I-3 A BROADBAND ABSORBING WALL FOR VHF RANGE UTILIZING THIN FERRITE TILES

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Introduction

In this paper, the author has presented a new idea for the synthesis method of the thin absorbing wall with ferrite plates for U.H.F. range anechoic chamber.

It has been proved that the broadband absorbing wall made of dielectric material —such as foamed polystyrene containing carbon powder or parallel resistive sheets —has the limit in its thickness, that is, the thickness of such type wall does not become shorter than $0.7\lambda_0$, where λ_0 is the wavelength in the free space of the lowest frequency.

Then our research went a step further to make the wall thinner one utilizing magnetic material. There were many attempts to construct the wall using of magnetic material in such way equating $\dot{\mu}_r$ and $\dot{\epsilon}_r$, but they all failed, where $\dot{\mu}_r$ and $\dot{\epsilon}_r$ is relative permeability and relative permittivity respectively. The reason of the failure was due to the fact that $|\dot{\epsilon}_r|$ is greater than $|\dot{\mu}_r|$ in general, and furthermore, even if one gets the condition $\dot{\epsilon}_r = \dot{\mu}_r$, it meets only at a point frequency, not in broad range of frequencies.

Magnetic resistive sheet

It is very useful to take the way of thinking "duality" or "analogy" in order to find the new idea in our research life. In our work of the absorbing wall, the way of thinking "duality" was also taken, and it is crowned with success, that is, the new idea is based on the dual version of the well-known resistive sheet wall, which is constructed with a sheet of resistive plate backed with a metal plate separated a quarter wavelength $\left(\frac{\lambda_0}{4}\right)$ as shown in Fig. 1. In this case, the surface resistivity R_s is chosen to be equal to $120\pi = 377\Omega$, that is,

$$R_s = \frac{1}{gt} = 120\pi\ [\Omega] \tag{1}$$

where g is the conductivity of the material and t is the thickness of the sheet. However the frequency response of this type of wall is not good, because the back impedance of the resistive sheet naturally changes as frequency changes.

On the contrary, the new wall presented in this paper is the dual version of such "electric resistive" sheet wall, that is, it is constructed of "Magnetic resistive" sheet (actually made of ferrite tiles) backed with a conducting plate just behind the tiles. Therefore, the back impedance of the magnetic resistive sheet is always constant being zero. The dual relationship between the "electric" and "magnetic" resistive sheets is shown in table 1.

At a glance on this table, one can get the design formula for the absorbing wall utilizing magnetic resistive sheet. The new wall is made of magnetic material, whose "magnetic resistivity" r_μ is chosen to meet the dual relationship of equation (1), as follows.

$$R_s = r_\mu t = 120\pi = 377\ [\Omega] \tag{2}$$

The relation ship between magnetic resistivity r_μ and complex permeability $\dot{\mu}_r = \mu_r' - j\mu_r''$

In order to explain the meaning of r_μ the dual relation between $\dot{\epsilon}_r$ and $\dot{\mu}_r$ is again shown in table 2.

Table 2

electric	magnetic
$g + j\omega\varepsilon = j\omega\varepsilon_0(\varepsilon_r' - j\varepsilon_r'')$	$r_\mu + j\omega\mu = j\omega\mu_0(\mu_r' - j\mu_r'')$
$\equiv j\omega\varepsilon_0\dot{\varepsilon}_r$	$\equiv j\omega\mu_0\dot{\mu}_r$
or $\dot{\varepsilon}_r = \varepsilon_r\angle\theta_\varepsilon = \varepsilon_r' - j\varepsilon_r''$ *	or $\dot{\mu}_r = \mu_r\angle\theta_\mu = \mu_r' - j\mu_r''$ *
$\begin{cases}\varepsilon_r' = \varepsilon/\varepsilon_0 \\ \varepsilon_r'' = g/\omega\varepsilon_0\end{cases}$	$\begin{cases}\mu_r' = \mu/\mu_0 \\ \mu_r'' = r_\mu/\omega\mu_0\end{cases}$

*tan θ_ϵ and tan θ_μ are called loss tangent.

Therefore, in order to get the matching condition for the wall, the following dual relation may be necessary.

Table 3.
Dual matching condition

electric	magnetic
$g \gg \omega\varepsilon$	$r_\mu \gg \omega\mu$
$\therefore\ g = \omega\varepsilon_0\varepsilon_r'' = \frac{1}{R_s t}$	$\therefore\ r_\mu = \omega\mu_0\mu_r'' = \frac{R_s}{t}$
or $\varepsilon_r'' = \frac{1}{\omega\varepsilon_0}\frac{1}{R_s t}$	or $\mu_r'' = \frac{1}{\omega\mu_0}\frac{R_s}{t} = \frac{120\pi}{\omega\mu_0 t} \gg \mu_r'$ (3)

Now, $\sqrt{\frac{\omega\mu_0}{\omega\varepsilon_0}} = 120\pi$, $\omega\sqrt{\mu_0\varepsilon_0} = 2\pi/\lambda$,

and then $\mu_r'' = \frac{1}{2\pi}\frac{\lambda}{t} \gg \mu_r'$ (4)

Therefore, combining Eq. (3) with (4) one can get the following important formula.

$$\omega\mu_0 = 120\pi\frac{2\pi}{\lambda} \quad (5)$$

This formula is quite different from the old one in which the value of μ_r'' should be rather smaller than μ_r' . This is the new innovation of the magnetic absorbing wall.

