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THE NEW METHODS OF SYNTHESIS AND MEASUREMENT OF THE MICROWAVE ABSORBER

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(I) New Methods of the Synthesis of the Microwave Absorber

For some years, several synthesis methods of the absorber have been reported, and the absorbers which have better characteristics of reflection than those constructed by the way of cut-and-try method have come into market. In these methods of the synthesis, however, frequency characteristics of VSWR cannot be given beforehand except for only a few cases.

The authors developed the new theoretical methods of synthesis of the multi-layer absorber for microwaves using lossy dielectric slabs. The advantages of these new methods are following: (1) it is possible to predetermine the frequency characteristics of VSWR, and (2) the material of which relative permittivity ε_r is not unity can be used for the absorbing material.

These methods consist of starting with a quarter-wave impedance transformer which is synthesized in the way of the exact design method and then replacing each element of the impedance transformer by a lossy dielectric counterpart(Fig.1). The replacement cannot be done directly because loss is included in each layer of the absorber, however, the approximation is introduced for each method. That is,

$$\text{method A}^{(1)}: \quad W_i = \xi_i , \qquad (1)$$

or

$$\text{method B}^{(2)}: \quad \Gamma_{I(i)} = |\Gamma_{II(i)}| , \qquad (2)$$

where W_i is the characteristic impedance of the (i)th section of the impedance transformer, ξ_i is the real part of the characteristic impedance $z_i = \xi_i + j\eta_i$ of the (i)th layer, $\Gamma_{I(i)}$ is the reflection coefficient between the (i)th and the (i+1)th sections of the transformer and $\Gamma_{II(i)}$ is the reflection coefficient between (i)th and (i+1)th layers of the absorber. Because ξ_i or $\Gamma_{I(i)}$ is a function of ε_{ri} and loss tangent $\tan\delta_i$ of the (i)th layer, the equation between relative permittivity and loss tangent is obtained from Eq. (1) or (2). Loss tangent is given beforehand as shown in Fig.2 in order that the same frequency characteristics of VSWR as those of impedance transformer may be obtained. On the one hand the method A or B has the two advantages mentioned above, on the other there is a drawback that the total thickness of the absorber is not so thin as other's because loss in each layer is not considered thoroughly. For this reason we improved method A furthermore. When loss in each layer is considered thoroughly, following equations are obtained from Eq.(2):

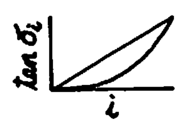

Fig.2- Loss tangent

$$|\Gamma_{II(i)}| = \Gamma_{I(i)} \cdot \varepsilon^{2\alpha_i y_i} , \qquad (3)$$

$$|\Gamma_{II(i)}| = \left\{ \frac{1 - \Gamma_{I(i-1)}}{1 - |\Gamma_{II(i-1)}|} \right\}^2 \cdot \Gamma_{I(i)} \cdot \varepsilon^{2\alpha_i y_i} , \qquad (4)$$

$$|\Gamma_{II(i)}| = \left[\prod_{k=1}^{i-1} \left\{ \frac{1 - \Gamma_{I(k)}}{1 - |\Gamma_{II(k)}|} \right\} \right]^2 \cdot \Gamma_{I(i)} \cdot \varepsilon^{2\sum_{k=1}^{i}(\alpha_k y_k)} \qquad (5)$$

where y_i is the thickness and α_i is the attenuation constant of the (i)th layer of the absorber. We synthesized

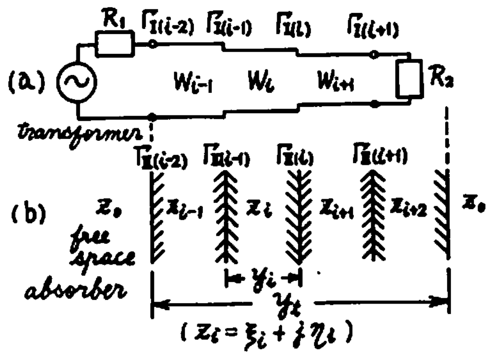

Fig.1- Analogous quarter-wave impedance transformer expression of the multi-layer absorber.

absorbers by methods A and B, and obtained the frequency characteristics of VSWR by numerical calculations. It became obvious that the frequency characteristics of VSWR of the absorbers synthesized by methods A and B are in good agreement with given characteristics of VSWR(Fig.3).

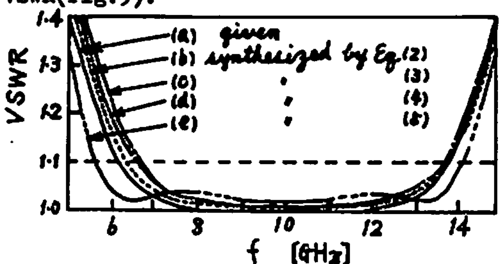

Fig.3- Frequency characteristics of VSWR of the 7 layers absorber.

(II) A New Measurement Method of the Reflection Coefficient

A new measurement method of the reflection coefficient of the microwave absorber when the plane wave is normally incident in free space is developed. In this method the sample is set in front of the horn antenna matched to free space sufficiently, and VSWR in guide, S, is Measured(Fig.4). The re-

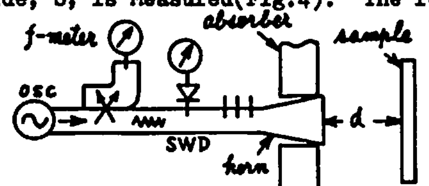

Fig.4- Measurement circuit.

flection coefficient $|\Gamma|$ is given by

$$|\Gamma| = \frac{8\pi d}{\lambda G}\left(\frac{S-1}{S+1}\right), \qquad (6)$$

where G is the gain of the antenna, d the distance between the antenna and the sample, λ the wave length. The minimum reflection coefficient that can be measured by our equipments is about 0.033 (VSWR=1.07). When the low gain antenna is used for the sample of small size, the distance d for which the reflection coefficient is accurately measured, is given by

$$\frac{\left\{jk\int_0^a \frac{d}{(\sqrt{d^2+\rho^2})^3}\cdot \varepsilon^{-j2k\sqrt{d^2+\rho^2}}\cdot\rho\cdot d\rho\right\}^2}{\frac{1}{4d^2}\cdot\varepsilon^{-j4kd}} = 1, \qquad (7)$$

where k is wave number. It is proved experimentally that the theoretical value of d is accurate as shown in Fig. 5, and that the distance d is D/λ for

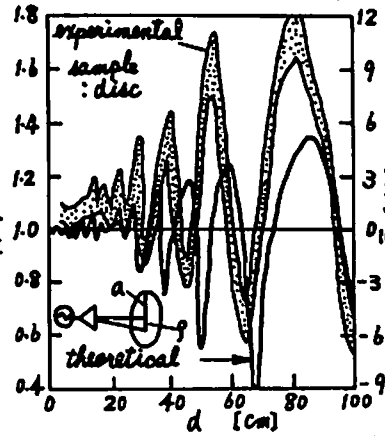

Fig.5- Theoretical and experimental values of the distance d.

the antenna of the gain of about 20 dB and the sample of which one side of the square is larger than 1.3D, where D is the maximum dimension of the aperture of the horn antenna. The measurement can be usefull for the sample of small size and the low gain antenna which could not be handled by the conventional methods. This experimental set-up is simple, and measurement is easy.

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