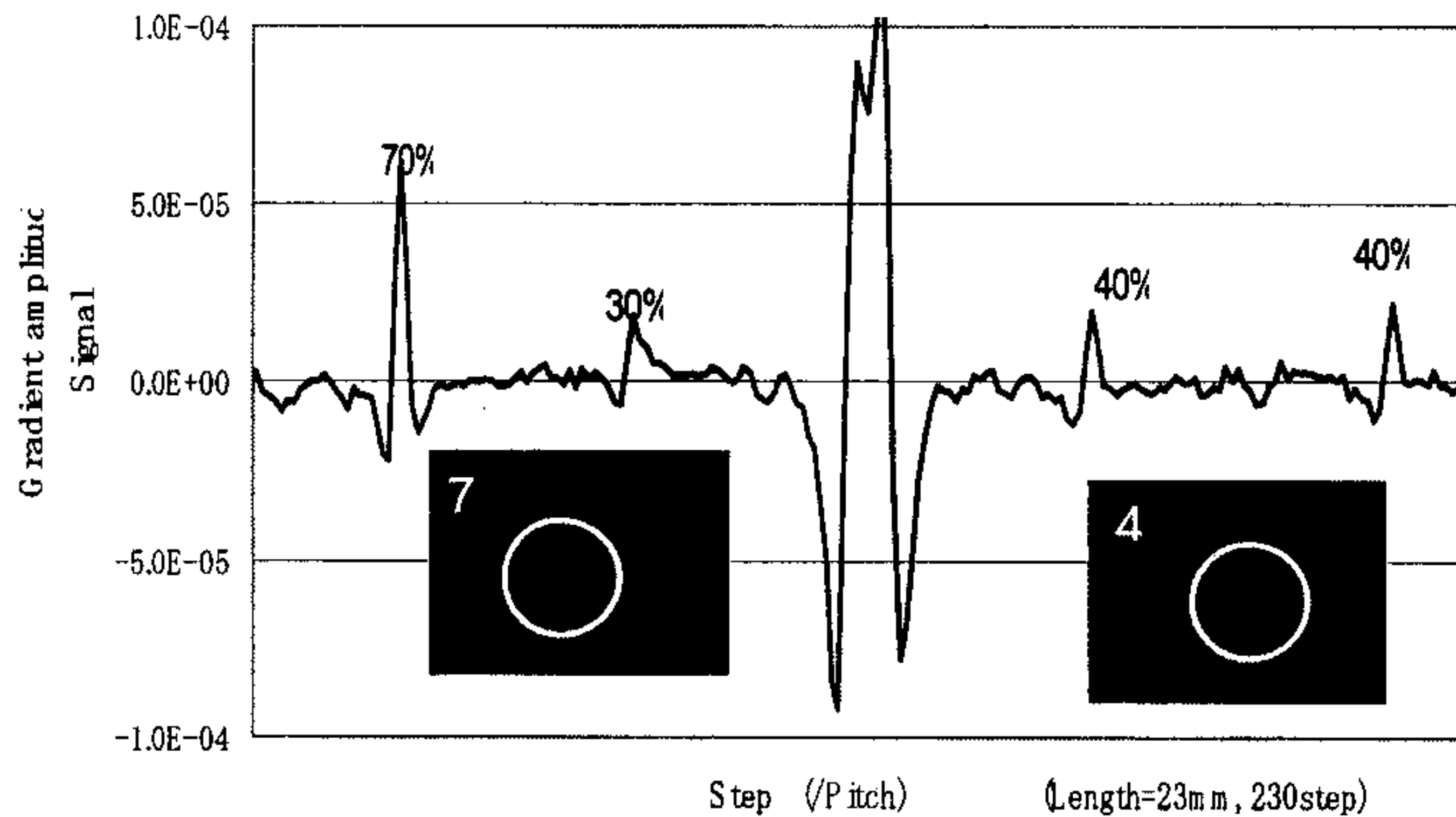


FIGURE 7. Strip chart of gradient signal on conductor.

