*Transactions of the Materials Research Society of Japan* 31[4] 997-1000 (2006)

# Improvement of Frequency Characteristics in RF Magnetic Shielding Effects of a Bincho-Charcoal Plate by the Superposition of a Ferrite Plate

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With rapid development in the field of information technology, there has been increased interest for electromagnetic shielding in the radio frequency (RF) region. An excellent RF magnetic shielding material, a very large value of relative permittivity in the RF region, can be realized by the use of bincho-charcoal, a high quality charcoal found in Japan, due to its very large value of relative permittivity in the RF region. The present paper has improved the RF magnetic shielding characteristics of a bincho-charcoal plate to realize a broadband frequency by the superposition of a ferrite plate over two bincho-charcoal plates. This configuration is termed the compound plate, and the RF magnetic shielding effects of the compound plate have been examined, including the characteristics of the RF magnetic shielding effect versus both the frequency and the RF magnetic power. In addition, an examination was conducted of the RF electric shielding effects as functions of the frequency and RF electric power.

Key words: RF magnetic shielding, bincho-charcoal plate, highly relative permittivity, ferrite plate

## 1. INTRODUCTION

Recently, electromagnetic environmental problems have become more serious, and increased with the increased employment of electronic devices [1]. The use of electromagnetic shielding has, therefore, also increased in order to improve environmental conditions [1]-[4]. As one of the basic areas of research for the improvement of the electromagnetic environment, the present paper has applied bincho-charcoal, a high quality charcoal in Japan, as RF magnetic shield [5]. A bincho-charcoal, which has a very large value of relative permittivity ($10^7$ - $10^4$) in the frequency region (1 MHz - 100 MHz), is an excellent material for use as a RF shield, such as reported in Ref. [6].

In this research, it is found that the value of the RF magnetic shielding degree $SD_H$ for a bincho-charcoal plate in the frequency region of 1 MHz to 3 GHz increased with frequency, with values of 1 dB at 1 MHz, and 53 dB at 3 GHz. It is important to realize an ideal electromagnetic shield, in the broadband frequency region from low frequencies to radio frequencies.

The present authors have improved the RF magnetic shielding effect of a bincho-charcoal plate in order to realize a broadband of frequency characteristics, by the superposition of a ferrite plate over the bincho-charcoal plate, termed the compound plate. The frequency characteristics of the magnetic shielding degree $SD_H$ for the compound plate were improved by constant values of approximately 50 dB in the frequency region of 1 MHz to 3 GHz.

Experimental results revealed several characteristics of the compound plates that include the RF magnetic and electric shielding degrees, $SD_H$ and $SD_E$, as functions of radio frequency $f$, and the non-dependence of $SD_H$ on the value of RF output power. Furthermore, additional RF electric shielding degree $SD_E$ of the compound plate were examined.

## 2. EXPERIMENTAL PROCEDURE

### 2.1 Fabrication of the bincho-charcoal plate

Such as reported in Ref. [6], the bincho-charcoal tiles (10 mm square, 5 mm thick) were fabricated by use of a diamond saw at low cutting speeds to inhibit any heat effects. The paste for gluing the tiles was prepared by the homogeneous mixing of polyvinyl-alcohol and bincho-charcoal powder (approximately 2 $\mu$m or smaller) milled with a planetary agate grinder. The tiles were glued using the paste, and then dried naturally at room temperature (300 K) for about 8 hours. These

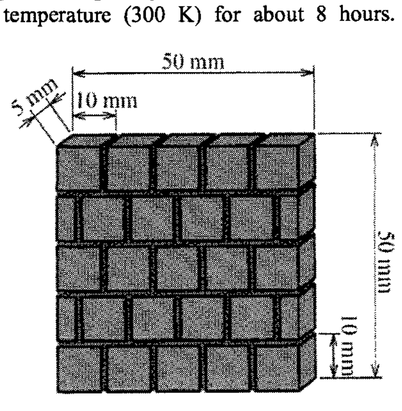


Fig. 1. Sketch of the geometry of a typical bincho-charcoal plate.

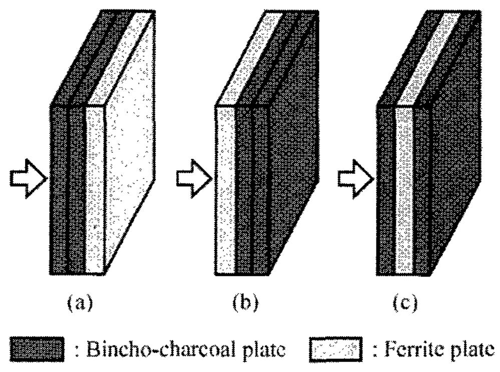


Fig. 2. Sketch of the geometry of three different compound plates. (a), (b), and (c) are the sample A, sample B, and sample C, respectively.

