A Novel Microwave Absorber with Surface-Printed Conductive Line Patterns

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***Abstract* — A novel microwave absorber with surface-printed conductive line patterns is proposed. The advantage of this absorber is to be able to control the matching frequency both toward a higher frequency or a lower frequency region and to offer twin-peaks characteristic using a conventional single material. The matching characteristics are investigated particularly for making a slim absorber by FDTD analysis and experiments. A slim absorber of 2mm thickness at 2.45 GHz is presented by computer-aided design.**

I. INTRODUCTION

Simple methods of changing the matching characteristics of microwave absorber have been proposed only using a single material from the viewpoints of effective use of materials and the necessity of quickly responding to recent demands for various kinds of EM wave absorber [1], [2].

The magnetized ferrite absorber can change its matching frequency characteristics toward higher frequency regions by controlling both the strength of a magneto static field that is applied perpendicularly to the surface of a ferrite absorber and the ferrite thickness simultaneously [1]. As a more simple method, a rubber ferrite absorber with multi-holes can provide the method of changing broadly the matching frequency region toward a higher frequency region by adjusting hole size and adjacent hole space [2]. Generally, it has been considered to be very hard to produce a new EM wave absorber possessing the matching frequency characteristic that we desire. This is because the absorbing materials are manufactured through the complex process of controlling the manufacturing conditions such as mixing rate of materials, sintered temperature, pressure etc. Usually, these have been done by trial and error. Therefore, it has been demanded to establish a simple method of realizing the matching frequency characteristic that we want.

This paper proposes a new method of changing a matching frequency characteristic and making a slim absorber by printing periodically small conductive line patterns on the surface of absorbing materials using a single absorbing material. A square conductive patch with a checkered pattern has been proposed by attaching it to a dielectric absorbing material [3], [4].

In this paper, however, microwave absorbers with conductive thin line patterns printed periodically on the surface of magnetic absorbing material such as ferrite are newly proposed. The advantage of using conductive line patterns is to be able to make microwave absorbers with the characteristics capable of changing the matching frequency both toward a higher and a lower frequency region and giving the matching characteristic of twin-peaks. This new idea is based on the principle that conductive line patterns printed on the surface of absorbing material can be constructed to give the nature of capacitance or inductance for the absorbing material depending on wavelength.

This paper first illustrates a few models of absorber to introduce the matching characteristics changing them toward a higher or a lower frequency region and the characteristic of twin-peaks. Next, the detailed matching characteristics of microwave absorber printed with a periodical square frame is investigated for the case of normal incidence, particularly focusing on the method of realizing a slim EM wave absorber. To investigate present fundamental matching characteristics, FDTD analysis is introduced. It is clarified that matching frequency characteristic is shifted toward a lower frequency region as size or width of the square is increased and as the adjacent space between square frames is decreased when the other parameters are kept as constants. A slim absorber with a thickness of 2.0mm is obtained at the frequency of 2.45GHz, using a carbonyl iron absorber.

II. FUNDAMENTAL CONSTRUCTION AND ANALYSIS

Fig. 1 shows the fundamental construction of microwave absorber printed with a thin conductive line on the surface of magnetic material. Fig.1 (a) and (b) show the patterns printed with a thin line lattice and cross patterns respectively. Fig 1(c) and (d) show microwave absorbers printed with periodical square frames and the absorber with double layered periodical square frames respectively. The back of EM wave absorber is attached to a conductive plate. To determine these fundamental matching characteristics, FDTD analysis has been introduced. Each matching characteristic in Fig.1 is shown in Fig. 2. Fig. 2 (a) and (b) show the matching characteristics in the cases of a thin conductive line lattice and cross line patterns, respectively. Fig. 2 (c) and (d) show the case of periodical squares and a double layered squares respectively. The matching characteristics shown in Fig. 2 (a) corresponding to Fig. 1 (a) shift toward higher frequency regions as the size of conductive lattice b is decreased. However, the matching characteristics in the case of Fig. 2 (b) and (c) shift toward lower frequency regions as the spaces between the adjacent conductive patterns are decreased.