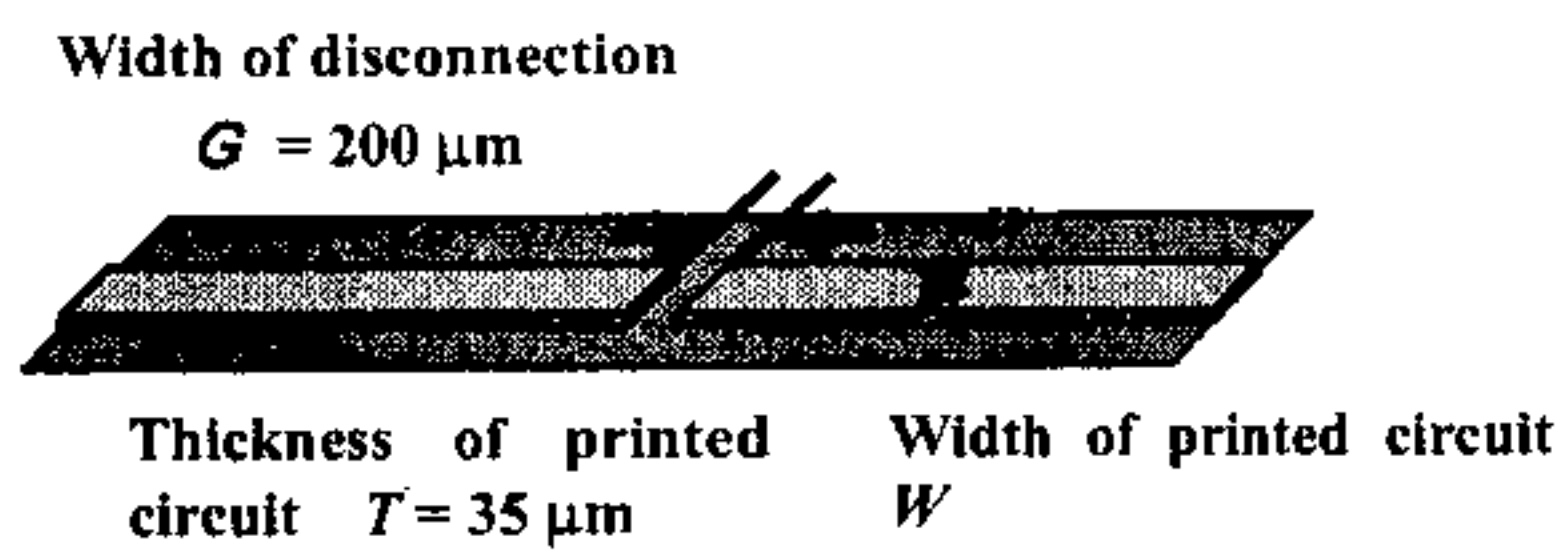
exists at the center. There are the chipping defects from 30 to 70 percent on the trace. The results show that these defects such as imperfection can be observed clearly.

Fig. 8 shows the signal characteristics as a function of the width of conductor with three disconnections. The figures (b)-(d) are for 300 μm , (c) for 200 μm , and (d) for 100 μm width respectively. Different kinds of noise generated by the non-equality of scanning are included in a place except disconnection. We discuss the characteristics of the probe based upon the trip chart. As shown in Fig. 9, the signal of the disconnection, V_s , and the noise, V_n , are defined by the peak to peak amplitude of the gradient value. The signal to noise ratio, V_s , is calculated by Eq. (1).

