A Free Scanning Method for Measuring Magnetic Distributions Using Magnetic Tracker
Ken Sato†, Naoki Miyata†, Yoshitsugu Kamimura†, Yoshifumi Yamada†
†Graduate School of Engineering, Utsunomiya University
7-1-2 Yoto, Utsunomiya-shi, 321-8585 Japan
†satok@teioh.is.utsunomiya-u.ac.jp

Abstract—Recently, it has been concerned to the influence on human health by the low frequency magnetic field. The safety limits of magnetic flux density for human health are defined in some guidelines, therefore we can know if there are some effects or not by comparing measured value with guidelines. In measurement of magnetic field distributions, it is important to identify the position of measuring points. Conventionally, it has been general that the measuring points are decided at lattice points of coordinate beforehand, and they are measured by using large-scale robot arms or by spending a great amount of time and manpower. In this study, the position of field sensor is decided automatically by using magnetic tracker from the viewpoint of the human interface. First, it is confirmed that this method can obtain field distributions in real time, and it can display distributions by interpolating measured data one after another. Next, the resolution at the position of the field sensor is discussed. As a result, it is found that the position of the field sensor is able to be identified within 1 cm of error range when the length of the rod is 80 cm.

Keywords: low frequency field, electromagnetic wave, field sensor, visualization

I. INTRODUCTION

Recently, an interest to health effects on human body from ELF magnetic filed has been rising. The influential threshold of safety levels of magnetic filed for human health is defined as guidelines by ICNIRP [1]. There is some equipment which evaluates whether a magnetic source is complained with safety guidelines; however an anxiety for health effect still remains because magnetic fields are not visible. In addition, it is not easy to measure 3-D distributions of magnetic field roughly, because it is necessary to spend a great amount of time and manpower for scanning sensor or to use large scale scanning system such as robot-arms [2]. The most important thing to measure the field distributions is to identify the measuring points.

In this study, we have developed the system which measure magnetic distributions in free coordinates. The system can measure at the point where we would like to know more minutely. In addition, we have also considered about an error of position data which is used for distinction measuring points.

II. A FREE SCANNING METHOD FOR MEASURING MAGNETIC DISTRIBUTIONS

A. The configuration of the system

Fig.1 illustrates the configuration of the free scanning system, and Fig.2 shows photos of field sensor and magnetic tracker.

Magnetic field measurement is performed by moving a rod freely. A field sensor is set on the tip and a position sensor is on the butt of a nonmetal rod. The specifications of two kinds of sensor are shown in TABLE I and TABLE II [3][4].

| Table 1: Specification of the H-field meter |
|------------------------------- |------------------ |
| Name                          | Wide band magnetic field sensor |
| Measurement interval          | 1.1 sec           |
| Frequency range               | 30 Hz - 1 kHz (LOW) |
|                               | 1kHz - 100 kHz (HIGH) |
| Accuracy                      | 0.1 \( \mu \) T    |
| Display resolution            | 0.1 \( \mu \) T (0.1 - 99.9) |
|                               | 1 \( \mu \) T (100 - 999) |
### TABLE II Specification of the position sensor

<table>
<thead>
<tr>
<th>Name</th>
<th>Polhemus PATRIOT system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement interval</td>
<td>&lt; 0.1 sec</td>
</tr>
<tr>
<td>Access latency</td>
<td>&lt; 20 msec</td>
</tr>
<tr>
<td>Sensor range</td>
<td>152 cm</td>
</tr>
<tr>
<td>Sensor resolution</td>
<td>0.0038 mm, 0.1 degree</td>
</tr>
</tbody>
</table>

A magnetic tracker can obtain coordinates \((x, y, z)\) and three kinds of angles (\(\theta\): yaw, \(\phi\): pitch, \(\varphi\): roll) using the magnetic field radiated from the transmitter located in origin. A transmitter of the magnetic tracker generates an original magnetic field to determine the location of the position sensor.

A magnetic distribution around the IH cooker illustrated in Fig.5 was measured by using this system. In convenience, the measurement was done as two-dimensional way of upper (\(x-y\) plane), side (\(y-z\) plane), and front (\(x-z\) plane) of the IH cooker. An acrylic resin board was set to fix measuring plane, then a rod scan on the surface of the board.

### B. Data processing for real-time display

To display distributions in real time by using measured value in free coordinate, the following processes are needed.