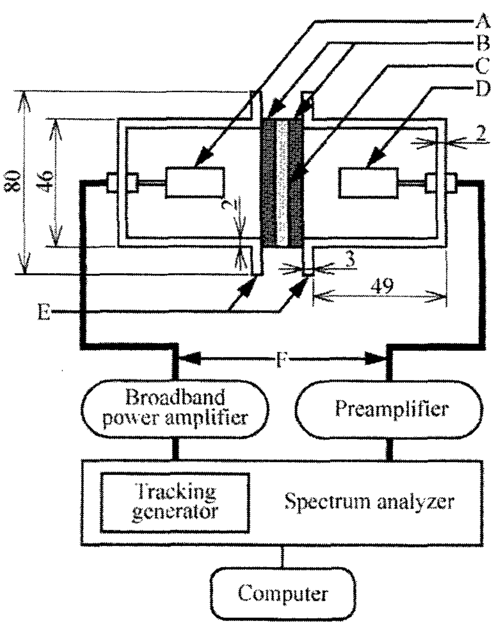


Fig. 3. Schematic diagram of the experimental arrangement used to measure the electromagnetic shielding characteristics for the compound plate. Here, A represents the transmitting antenna, B the bincho-charcoal plate, C the ferrite plate, D the receiving antenna, E the metal cell, and F the coaxial cable.

glued tiles, as a bincho-charcoal plate, were cut into four square-shaped specimens (50 mm square) such as shown in Fig. 1, using a diamond saw at a low cutting rate, and then polished with fine sandpaper. In the present research, another use was also made of a commercial ferrite plate (TDK, IB-015, 50 mm square, 6 mm thick), placed over the bincho-charcoal plate to form the compound plate.

2.2 Construction of the compound plate

In present experiment, three different compound plates were prepared as shown in Fig. 2. The constructions (a), (b), and (c) are termed the sample A, sample B, and sample C, respectively. In this figure, the direction of an arrow is the incident direction of the electromagnetic wave.

2.3 System for measuring the RF magnetic shielding effect

Fig. 3 is a schematic diagram of the experimental arrangement used to measure the RF electromagnetic shielding effects, the magnetic shielding degree $SD_H$ and electric shielding degree $SD_E$. The RF output (1 MHz - 3 GHz) of the tracking generator with a spectrum analyzer (HP, 8594E) is amplified by 50 dB with a broadband amplifier (Kalmus, 210LC-CE), and guided to a transmitting antenna. The output of the receiving antenna is amplified by 38 dB with the use of a preamplifier (Sonoma, 317). The results from the spectrum analyzer are then transferred through a GPIB to a laptop computer. In the measuring system of the RF magnetic shielding effect, propagation of the electromagnetic wave from the transmitting antenna to the receiving antenna was always arrayed to be perpendicular to the surface of the compound plate. The two metal cells E, as shown in Fig. 3, have the same shape and size. In the present research, the input power of the transmitting antenna and the distance (19 mm) between the two cells are held constant. Loop and probe antennas are used for the measurements of the $SD_H$ and $SD_E$, respectively.

The electromagnetic shielding degree $SD$ can be defined in terms of the reduction in RF magnetic and/or electric field strength that occurs due to the shielding plate [7]. In general, the magnetic shielding degree $SD_H$ is defined as

$$SD_H = 10\log\frac{P_{H0}}{P_{H1}} \quad \text{(dB)}, \qquad (1)$$

where $P_{H0}$ and $P_{H1}$ are the strengths of the incident magnetic field power and the magnetic field of the transmitted wave as it emerges from the shielding plate, respectively. The electric shielding degree $SD_E$, similar to Eq. (1), is defined as the ratio $P_{E0}/P_{E1}$. Here, $P_{E0}$ and $P_{E1}$ are the strengths of the incident electric field power and the electric field of the transmitted wave as it emerges from the shielding plate, respectively.

## 3. RESULTS AND DISCUSSION

3.1 RF magnetic shielding effects of bincho-charcoal and ferrite plates

Fig. 4 shows the RF magnetic shielding degree $SD_H$ as a function of the frequency $f$, over the frequency range from 1 MHz to 3 GHz, under a constant RF output power $P_H$ of 10 dBm of the transmitting antenna. In this figure, the curves formed by the open circles and open squares represent the shielding characteristics for the single bincho-charcoal and ferrite plates, respectively. As can be seen in Fig. 4, the values of $SD_H$ for the single bincho-charcoal plate increase as the values of the frequency $f$ increase, in the frequency region from 1 MHz to 3 GHz. And also, it can be seen that the characteristics of $SD_H$ for the single ferrite plate decrease as the frequency $f$ increases. Similar results such as shown in Fig. 4 were obtained for double bincho-charcoal and ferrite plates, over this frequency region (not shown).