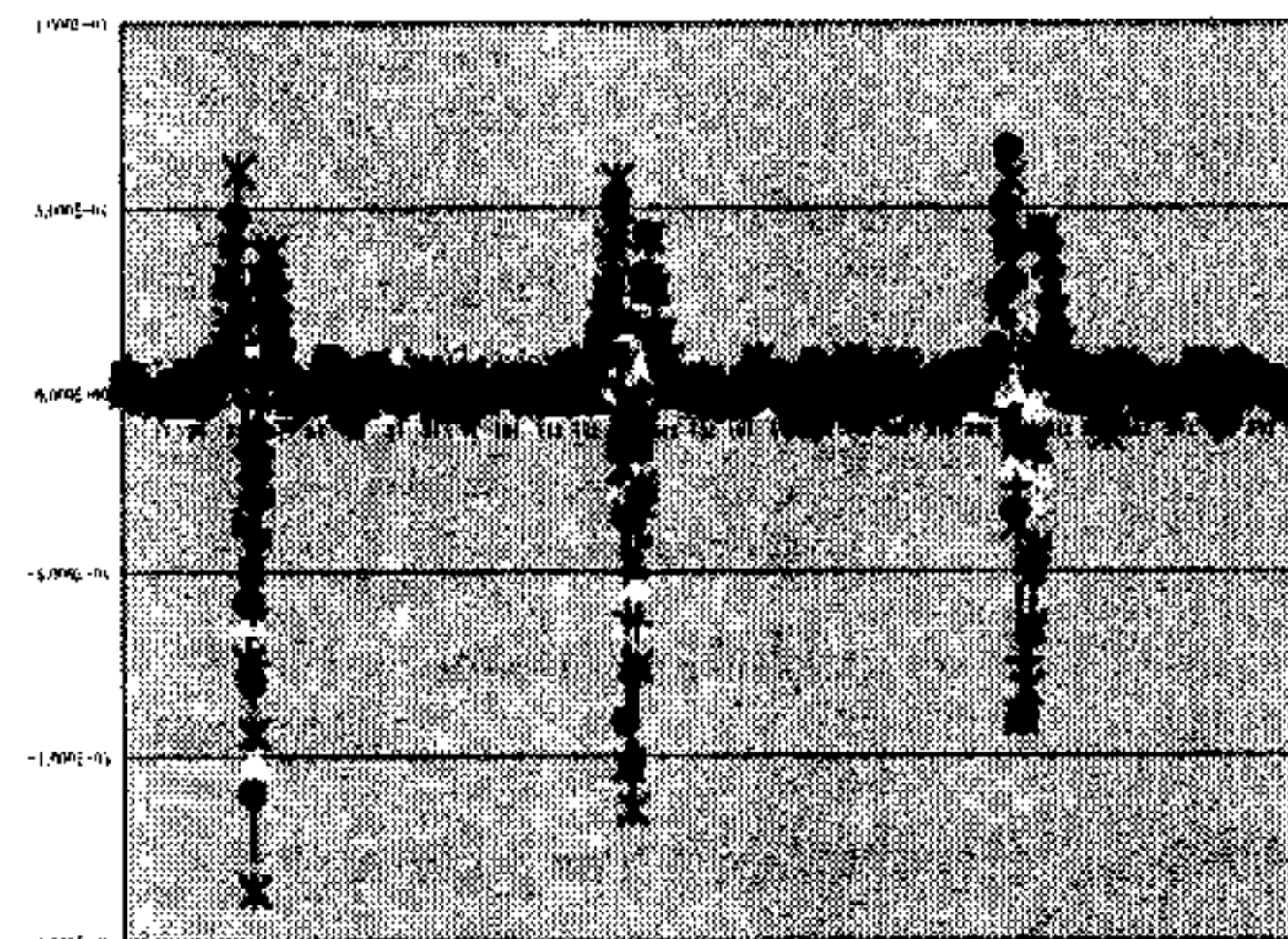
$$R_{sn} = 20 \log_{10}(V_s / V_n) \quad (1)$$

Fig. 10 shows the comparison of signal-to-noise ratio between solenoid type and GMR type probe. According to the result, we can obtain the improvement up to 10 dB. The

