CORROSION SCIENCE AND TECHNOLOGY, Vol.9, No.4(2010), pp.153~158

Development of Heat Absorbing and High Electromagnetic Shielding Pre-Painted Steel Sheet

Tomoaki Hosokawa†, Kohei Ueda, Kensei Yuasa, and Makoto Nakazawa

Steel Research Laboratories Technical Development Bureau, Nippon Steel Corporation, 20-1 Shintomi, Futtsu City, Chiba Pref., 299-8511 Japan
(Received July 24, 2009; Revised August 3 2010; Accepted August 6, 2010)

Electrical appliances such as audiovisual equipment and personal computers have recently had heat and electromagnetic problems. In order to solve those problems, 'High heat absorbing pre-painted steel sheet (hereinafter referred to as PSS)', 'High electromagnetic shielding PSS' and 'High heat absorbing and high electromagnetic shielding PSS' have been developed. In this paper, the heat characteristics and electromagnetic shielding properties of PSS are investigated by methods that use enclosures and their mechanisms are discussed. It was found that 'High heat absorbing PSS' and 'High heat absorbing and high electromagnetic shielding PSS'could reduce the heat problem. The mechanism of the heat characteristics was presumed for the high heat absorptivity of the back coating inside the enclosure. And it was also found that 'High electromagnetic shielding PSS' and 'High heat absorbing and high electromagnetic shielding PSS' could shield electromagnetic waves well. The mechanism of the electromagnetic shielding properties was considered for the low transfer impedance of the back coating inside the enclosure.
'High heat absorbing PSS' and 'High electromagnetic shielding PSS' have been adopted as materials for electrical appliances and 'High electromagnetic shielding and high heat absorbing PSS' have been tested for that purpose.

Keywords *: pre-painted, electrical appliances, heat absorbing, heat emission, electromagnetic shielding, transfer impedance*

1. Introduction

PSS has mainly been used in appliances and for construction because reduced environmental impact through a decrease in VOC (Volatile Organic Compounds) and increased productivity are achieved by using PPS.[1)] In the case of electrical appliances such as audiovisual equipment and personal computers, PSS has been used widely. With digitalization and the development of technical advantages, a lot of ICs and LSIs have been installed in electrical appliances, and increases of heat and electromagnetic waves from those appliances have become a problem. Rising temperatures inside appliance cases have resulted in improper operating signals and decreased product life. To solve those problems, techniques such as using fans to expel exhaust heat and installing heat sinks have been developed. Electromagnetic wave leaks have also affected the operation of other equipment. To control the emission of electromagnetic waves, an upper limit of electric intensity from 30 to 1000 MHz has been established by International Standard CISPR 22. A joint structure comprising an electromagnetic wave absorption material and an electromagnetic shielding material has been developed. Technical development of the materials used to make cases has also been required.

In order to solve the above-mentioned problems, 'High heat absorbing PSS', 'High electromagnetic shielding PSS' and 'High heat absorbing and high electromagnetic shielding PSS' have been developed. The section compositions of paint film are shown in Fig. 1. In this paper, the heat characteristics and electromagnetic shielding properties of PSS are investigated and their mechanisms are discussed.

High heat absorbing High electromagnetic shielding High heat absorbing and high electromagnetic shielding pre-painted steel sheet pre-painted steel sheet pre-painted steel sheet

† Corresponding author: hosokawa.tomoaki@nsc.co.jp

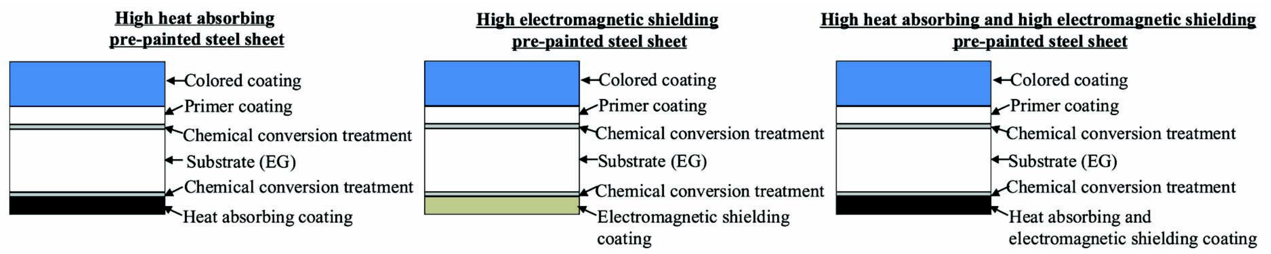


Fig. 1. Coating structure of newly developed types of PSS.