The characteristics of the magnetic shielding degree

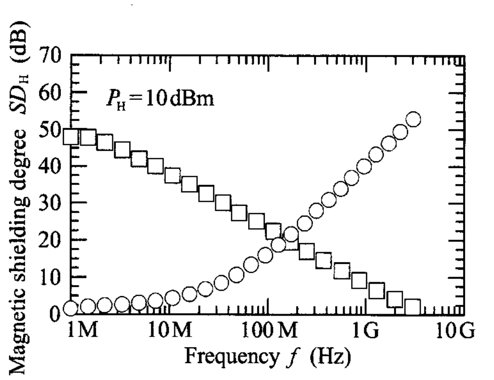


Fig. 4. RF magnetic shielding degree $SD_H$ for the single bincho-charcoal and ferrite plates as functions of frequency $f$. The open circles and open squares represent the single bincho-charcoal and ferrite plates, respectively.

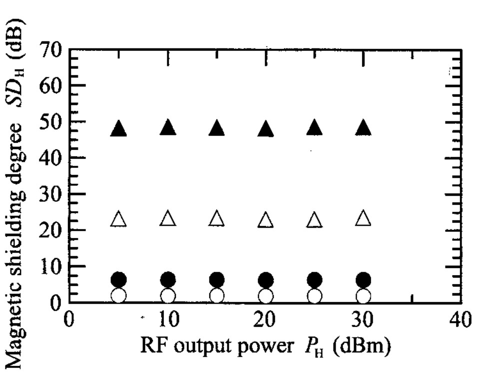


Fig. 5. Typical characteristics of $SD_H$ for the single bincho-charcoal plate as functions of RF output power $P_H$. The open circles, solid circles, open triangles, and solid triangles represent the result for 2 MHz, 20 MHz, 200 MHz, and 2 GHz, respectively.

$SD_H$ for values of RF output power $P_H$ of the transmitting antenna for the single bincho-charcoal plate at 2 MHz (open circles), 20 MHz (solid circles), 200 MHz (open triangles), and 2 GHz (solid triangles), are displayed in Fig. 5. It can be seen that the characteristics of $SD_H$ for the single bincho-charcoal plate display no evidence of dependence on the values of $P_H$ in the region between 5 dBm and 30 dBm. Similar tendency for the single ferrite plate, such as those shown in Fig. 5, are obtained for the power region (not shown).

3.2 RF electric shielding effects of single bincho-charcoal and ferrite plates

The plotted points in Fig. 6 denote the RF electric shielding degree $SD_E$ for the single bincho-charcoal and ferrite plates as functions of the frequency $f$, over the range from 1 MHz to 3 GHz, under a constant RF electric field output power $P_E$ of 10 dBm of the transmitting antenna. In this figure, the open circles and open squares represent the shielding characteristics for the single bincho-charcoal and ferrite plates, respectively. The electric shielding characteristics for the ferrite plate exhibit no remarkable effect, and remain fairly constant as the frequency increases, as shown in

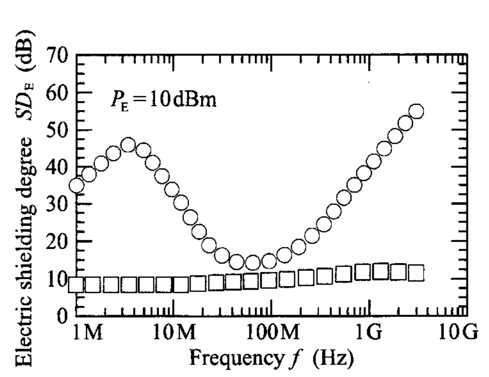


Fig. 6. The RF electric shielding degree $SD_E$ for the single bincho-charcoal and ferrite plates as functions of frequency $f$. The open circles and open squares represent the single bincho-charcoal and ferrite plates, respectively.

this figure.

The RF electric shielding degree $SD_E$ displayed no dependence on the value of $P_E$ for the single bincho-charcoal plate in the range from 5 dBm to 30 dBm (not shown), and displayed the same tendency as in Fig. 5. That is, the values of $SD_E$ are constant and do not change with changes in the RF output power $P_E$ for given values of RF. In the same manner of the single bincho-charcoal plate, the characteristics of $SD_E$ for the single ferrite plate displayed no evidence of dependence on $P_E$ for given values of RF in the power range between 5 dBm to 30 dBm (not shown). Similar tendency such as shown in Fig. 5 were obtained for double bincho-charcoal and ferrite plates (not shown).