If a plate with a double-layered line pattern of squares is attached to the surface of ferrite absorber, the matching characteristic becomes to exhibit a twin-peaks characteristic as shown in Fig. 2 (d).

For these theoretical analyses, a slab waveguide is introduced as an analytical model for calculating reflection coefficients as shown in Fig.3 [2].

Since the present absorber has a periodical structure, periodical boundaries are introduced and at the opposite side of ferrite absorber, a 16 layer PML absorbing boundary is set up.

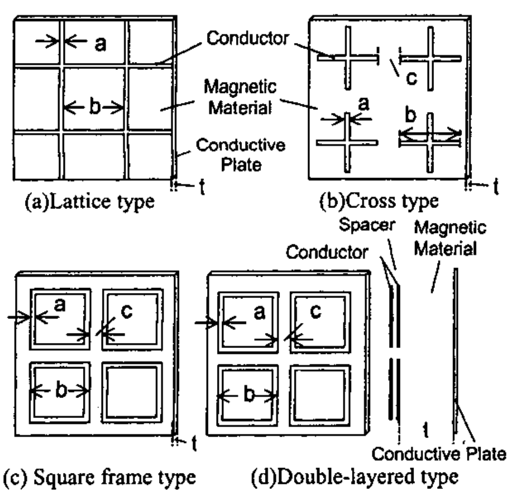

Fig. 1 Examples of EM wave absorber with the surface of conductive line patterns.

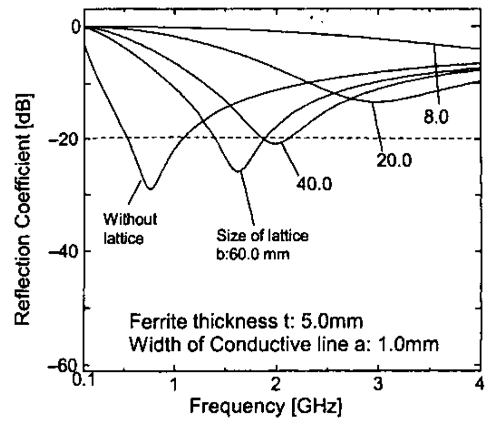

Fig.2 (a) Matching characteristics of lattice type.

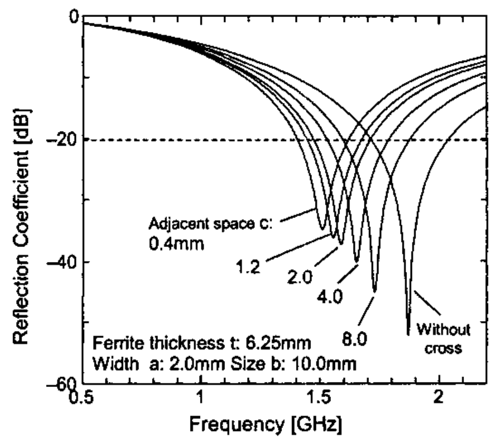

Fig.2 (b) Matching characteristics of cross type.

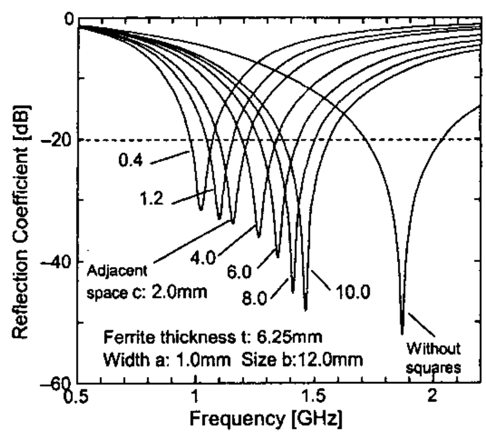

Fig.2(c) Matching characteristics of square frame type.