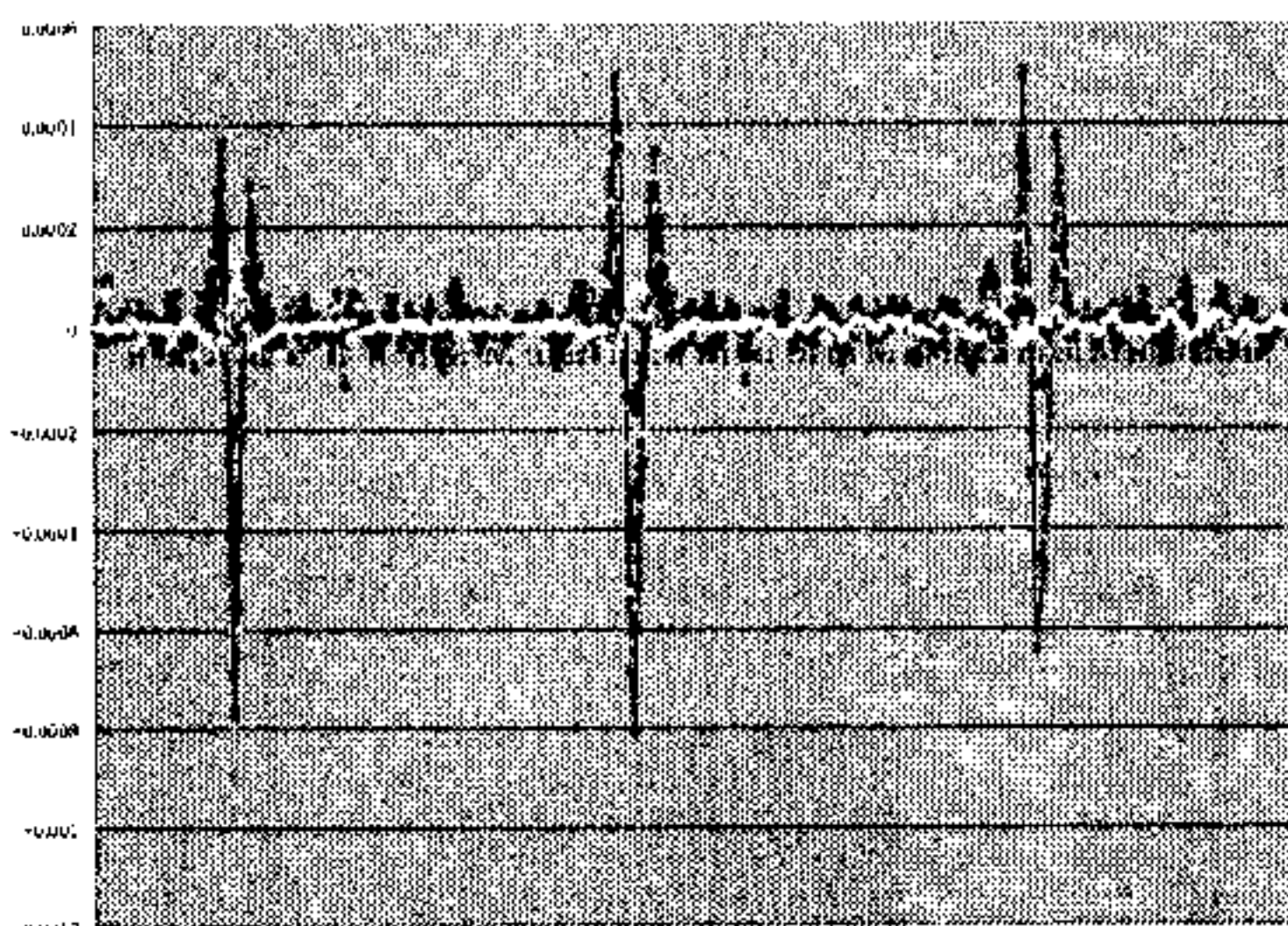
result shows the possibility to detect disconnection on the narrow conductor with less than $100\ \mu\text{m}$ width. The examination of the optimal structure will enable us to give more improvement of the resolution.