- Arrangement of the measured data
- Interpolation of data

The coordinate data which is obtained from position sensor are real number. Therefore it is necessary to convert into an integer to treat as array. Thus the obtained magnetic field strength value is allocated in array as digitized coordinate space. If there are non-measured points in array, these points are interpolated by calculating as possible to make a distribution map. Concerning \(x-y\) plane for example, the linear interpolations are done in the \(x\) direction first, and then same operations are done in the \(y\) direction using interpolated result of \(x\) directions. The measured data and the interpolated data are classified in array. When a new data is obtained by measuring, interpolated data is replaced by this value. The outline of interpolation process is shown in Fig.4.

### III. Experiment

#### A. Method

A magnetic distribution around the IH cooker illustrated in Fig.5 was measured by using this system. In convenience, the measurement was done as two-dimensional way of upper (\(x-y\) plane), side (\(y-z\) plane), and front (\(x-z\) plane) of the IH cooker. An acrylic resin board was set to fix measuring plane, then a rod scan on the surface of the board.

#### B. Real-time display of distributions

Both the position data of the position sensor and the filed strength are acquired when a rod is moving one after another. The coordinate of field sensor can be calculated by obtained position data using equation (1). Magnetic distribution map is made from these data. The originality of this method is to be possible to scan freely in measuring area. If it is possible to display magnetic field distribution one after another using...
obtained results, we can continue measuring with confirming the actual distributions. Therefore, we have confirmed the way to show distribution map in real time. Interpolation process shown in Fig.4 is performed to obtained data, and magnetic distribution is displayed as 2-D map. GrWin graphic library [4] is used for graphic display. Fig.6 shows a distribution map of x-y plane (upper of the IH cooker). The number of all measuring points was 250, and it took 275 seconds to measure all points because it takes 1.1 seconds per point. It is limited by interval time of the field sensor. A red line in this figure shows a track of a magnetic field sensor. According to the map shown in Fig.6, strong magnetic area exists at the center of IH cooker. Fig.7 shows a distribution map of x-z plane (front of the IH cooker) measured at 147 points, and Fig.8 shows map of y-z plane (side of the IH cooker) measured at 214 points.

IV. ERROR OF SENSOR POSITION

The coordinate of field sensor (X, Y, Z) can be calculated by using the length of rod R, position data (x, y, z, θ, φ, ϑ), and equation (1). According to propagation law of error, the error of coordinate of field sensor (ΔX, ΔY, ΔZ) is given as follows:

\[
|\Delta X| = |\Delta x| + |\Delta R| \sin \theta \sin \phi + R| \sin \phi \cos \theta | \Delta \phi | + R| \cos \theta \cos \phi | \Delta \theta |
\]

(2)

Similarly, ΔY and ΔZ is also given as follows:

\[
|\Delta Y| = |\Delta y| + |\Delta R| + R | \Delta \theta |
\]

(3)

\[
|\Delta Z| = |\Delta z| + |\Delta R| + R | \Delta \phi |
\]

(4)

Where, Δx, Δy, and Δz are errors measured at position sensor, and these values can be assumed within 1 mm of error, according to specifications shown in TABLE I.

| \begin{align*}
|\Delta X| & = 72.4 + 0.0017 \times 80 = 72.472 \\
|\Delta Y| & = 36.3 \\
|\Delta Z| & = 72.4
\end{align*} |

(5)

As a result the system can identify the position of the field sensor within 1 cm of error range when the length of the rod is 80 cm.
V. DISCUSSION

It has been confirmed visually from the result shown in Figs 6 to 8 that the strength of magnetic distribution is most strong at the center of IH cooker. And it has been also confirmed that it is enough to measure the distributions at each plane of the IH cooker in about 5 minutes. The measuring time can be reduced if it is possible to shorten the sampling cycle of the field sensor.

On this system we used the magnetic tracker to determine the position of the field sensor. The magnetic tracker can not send correct position data when there is some metal or electronic device. Therefore, several studies have reported that it is possible to use not only the magnetic tracker but also optical tracker to determine the position data. It may be also effective for this system to use magneto-optic hybrid tracker [5] [6].

VI. CONCLUSION

In this study, we have confirmed that our new method is effective and user-friendly using magnetic tracker to identify the sensor’s position for measuring field distributions. It has been confirmed that it is able to identify the position of the field sensor within 1 cm of error using magnetic tracker, and it has precision enough for a purpose of visualizing a leakage magnetic field from the IH cooker.

Usually, an identification of measuring point has been performed only at a fixed point on the grid by using robot arms for example. On this study, our system is possible to measure flexibly even though a peak of the field strength is found at unexpected area, because the system can measure freely. Therefore, it is able to measure more minutely around the area where it has been detected the value larger than the one defined in a protection guideline. As future study it is necessary to consider the method which displays magnetic field distribution in 3-D. In this study, we have used 2-D data to make distribution map, however it is possible to make spatial distribution by using 3-D data.

REFERENCES