Broadband EM-Wave Absorber Based on Integrated Circuit Concept

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***Abstract* — A broadband EM-Wave absorber based on the structural concept of microwave integrated circuit is proposed. Following the fundamental principle and construction, the method of converting the actual microwave circuit into the integrated circuit type absorber is clarified. The problem of fine control of the resistance on the circuit is resolved by changing the configuration of a unit circuit element in a cross shape. Broadband matching characteristics with an absorption band 1.9 times as broad as a conventional Salisbury screen absorber with resistance and capacitance, and 2.6 times as a typical Salisbury absorber are obtained. The thickness of the present absorber is further reduced by introducing a ferrite material, while keeping almost the same broadband matching frequency.**

I. Introduction

Many types of EM-wave absorber with conductive patterns on the surface of them have been proposed. These are largely divided into two types. One is the absorber mounted conductive patterns on the surface of lossy materials such as magnetic or dielectric material with loss [1][2]. The other is the absorber mounted conductive patterns on the surface of loss less or low loss material [3].

Regarding the former case, we have proposed a microwave absorber with conductive line patterns on the surface of rubber ferrite [9]. This absorber has a special feature that the matching frequency characteristic is easily changed toward a low frequency region by controlling the size of conductive line patterns without changing the material constants and the absorber's thickness. As the result, a new thinner absorber than the original one can be constructed. However, the matching frequency band of this absorber has been relatively narrow.

As the latter example, the two-sheet Jaumman absorber has been proposed [3]. This absorber is composed of two-sheet Jaumman absorber mounted homogeneous resistive patterns with resistance and capacitance on the surfaces of two-sheet with common spacing by air gaps. The broadband matching characteristics are obtained in this construction.

In this paper, the single sheet broad band EM-wave absorber with whole circuit elements of resistance, capacitance, and inductance, which covers microwave and millimeter wave region, is proposed from microwave integrated circuit viewpoint. These three circuit elements are needed to finely control resonant condition in the microwave circuit, that is, to obtain an optimum broad band matching condition. After introducing how to construct the present absorber, the problem of finely controlling the resistance on the circuit is clarified for a normal incident case together with the detailed matching characteristics. By taking the size and the resistivity on the circuit constant as parameters, the matching characteristics are investigated with the aid of FDTD analysis [4]-[6].

II. Fundamental Principle and Construction

To realize a broadband EM-wave absorber based on the structural concept of microwave integrated circuit, the methods of arranging three circuit constants or resistance, capacitance, and inductance have been investigated.

In this construction, the variable function of the circuit constants is also important factor of the present absorber. Fig.1 (a) shows the equivalent circuit of transmission line to the simplest EM-wave absorber with space, d and a conductive plate at the back of the absorber. To make this circuit come true on a substrate backed with a conductive plate, the method of arranging a unit circuit element which consists of different conductive sections is introduced as shown in Fig.1 (b). That is, a unit circuit element is composed of a high and a low conductive part to give resistance and inductance as shown in Fig.1 (a).

The resistance and the inductance can be changed by adjusting each area of a high and a low conductive part or their occupied areas. Capacitance is given by changing the adjacent space between the tips of the unit circuit elements in a cross shape. When the large capacitance is needed, the adjacent space between the tips of the unit circuit elements becomes too narrow. To avoid this inconvenience, a unit circuit element with a high conductivity at the tip of it is used as shown in Fig.2 (a). By introducing these structures just mentioned, the variable factors for each circuit constant can be provided.

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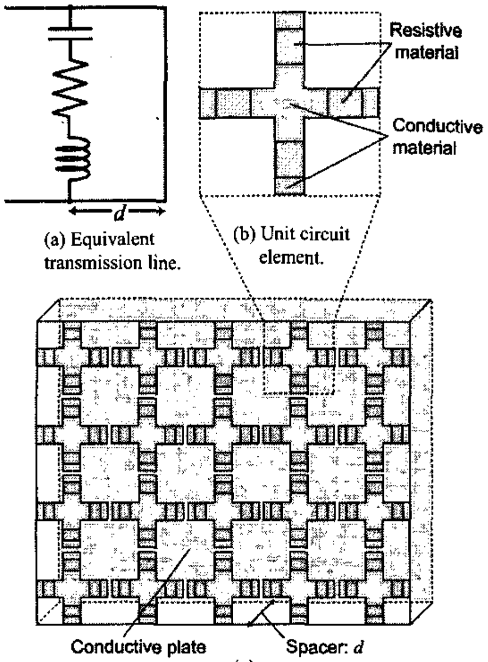
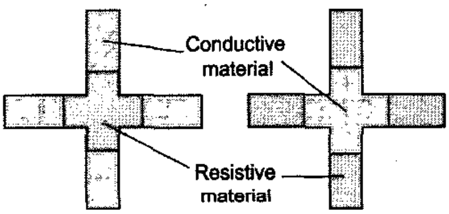


(a) Equivalent transmission line. (b) Unit circuit element. (c)

Fig.1 Configuration of the present EM-Wave absorber.