3.3 RF magnetic and electric shielding effects for three different compound plates

To further improve the RF magnetic shielding in order to realize a broadband of frequency characteristics, the three different compound plates, samples A, B, and C, were constructed such as shown in Fig. 2 (a), (b), and (c). Fig. 7 displays the typical RF magnetic shielding characteristics of the compound plates as functions of frequency $f$, over the frequency range from 1 MHz to 3 GHz, under a constant RF output power $P_H$ of 10 dBm of the transmitting antenna. In this figure, the curves formed by the solid triangles, open diamonds, and solid circles represent the shielding characteristics for the sample A, sample B, and sample C, respectively. It was determined that the characteristics of $SD_H$ for three compound plates displayed no evidence of dependence on the values of $P_H$ in the region between 5 dBm and 30 dBm (not shown).

For example, the values of $SD_H$ improved over that of sample C by a construct of the sandwich structure with a ferrite plate between two bincho-charcoal plates, in the frequency region from 1 MHz to 1 GHz. That is, the values of $SD_H$ for this plate remain fairly constant at approximately 50 dB over this frequency region. As can be seen in Fig. 7, the values of $SD_H$ increase as the values of frequency $f$ increase, in the frequency region from 1 GHz to 3 GHz. It can also be seen that the characteristics of $SD_H$ for the all plates are the same form as that of the double bincho-charcoal plate, over

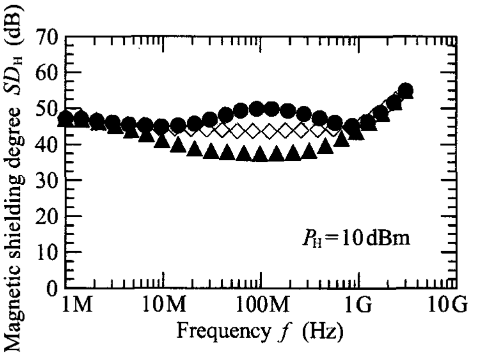


Fig. 7. Distributions of the RF magnetic shielding degree $SD_H$ for the three different compound plates as functions of frequency $f$, under constant RF output power $P_H$ (10 dBm) of the transmitting antenna. The solid triangles, open diamonds, and solid circles represent the samples A, B, and C, respectively.

this frequency region.

Furthermore, it can be seen in Fig. 7 that the characteristics of $SD_H$ for the three different compound plates are different each other, in the frequency region from 10 MHz to 1 GHz. The present authors are now investigating the physical meaning of these characteristics. These results demonstrate an important criterion for improving the frequency characteristics in the application of practical electromagnetic shielding.

The results of the RF electric shielding degree $SD_E$ for the three different compound plates are almost same as the characteristics of single bincho-charcoal plate (open circles), such as shown in Fig. 6, in the frequency region from 1 MHz to 3 GHz (not shown). It can be seen that the characteristics of $SD_E$ for the compound plates display no evidence of dependence on the values of RF output power $P_E$ in the region between 5 dBm and 30 dBm (not shown).

## 4. CONCLUSIONS AND SUMMARY

As one of the basic areas of research for improvement of the electromagnetic environment by using a bincho-charcoal, the present paper has examined and clarified the RF electromagnetic shielding effects of three different compound plates, samples A, B, and C. Improvement of the $SD_H$ over that of the bincho-charcoal plate was achieved by use of three different compound plates, over the broadband frequency. The results for the compound plates can be summarized as:

(1) The values of RF magnetic and electric shielding degrees, $SD_H$ and $SD_E$, for all sample remained constant when changing the magnetic and electric output power, $P_H$ and $P_E$, in the region between 5 dBm and 30 dBm, such as shown in Fig. 5.

(2) The values of RF electric shielding degree $SD_E$ for those plates exhibit no remarkable effects, such as shown in Fig. 6.

(3) The values of $SD_H$ of the sample C for constructing the sandwich structure with a ferrite plate between two bincho-charcoal plates, for example, remain fairly constant at approximately 50 dB in the frequency region from 1 MHz to 1 GHz, such as shown in Fig. 7.

(4) The characteristics of $SD_H$ for three different compound plates are different each characteristic, in the frequency region from 10 MHz to 1 GHz, such as shown in Fig. 7.

(5) The values of $SD_H$ increase as the values of frequency $f$ increase, in the frequency region from 1 GHz to 3 GHz, such as shown in Fig. 7. That is, the characteristics of $SD_H$ for three different compound plates are the same form as that of the double bincho-charcoal plate, over this frequency region.

These results represent important criteria fundamental in the design of a highly effective RF shielding room in the broadband frequency having high reliability. The present authors are now investigating the physical meaning why the characteristics of $SD_H$ for three different compound plates are different each characteristic, in the frequency region from 10 MHz to 1 GHz.

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(Received July 12, 2006;Accepted September 15, 2006)