Now the necessary condition for the magnetic material to make the absorbing wall is

$$\begin{cases} 1 \ll \mu_r'' \propto \lambda \propto 1/f \\ \mu_r'' \gg \mu_r' \end{cases} \quad \text{or} \quad \begin{cases} 1 \ll |\dot{\mu}_r| \propto \lambda \propto 1/f \\ \angle\theta_\mu \simeq 90° \end{cases}$$

Such frequency characteristics of the magnetic material will be found in the region above the point of the magnetic resonance frequency on some ferrite material. The typical frequency response is illustrated in Fig. 2.

In this figure, f_r is the frequency of magnetic resonance, and the region A corresponds to an old idea for magnetic absorbing wall, and the region B to the new idea in which $\mu_r'' \gg \mu_r'$, and μ_r'' decreases gradually as frequency increases. Therefore, if one finds a suitable ferrite material whose μ_r'' decreases inversely as frequency increases and $\mu_r'' \gg \mu_r'$, a very thin wall will be obtained, whose thickness $t = \frac{\lambda}{2\pi} \frac{1}{\mu_r''}$ is about $\frac{\lambda}{60} \sim \frac{\lambda}{100}$, assigning $\mu_r'' = 10 \sim 15$, and its working frequency range will be very wide.

Experiment

About many ferrite materials, their permeability $\dot{\mu}_r = \mu_r \angle \theta_\mu$ are measured. And some of the results are shown in Fig. 3. A ferrite named "D_1B" made by T.D.K.*, whose contents are N_i, Z_n, F_e, is suitable one. (*T.D.K. is abbreviated form for Tokyo Denki Kagaku L.T.D.)

This material is made into a flat toroidal shape or annular shape whose cross section is a rectangle and is inserted in a coaxial line and backed with a conducting plate just behind the plate. This wall of only 6mm thickness has shown good performance in that the VSWR is less than 1.2 in the wide frequency range from 400 to 1600 MC/s as shown in Fig. 4.

Now we attempt making the tiles to the hexangle shape in order to arrange them more closely together on the back metal plate. The result will be presented at the meeting.

Conclusion

A new idea for the synthesis method of the thin absorbing wall with ferrite tiles for the V.H.F. range anechoic chamber. The complex relative permeability of ferrite $\dot{\mu}_r = \mu_r' - j\mu_r''$ should be chosen so that $\mu_r' \ll \mu_r''$ and $\mu_r = \frac{\lambda}{2\pi} \frac{1}{t}$ where t is the thickness of the ferrite tiles.

The restriction $\mu_r' \ll \mu_r''$, and $\mu_r'' \propto 1/f$ seems to be contrary to the old idea, in which the value of μ_r' should be larger than μ_r''. This is the new innovation of this magnetic absorbing wall. The prototype of absorbing wall made of ferrite material (a kind of Z_n, C_u, F_e) with only 6mm thickness has shown good performance in which the reflection coefficient is less than -20dB in the wide frequency range from 400 to 1600 MC/s.

	Electric	Magnetic
Constants	$j\omega\mu_0$ $[\Omega/m]$ $g + j\omega\epsilon \rightarrow g$ $[\mho/m]$	$r_\mu + j\omega\mu \rightarrow r_\mu$ $[\Omega/m]$ $j\omega\epsilon$ $[\mho/m]$
Construction of the wall E or V —— H or I ----	$Z_b = \infty$ t $R_s = \frac{1}{gt} = 120\pi$ $[\Omega]$	$Z_b = 0$ t $R_s = r_\mu t = 120\pi$ $[\Omega]$

TABLE 1.

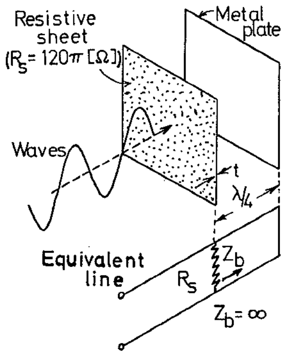

FIG. 1. ELECTRIC RESISTIVE SHEET WALL

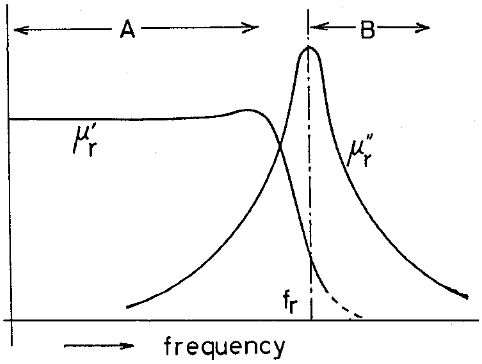

FIG. 2. FREQUENCY RESPONSE

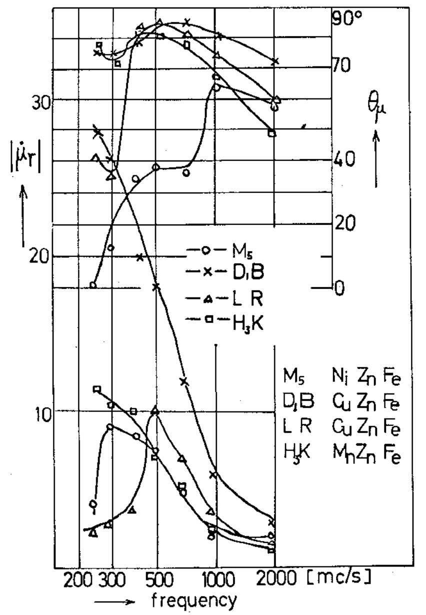

FIG. 3. MEASURED VALUES OF $\dot{\mu}_r = \mu \angle \theta_\mu$

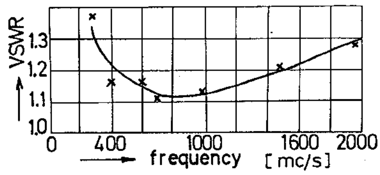

FIG. 4. CHARACTERISTICS OF THE WALL IN THE COAXIAL LINE