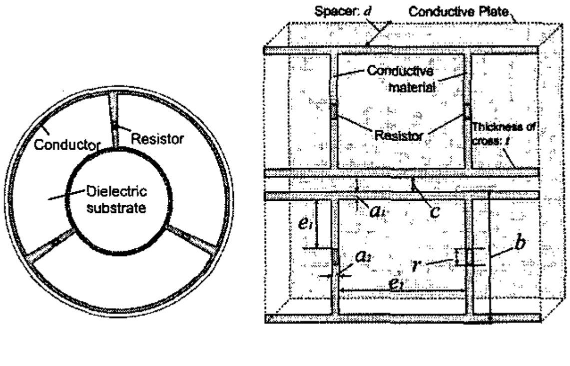


(a) (b)

Fig.2 Various unit circuit elements.

III. Approach to Design IC Type Absorber

To check the absorbing characteristic or the matching characteristic of the present absorber based on microwave integrated circuit concept, the fundamental experiments have been conducted. Fig.3 shows the actual circuit of the absorber being composed of parallel stripe lines which is connected by microchip resistors on the surface of a substrate with spacing backed with a conductive plate. A 39D coaxial waveguide (An outer and an inner diameter is 38.8 mm, 16.9 mm, respectively) which is capable of applying the idea of image method to simply reproduce the periodical circuit elements in the cross shape is used for the measurement of reflection coefficient. The reflection coefficient was measured by mounting this circular circuit



(a) (b)

Fig.3 Model for experiment.

TABLE I
Size of unit circuit element used for experiment.

a_1	0.7 mm	b	9.7 mm	e_1	3.4 mm	r	1.3 mm	d	23.5 mm
a_2	1.2 mm	c	1.2 mm	e_2	27.9 mm	t	1.6 mm	R	89 Ω

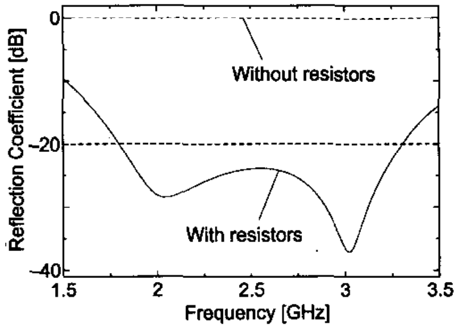


Fig.4 Experimental matching characteristics.

at the terminal end of a coaxial waveguide and by attaching it to a shorting plate. This circular circuit in Fig.3 (a) can be converted into Fig.3 (b) based on the conformal mapping principle.

Fig.4 shows an example of the reflection coefficient in the case of Fig.3 (a). A solid line represent the matching characteristic of the present case, the resistance value of 89 ohm and other parameters are shown in Table I. When the microchip resistors do not exist, that is, the circuit is composed of only high conductive strip lines, the matching can not be obtained as shown in Fig.4 with a dotted line. The tendency of this broadband matching characteristic agrees with the theoretical result of FDTD analysis.

To find general design data, computer aided design is introduced using FDTD analysis due to many parameters. The validity of FDTD program developed by us has been often checked by experimental data [8][9].

IV. Methods of Controlling the Resitive Value

The present construction, however, has a problem that it is difficult to reproduce the finely controlled value of the resistive part which we found by optimization by computer aided design. To resolve this problem, introduced are the methods of controlling each size of the unit circuit element, that is, a total length of the cross element, *b*, width, *a*, the length of a high conductive part, *e*, the length of resistive part, *r* and the capacitance or a degree of strength of electric field coupling between the tips of the unit circuit element.

Fig.5 shows the matching characteristics when the resistivity value of the resistive section on the unit circuit element are taken as parameters, keeping other parameters as constants. This corresponds to the structure in Fig.2 (a) which is similar t the type of Fig.3. Other constants are shown in Table II. In the present study, every parameter including the resistivity is normalized by the wavelength. It is found that the broad band matching characteristic or optimized matching characteristic is obtained when the resistivity of the resistive section 2.144. However, as mentioned above, it is difficult to reproduce the rigorous value of the resistivity. Therefore, the better way to obtain a broadband matching characteristic is to control other parameters related not to material constants but to the size of the unit circuit element. Fig.7 shows the case of the matching characteristics when the length of a high conductive section, *e* is taken as a parameter, keeping the resistivity of resistive part and other parameters as constants. Only by controlling the length of the tip of a high conductive section, *e*, even if the resistivity of the resistive part and the other parameters are taken as constants, the broadband matching characteristics are obtained. The broadband matching characteristic is taken from 3.4 GHz to 6.9 GHz with the total thickness of 13 mm at the central frequency 5.2 GHz for example.

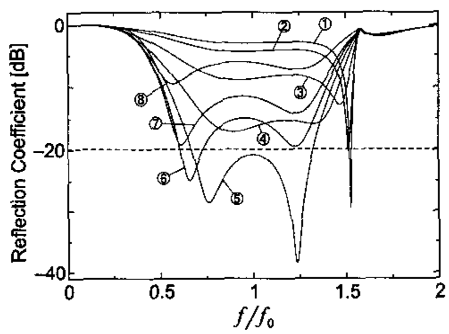


Fig.5 Matching characteristics taking the value of resistivity, ρ as a parameter.