Table 1. Measurements pecimens

Name	Substrate	Front coating	Back coating	
EG	Electro-galvanized steel sheet	-(None)	-(None)	
PSS-1		Primer and colored top paint (Polyester/ Melamin type)	Electromagnetic shielding type	Developed product
PSS-2			Electromagnetic shielding and heat absorbing type	Developed product
PSS-3			Heat absorbing type	Developed product
PSS-4			Normal type (Not electromagnetic shielding and heat absorbing type)	Conventional product

*Substrate:0.5 mmt electro-galvanized steel sheet
*Front coating thickness: Primer 5 µm Top paint 15 µm

2. Experimental

2.1 Sample

Table 1 lists the sample specimens in this study. PSS-1, PSS-2, PSS-3 are the products that were developed, and PSS-4 is a conventional product. The different types of PSS vary in their back coating.

2.2 Test methods

2.2.1 Measurement of intensity of infrared emission energy

The infrared emission energy of each sample from 500-3000 cm^{-1} was measured by FT-IR as shown in Fig. 2. The sample was heated to 80 ℃ by a heater, and the back coating side was then measured. The intensity of emission energy was calculated inequation (1) using Planck's radiation formula.[2)]

$$E_{\lambda b} = \frac{C_1 \lambda^{-5}}{\exp(C_2/\lambda T)} \ [\mathrm{W}/m^3] \quad (1)$$

where $E_{\lambda b}$: Intensity of emission energy of ideal black body
λ: wavelength [m]
T: Absolute temperature [K]
C_1: 3.7402×10^{-16} [W · m^2]
C_2: 1.438481×10^{-2} [m · K]

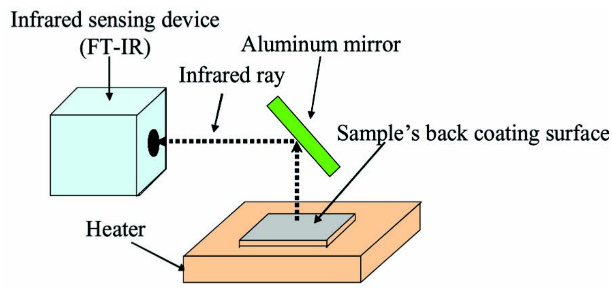


Fig. 2. Measurement of spectrum infrared emission.

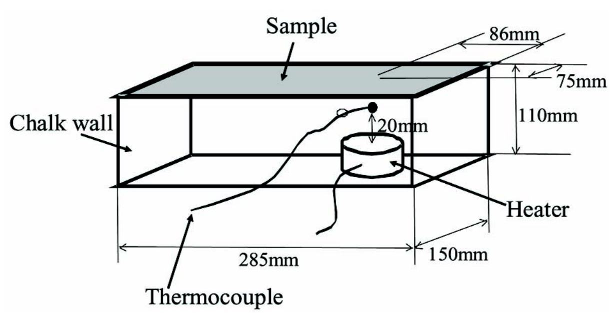


Fig. 3. Evaluation of heat characteristics of PSS.

2.2.2 Examination of heat characteristics

Using the evaluation equipment indicated in Fig. 3, the heat characteristics of each sample were investigated. The bottom and side of the box were made of chalk wall, and the upper surface was covered with the sample. The temperature inside the box was measured by a thermocouple.

2.2.3 Examination of electromagnetic shielding properties

Using the evaluation equipment illustrated in Fig. 4, the electromagnetic shielding properties were evaluated. A transmitting antenna was put inside a metal enclosure with a 135 mm×135 mm apertural area. The apertural area was covered with a sample. A gasket (RFSG(width 5 mm× height 4 mm) of SEIWA ELECTRIC MFG. CO. Ltd.) was set between the back coating side of the sample and the metal enclosure. The surface pressure was 5×10^{-3} MPa. The electromagnetic shielding properties between the sample and the gasket can be evaluated. The seam imitates the seam of an electrical appliance. Areceiving antenna was put outside the metalenclosure, and a network analyzer was used as the transmitting and receiving apparatus. Electric intensity in the frequency range of 30 to 1000 MHz was measured in an electric wave fully anechoic room as the CISPR 22 recommends.