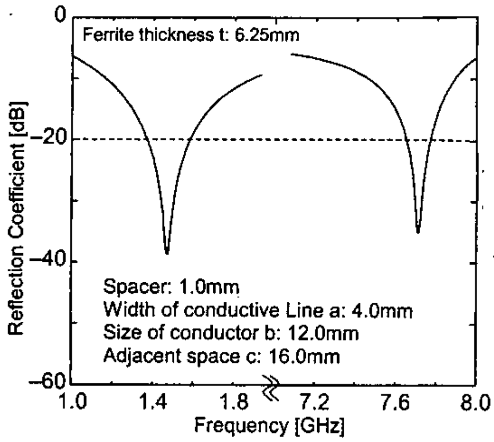

Fig.2 (d) Matching characteristics of double layered square type.

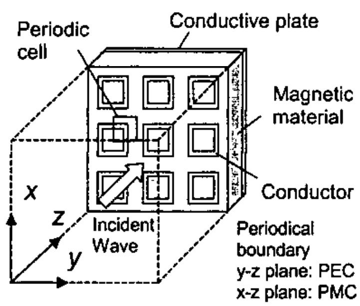

Fig.3 Model for Analysis

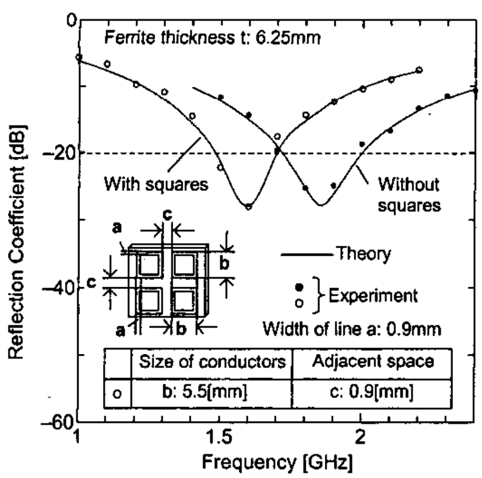

Fig.4 Comparison of theoretical values with measurement values.

Fig. 4 shows the comparison of theoretical values with experimental values in the case of periodical square patterns. Fig. 4 represents the validity of FDTD analysis.

This paper focuses on the investigation of the matching characteristics for an absorber with the square line patterns as shown in Fig. 1 (c), particularly for a normal incidence due to many parameters for the present.

III. INVESTIGATION OF MATCHING CHARACTERISTICS

Fig. 5 shows that the matching characteristics when the size of conductive square b is changed from 4 mm to 22mm, taking the other parameter such as frame width being a=1 mm, adjacent space being c=2mm, and absorber thickness of 6.25 mm as constants. In this case, a rubber ferrite is used as the absorbing material. Square conductivity is given a value of 3.5×10^7 S/m by assuming an aluminum foil. Original matching frequency in this ferrite is around 1.8 GHz. From Fig. 5, it is found that the matching frequency characteristic tends to move toward a lower frequency.

Fig. 6 shows the case where the frame width a is taken as a parameter, keeping other parameters constant as shown in the figure. It becomes clear that the matching frequency characteristic is shifted toward a lower frequency as the width is increased. Adjacent space as parameter, keeping the other parameters as constants, has already been shown in Fig 2 (c).

Next, the conductivity of square frames is examined. A good matching characteristic is kept when conductivity takes the value more than 10^4 S/m.

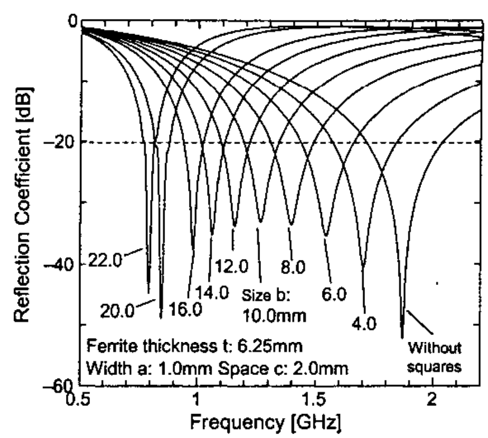

Fig. 5 Matching characteristics of EM wave absorber with conductive square frames.