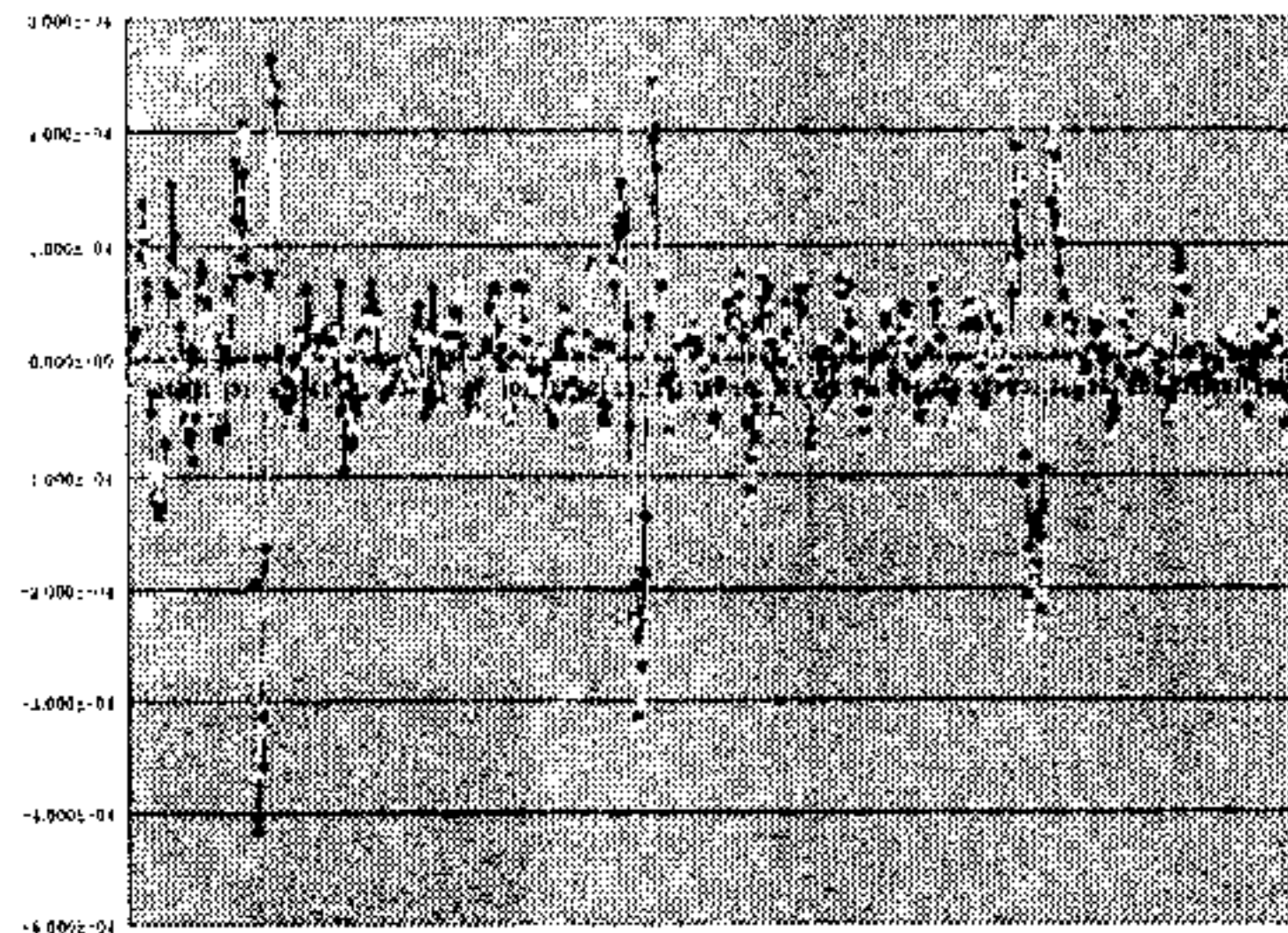
(a) Model printed circuit.



(b) Width $W = 300\ \mu\text{m}$.



(c) Width $W = 200\ \mu\text{m}$.



(d) Width $W = 100\ \mu\text{m}$.

FIGURE 8. Strip chart of disconnection signal vs. the width of printed circuit.