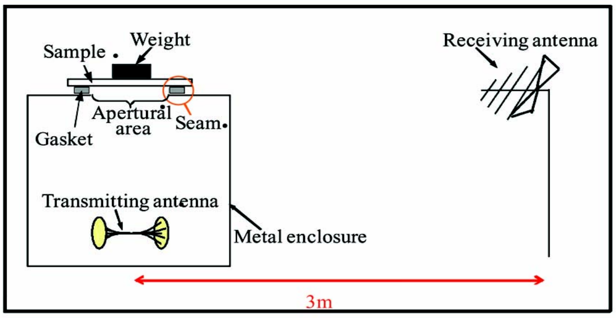


Fig. 4. Evaluation method of electromagnetic shielding properties.

Shielding effectiveness (hereinafter referred to as SE) was evaluated by equation (2).

$$SE\ (dB) = 20\log(\text{Electric intensity without sample} / \text{Electric intensity with sample}) \quad (2)$$

2.2.4 Measurement of transfer impedance Ztr

The measurement of transfer impedance (hereinafter referred to as Ztr) has been conducted to evaluate electromagnetic shielding properties.[3)4)5)] Fig. 5 shows the Ztr test fixture(ZTR39D of Mitsubishi Cable Industries, Ltd.)[3)] and the equivalent circuit schematic. An insulating plate, sample and conductor ring in the form of a hollow circle were set up at a sample surface pressure of 0.65 N/cm^2. The Ztr test fixture was connected to a spectrum analyzer (R3316A of Advantest Co.) with a coaxial cable. At the measurement site, the current flows on the sample's surface, and the Ztr was evaluated by equation (3). The Ztr is supposed to be much smaller than Z_0.

$$Ztr(\Omega) = 2Z_0(V_2/V_1) \quad (3)$$

3. Results and discussion

3.1 Heat characteristics

Fig. 6 shows the intensity of the infrared emission energy of EG, PSS-2 and PSS-3. The intensity of the infrared emission energy for both PSS-2 and PSS-3 is much higher than that of EG.

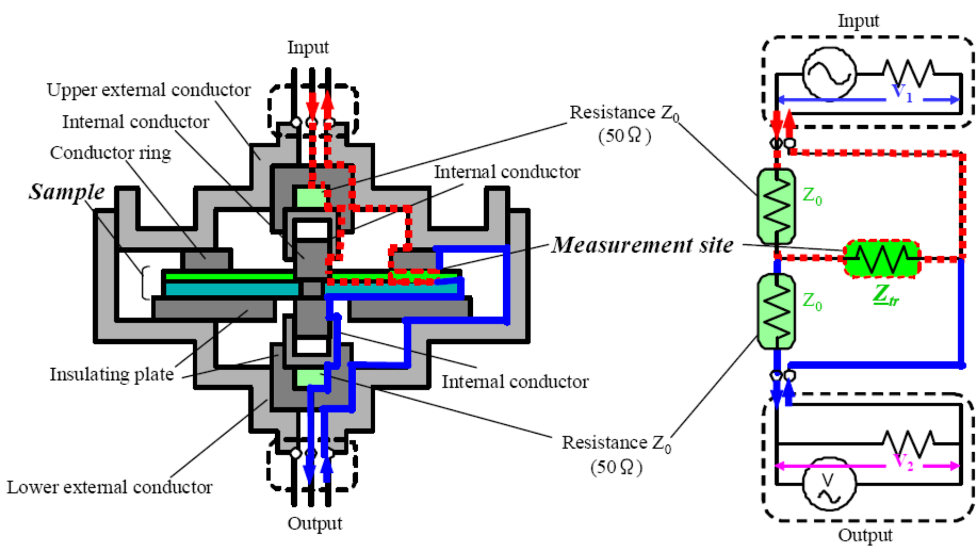


Fig. 5. Transfer impedance test fixture and equivalent circuit schematic.