TABLE II

Normalized size of construction and resistivity for FDTD analysis.

	Fig.5 ρ: Parameter	Fig.7 e, b: Parameter		Fig.8 a, b: Parameter	
	ρ	e	b	a	b
①	15.011	0.045	0.270	0.060	0.510
②	10.007	0.105	0.390	0.090	0.540
③	5.004	0.165	0.510	0.120	0.570
④	3.002	0.195	0.570	0.150	0.600
⑤	2.144	0.210	0.600	0.180	0.630
⑥	1.668	0.240	0.660	0.210	0.660
⑦	1.365	0.270	0.721	0.240	0.690
⑧	0.751	0.330	0.841	0.300	0.751
a	0.120	0.120		Parameter	
b	0.570	Parameter		Parameter	
c	0.060	0.060		0.060	
e	0.195	Parameter		0.195	
r	0.030	0.030		0.030	
t	0.015	0.015		0.015	
d	0.225	0.225		0.225	
ρ	Parameter	2.144		2.144	

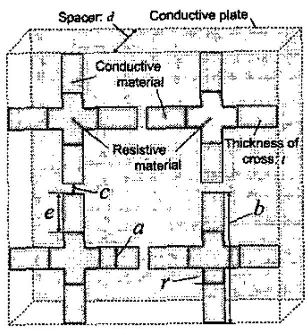


Fig6. Construction of EM-wave absorber model for analysis.

At the frequency 60 GHz, the whole size, *b* and the width, *a* of the unit circuit element for example is 2.85mm, and 0.6 mm, respectively. Production of these fine unit circuit elements becomes possible by applying the integrated circuit technology to the present absorber. That is because we call this kind of EM-wave absorber integrated circuit type.

In the same way, Fig.8 represents the matching characteristics when the width, *a*, of the cross element is taken as parameters, keeping others as constants. Further, it was clarified that the other types of the unit circuit elements as shown in Fig.1 (b) and Fig.2 (b) exhibit almost the same broad band matching characteristics by controlling the size of each section of the unit circuit elements and the resistivity. Further, thinner absorbers can be obtained by introducing a ferrite material as a part of the spacer, while keeping the broadband matching characteristic. As is clarified from these investigations, the present construction based on the structural concept of microwave integrated circuit enables to make a new EM-Wave absorber with a broad band matching characteristics as shown in Table III [10].

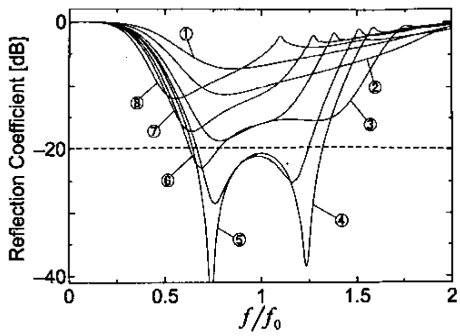


Fig7. Matching characteristics taking the size of conductor, e as a parameter.

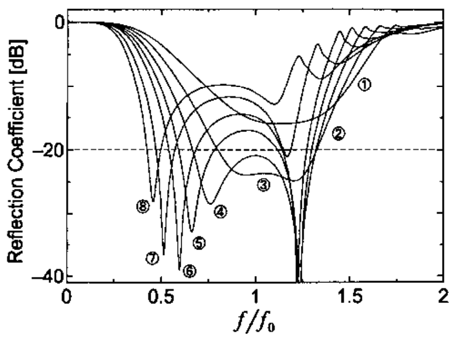


Fig.8 Matching characteristics taking the size of line width, a as a parameter.

TABLE III
Comparison of present EM-Wave absorber with previous ones.

Absorber Type	-20dB fractional Bandwidth %	d
Salisbury screen	25.3	0.250
Salisbury screen with series RC	34.7	0.188
Present absorber with series RCL	65.8	0.240

V. Conclusion

A broad band EM-Wave absorber based on the structural concept of microwave integrated circuit was proposed. After describing the fundamental principle and construction, an actual circuit of the absorber being composed of parallel strip line which is connected by microchip resistances on the substrate with spacing and a conductive plate was demonstrated to investigate the possibility of constructing an EM-Wave absorber.

As the next step, the method of representing this circuit as a kind of microwave integrated circuit are examined. Finally, this circuit was presented using the unit circuit elements with whole circuit constants of resistance, inductance and capacitance, which is periodically distributed on the substrates.

The problem of fine control of the resistive section on the unit circuit element is resolved by the idea of controlling whole size and each section of the cross element without changing the resistivity of the resistive section. Broadband matching characteristics with an absorption band 1.9 times as broad as a conventional Salisbury screen absorber with resistance and capacitance, and 2.6 times as typical Salisbury absorber are obtained. Since all data calculated in this paper are normalized by a wavelength, these characteristics can be easily extended to millimeter frequency region by applying the integrated circuit technology. Oblique incident characteristic would be a matter for future walk.

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