From further detailed investigations, it is concluded that a slim magnetic absorber is obtained when the real and imaginary value of permeability and the real part of relative dielectric constant take large values simultaneously.

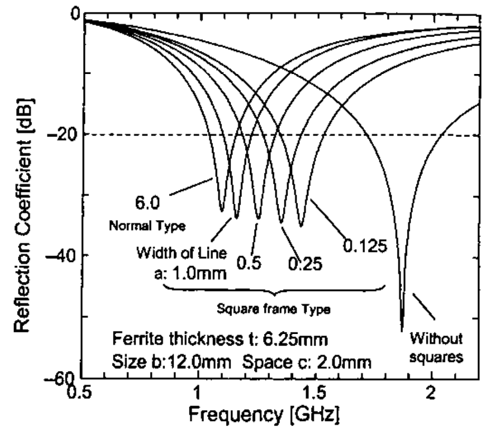

Fig. 6 Matching characteristics of EM wave absorber with conductive square frames.

IV. SLIM EM WAVE ABSORBER

On the bases of these investigations mentioned herein, a slim EM wave absorber is designed so as to be able to take matching characteristic at the frequency of 2.45 GHz or ISM band as shown in Fig.7. A carbonyl iron is selected as the absorbing material which satisfies the above condition. This carbonyl iron has an original matching frequency around 3.8GHz.and the thickness of 2 mm. This matching thickness is one third the thickness of a conventional rubber ferrite being used in the present frequency region.

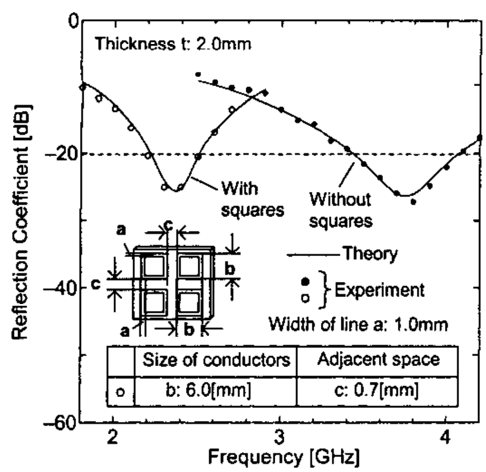

Fig. 7 Matching characteristic of slim EM wave absorber.

V. CONCLUSION

A new method of changing matching frequency characteristic both toward a lower or a higher frequency region and obtaining the matching characteristic of twin-peaks was proposed by simply printing the conductive line patterns on the surface of absorbing material, using a conventional single material. The matching characteristics of microwave absorber depending on the constituent such as material constants and the shape of the conductive line patterns were investigated in detail. The slim magnetic absorber with the thickness of 2 mm at the frequency of 2.45 GHz is obtained by printing square conductive line patterns on the surface of carbonyl iron.

The concept presented here is also available for millimeter frequency regions.

REFERENCES

[1] Y. Kotsuka, H. Yamazaki, "Fundamental Investigation on a Weakly Magnetized Ferrite Absorber, *Trans. on IEEE*, vol. 42, no. 2, May 2000.

[2] Y. Kotsuka, M. Amano, "A method of effective use of ferrite for microwave absorber" *2001 IEEE MTT-S Int. Microwave Symp. Dig*, pp.1187-1190, Phoenix, USA, May 2001.

[3] T. Ojima, "Reflectivity Calculation of a Periodical-Patch-Loaded Absorber by the FD-TD Method, " *1999 IEEE Int'l Symp.* on EMC, Seattle, WA, pp.340-344, August 1999.

[4] T. Ojima, "Numerical Experiments of a Periodical-Patch-Loaded Absorber by FDTD Computation, " *2000 IEEE Int'l Symp.* on EMC, Vol.2, pp.785-788, 2000.