The transfer of heat by radiation is only one of numerous electromagnetic phenomena. When radiation impinges on a body, it is partially absorbed, partially reflected, and partially transmitted. The relation between the absorbed, reflected, and transmitted energy is

$$\alpha + \rho + \tau = 1 \tag{4}$$

where α = absorptivity, i.e., the fraction of the incident radiation absorbed by the body ;
ρ = reflectivity, i.e., the fraction of the incident radiation reflected from the surface of the body
τ = transmissivity, i.e., the fraction of the incident radiation transmitted through the body

The majority of solid materials encountered in practice absorb practically all of the radiation in a very thin layer. Bodies that do not transmit radiation are called opaque, and for these equation (4) is reduced to

$$\alpha + \rho = 1 \tag{5}$$

Kirchhoff's law[2] states that the ratio of the emissive power of a surface to its absorptivity is the same for all bodies at thermal equilibrium. That is, a body that radiates a lot of heat absorbs a lot of heat.

The data in Fig. 6 indicates that PSS-2 and PSS-3 have high heat absorptivity.

The effect of the high heat absorptivity of PSS-2 and PSS-3 is given in Fig. 7. PSS-2 and PSS-3 were set up so that the back coating of the sample becomes the interior surface. In 120 minutes, the temperatures inside the boxes made of PSS-2 and PSS-3 were about 10 ℃ lower than that of the box made of EG.

It was found that PSS-2 and PSS-3, which were developed as a case material to solve the heat problem, can decrease the temperature inside the box effectively.

In addition, the result of investigating the influence of the coating position is shown in Fig. 8. Using EG, EG painted high heat absorbing coating on exterior surface, and EG painted high heat absorbing coating on interior surface, as shown in Fig. 9, the temperature inside the box was measured after 120 minutes The temperatures inside the boxes of EG and EG painted high heat absorbing coating on exterior surface are high and almost the same. The temperature inside the box of EG painted high heat absorbing coating on the interior surface is much lower than that of EG and EG painted high heat absorbing coating on the exterior surface. As suggested by those results, it is considered that the influence of heat absorption is larger than that of heat emission. The characteristic of decreasing the temperatures inside the boxes made of PSS-2 and PSS-3 is attributed to the high heat absorptivity of the back coating on the interior surface of the box.

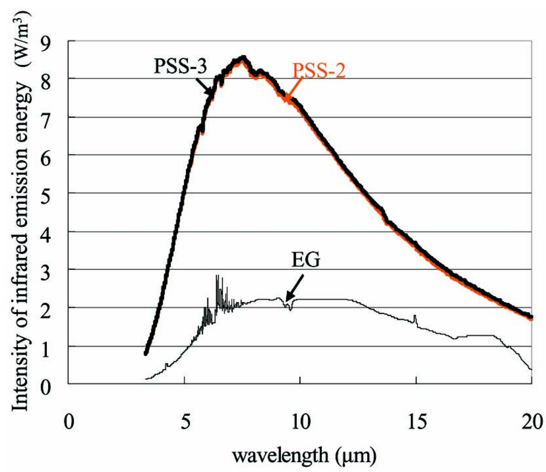


Fig. 6. Measuring results of intensity of infrared emission.

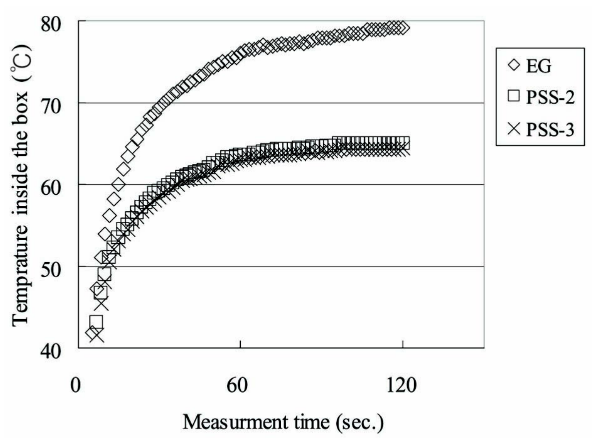


Fig. 7. Measurement results between measurement time and temperature inside.
*The amount of heat: 10 W