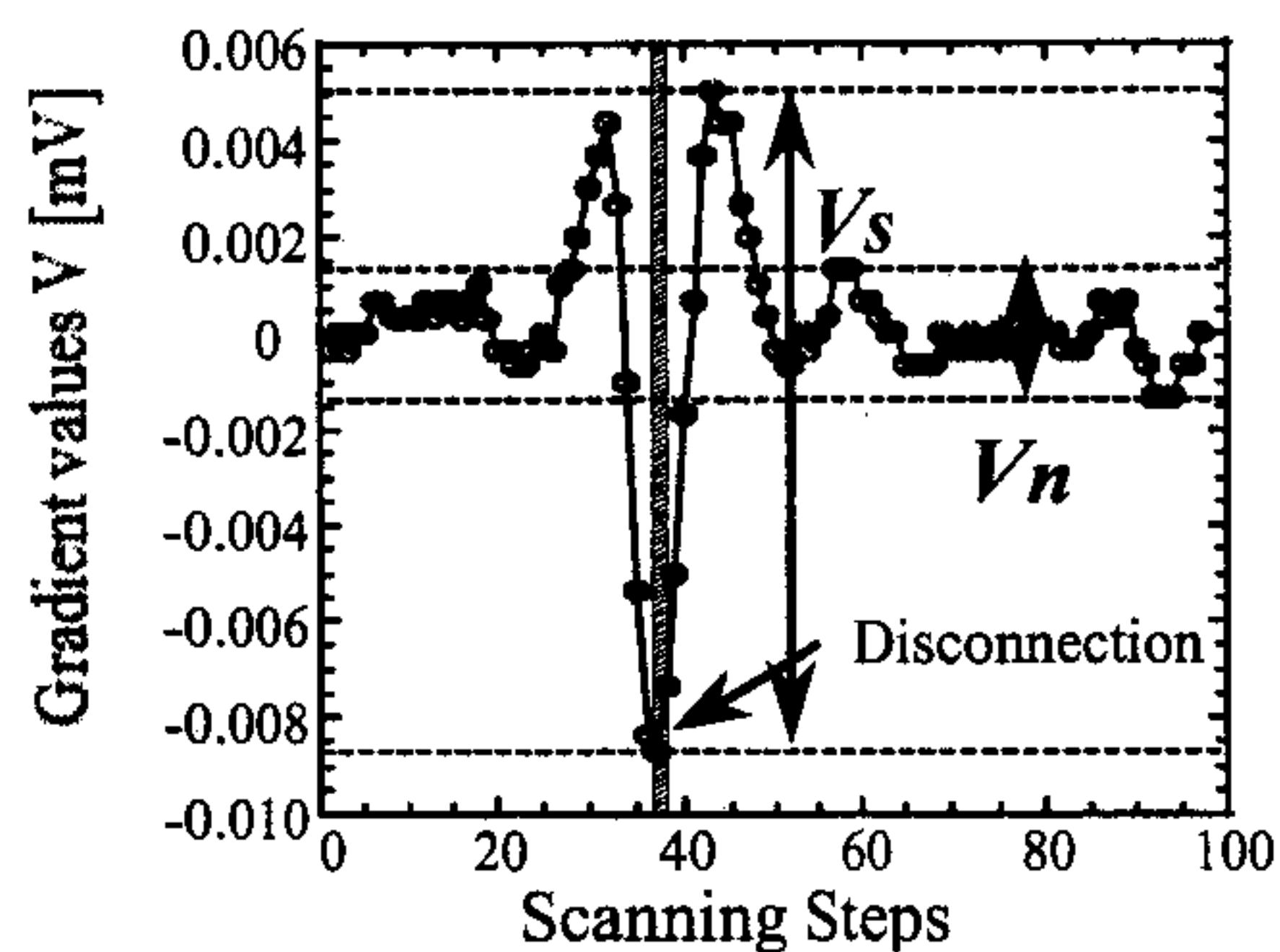


FIGURE 9. Definition of signal-to-noise ratio.

Fig. 11 shows the comparison of 2-D images by two probes. The model PCB has two type conductors of width 200 and 800 μm , soldering points and disconnections. The printed conductors are cut at six different points to make defects of sizes 0.1 -0.2 mm as shown in Fig. 11(a). Definitely the image by GMR probe is clearer than by solenoid coil probe. Since the ECT image includes many kinds of signal originated from disconnections as well from PCB pattern, a signal processing is needed in order to choose only the defect point in the 2-D image [3].