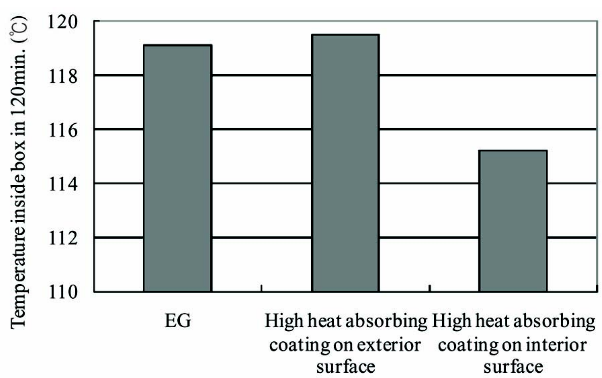


Fig. 8. Influence of coating position.
*Heater temperature: 230 ℃

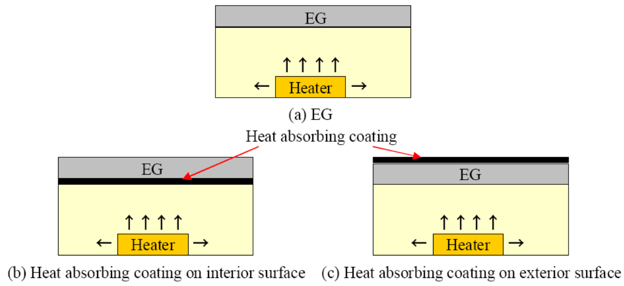


Fig. 9. Schematic images of influence of coating position.

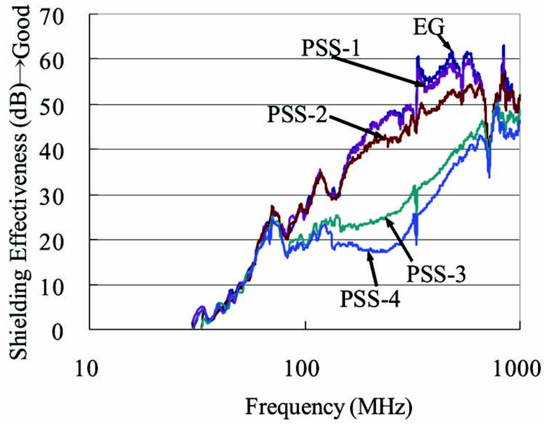


Fig. 10. Measurement results of shielding effectiveness.

3.2 Electromagnetic properties

The curves shown in Fig. 10 are the measurement results of shielding effectiveness. The SE of unpainted EG is the highest. The SE of PSS-1 coated with electromagnetic shielding, in second place, is also high. The SE of PSS-2, which has heat absorbing and electromagnetic shielding coating, is also high. The SEs of PSS-3, which has heat absorbing coating, and of PSS-4, which has normal coating, are low. The shielding effectiveness of the developed product PSS-1 is approximately 27 dB at 200 MHz and approximately 21 dB at 500 MHz, higher than that of the conventional product PSS-4. It was found that PSS-1, which was developed to solve the electromagnetic problem, and PSS-2, which was developed to solve both the heat and electromagnetic problems, could decrease electromagnetic wave leakage effectively.

The curves shown in Fig. 11 are the measured results of the Ztr. The Ztr is lowest in EG, followed by PSS-1, PSS-2. The Ztrs of PSS-3 and PSS-4 cannot be measured because they are too high.

The relationship between the Ztr^{-1} and shielding effectiveness is summarized in Fig. 12. As the Ztrs of PSS-3 and PSS-4 are too high, Ztr^{-1} of PSS-3 and PSS-4 become approximately 0. As shown in Fig. 12, the lower the Ztr, the higher the shielding effectiveness. It is thought that even if the electric intensity is not measured in an electric wave fully anechoic room, the electromagnetic shielding property of PSS is easily evaluated by measuring the Ztr in a laboratory.

The presumption mechanism of electromagnetic shielding is discussed herein. Figs. 13 and 14 illustrate the schematic images of the mechanism of electromagnetic wave leakage. The current is induced by electromagnetic waves. In the case of a high Ztr, most current is not able to cross seams and leaks outside, generating electromagnetic waves. In the case of a low Ztr, most current crosses seams and the amount of current leaking outside is reduced. Therefore, it is thought that the lower the Ztr, the higher the electromagnetic shielding property.