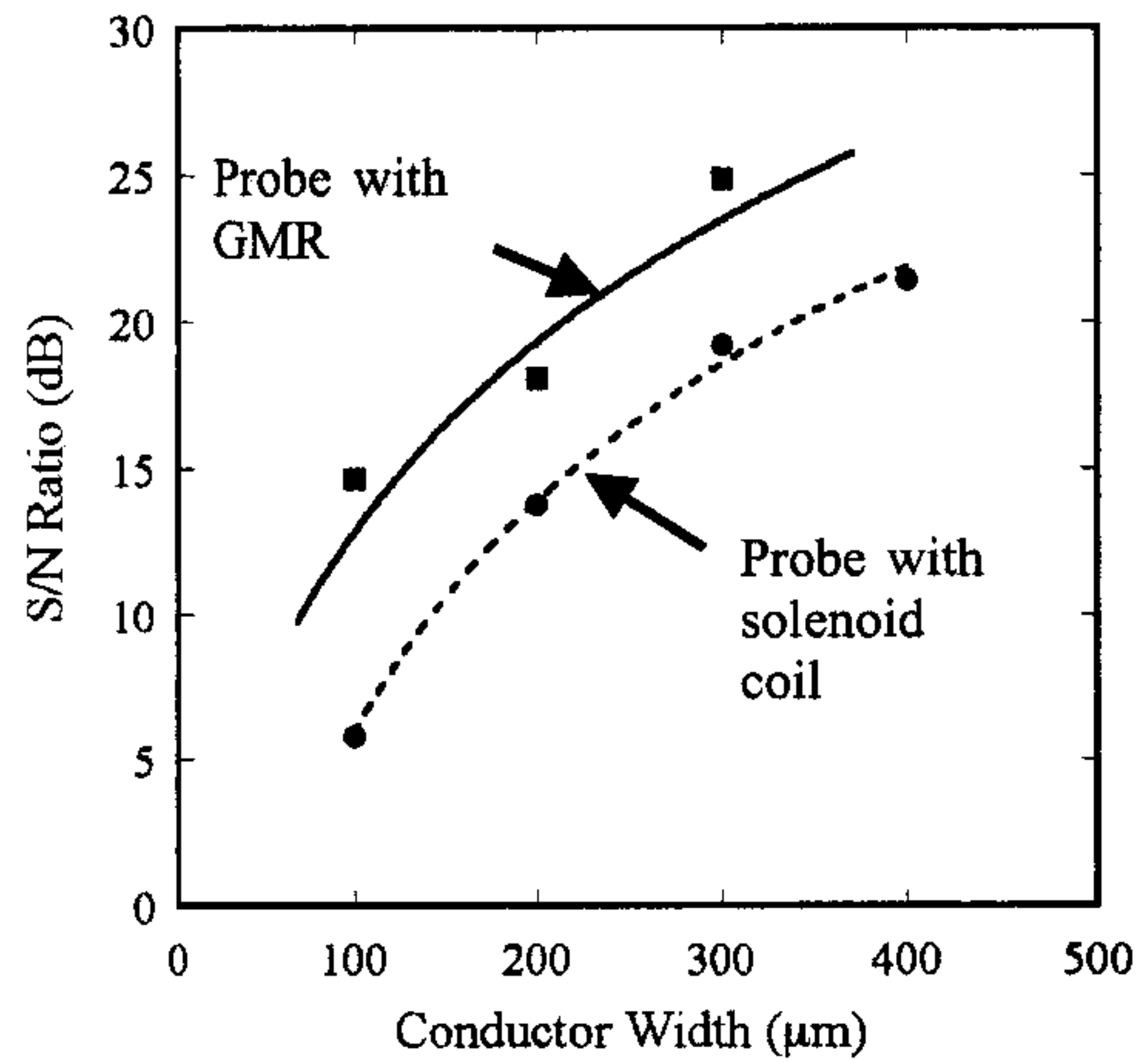


FIGURE 10. Signal to noise Ratio R_{sn} versus width of PCB conductor.

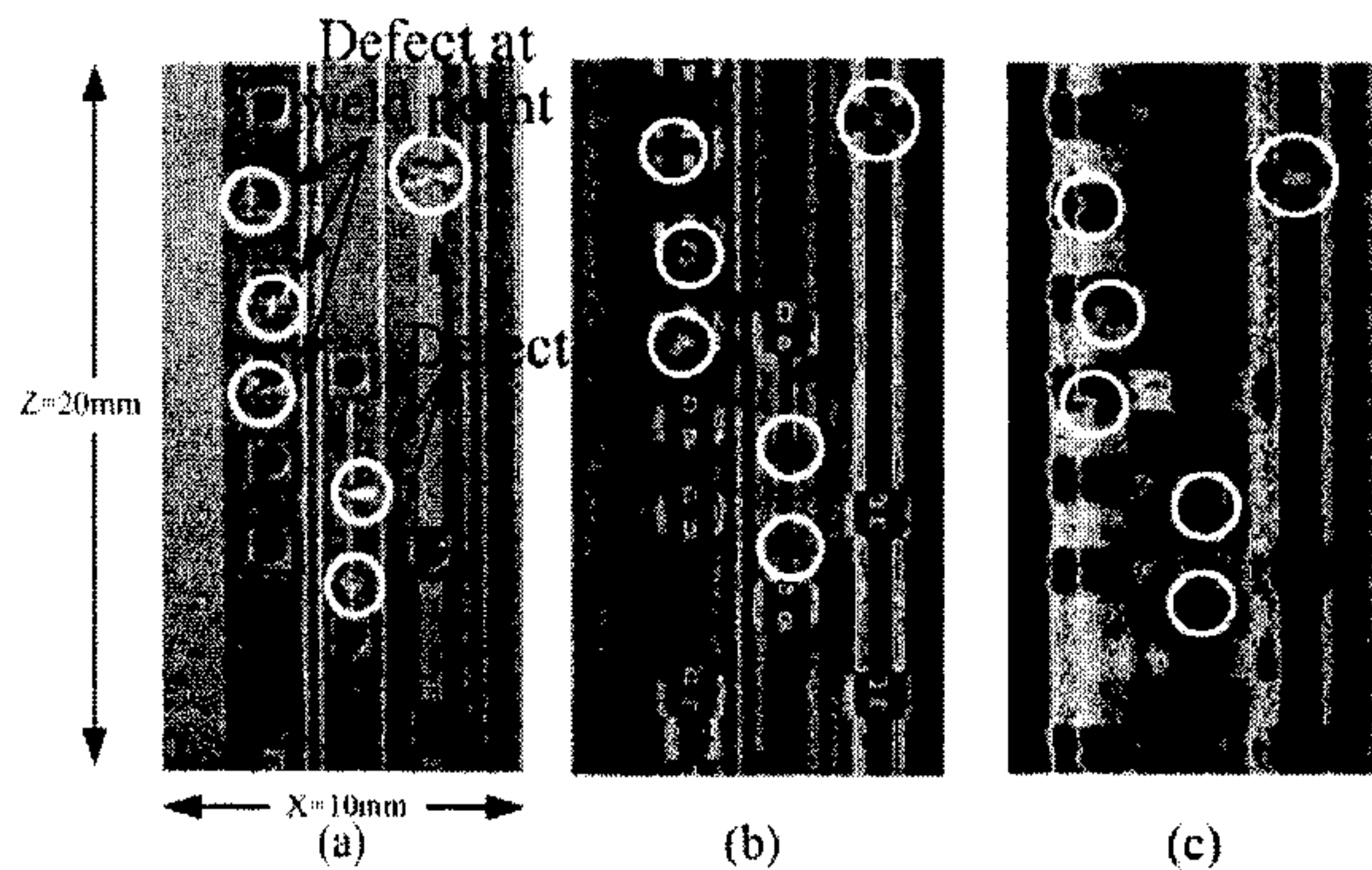


FIGURE 11. 2-D image of model PCB. (a) PCB model with defects, (b) tested results by GMR sensor, and (c) by solenoid coil.

CONCLUSIONS

We proposed the inspection of bare printed circuit by ECT technique. We fabricated two type ECT probes for the purpose of the PCB inspection, meander/solenoid type probe and meander/GMR type probe. As the results, the meander/GMR probe has better resolution and sensitivity. The measured result gives the possibility of inspecting disconnection on the printed circuit with less than 100 micro m width.

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