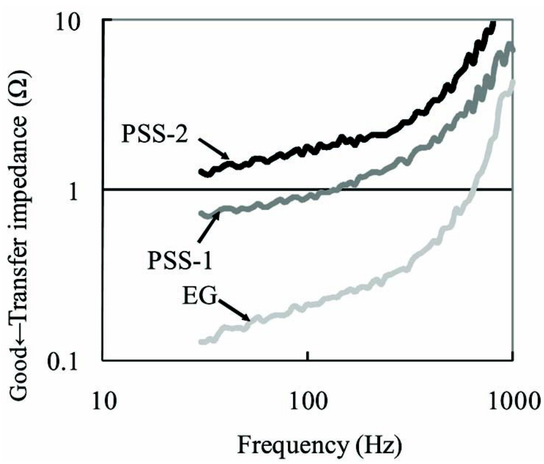


Fig. 11. Measurement results of transfer impedance.

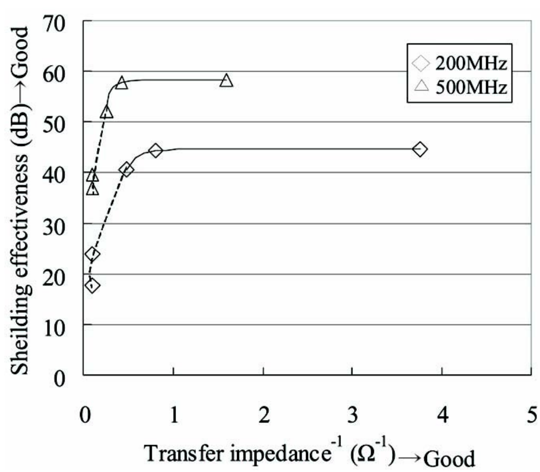


Fig. 12. Relationship between the reciprocal of transfer impedance and shielding effectiveness.

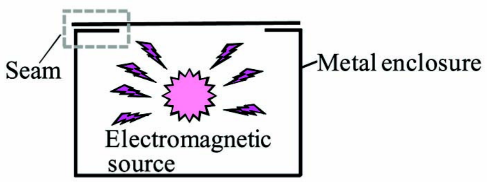
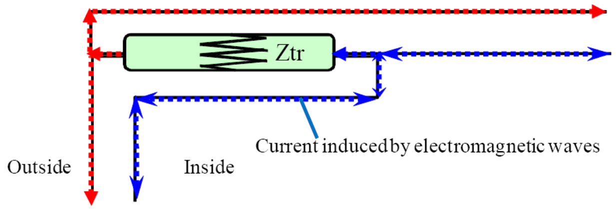
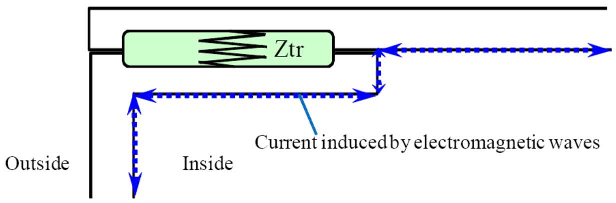


Fig. 13. Metal enclosure with electromagnetic source.



(a) In the case of high transfer impedance



(b) In the case of low transfer impedance

Fig. 14. Flow of current induced by electromagnetic wavez at seam.

4. Conclusions

The heat characteristics and electromagnetic shielding properties of PSS were investigated. It was found that 'High heat absorbing PSS'and 'High heat absorbing and high electromagnetic shielding PSS' could decrease the temperature inside a box efficiently. And it was also found that 'High electromagnetic shielding PSS' and 'High heat absorbing and high electromagnetic shielding PSS' could effectively decrease electromagnetic wave leakage. The mechanism of the heat characteristics was presumed for the high heat absorptivity of the back coating. The mechanism of the electromagnetic shielding property was considered for the low transfer impedance of the back coating. Furthermore it was considered even if the electric intensity was not measured in an electric wave fully anechoic room, the electromagnetic shielding properties of PSS were easily evaluated by measuring the Ztr in a laboratory.

'High heat absorbing PSS' has been adopted for the top panels of DVD players, TV tuner covers and so on. 'High electromagnetic shielding PSS' is currently being used for the back panels of plasma TVs and the top panels of DVD players. 'High electromagnetic shielding and high heat absorbing PSS' has been tested for those purposes.

References

1. K. Ueda, *J. Jpn. Soc. Color Material*, **72**, 525 (1999).
2. F. Kreith, *Principle of Heat Transfer, second ed.,* 204 (1965).
3. T. Kudo, *EMC*, **34**, 49 (1991).
4. A. N. Faught, *IEEE int. Symp. On EMC*, 38 (1982).
5. R. J. Mohr, *IEEE int. Symp. On EMC*, 81 (1987).