Rubber–Ferrite Absorber

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1. INTRODUCTION

This paper is concerned with electromagnetic wave absorber, a mixture of rubber and ferrite, and is aimed to investigate several electromagnetic characteristics to apply it for microwave antennas.

In microwave antennas, radiation of unnecessary electromagnetic wave backward and side direction is chiefly due to its diffraction and scattering at the rim of an antenna. To suppress this radiation, it has been suggested recently to attach absorbers to the rim of an antenna and to the supporting poles of a primary radiator. It is required, however, that the materials of such absorber are of high flexibility and possibly thin to be applied to the curved surfaces.

Electromagnetic absorbers so far used have been multilayered and quite thick ones of lossy dielectric materials. It has been found, however, that very thin rubber-ferrite is applicable as an absorber at UHF, VHF bands

2. PRINCIPLE

Let complex relative permeability and permittivity of rubber-ferrite be $\dot{\mu}r$, $\dot{\varepsilon}r$

then

$$\left.\begin{aligned}\dot{\mu}r &= \mu_r' - j\,\mu_r'' \\ \dot{\varepsilon}r &= \varepsilon_r' - j\,\varepsilon_r''\end{aligned}\right\} \quad \cdots\cdots ①$$

where μ_r' : real part of $\dot{\mu}r$

μ_r'' : imaginary part of $\dot{\mu}r$

ε_r' : real part of $\dot{\varepsilon}r$

ε_r'' : imaginary part of $\dot{\varepsilon}r$

As shown in Fig. 1, let rear face of rubber-ferite be intimately contacted to a conductor. Normalized input impedance $\dot{Z}$ and reflection co-efficient $\dot{S}$ under this condition for plane incident wave are given as follows.

$$\dot{Z} = \sqrt{\dot{\mu}r / \dot{\varepsilon}r}\ \tanh\left(j\frac{2\pi}{\lambda}\sqrt{\dot{\mu}r\ \dot{\varepsilon}r}\ d\right) \quad \cdots\cdots ②$$

$$\dot{S} = (\dot{Z}-1)\ /\ (\dot{Z}+1) \quad \cdots\cdots ③$$

where d : thickness of absorber

λ : wave-length of incident wave in a vacuum.

In Fig. 1 $\dot{Z}=1$ is necessary for $\dot{S}=0$.

then Eq. ① must satisfy following Eq. ④.

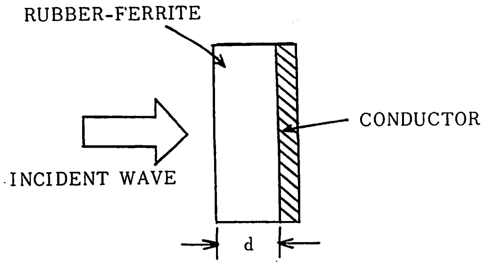


Fig. 1

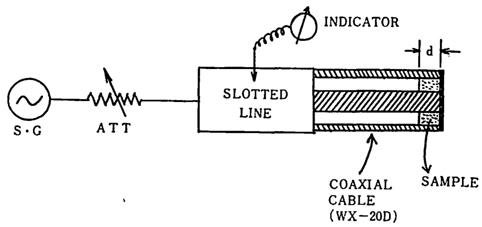


Fig. 2 MEASUREMENT SYSTEM

$$-jw\tanh w = \dot{\varepsilon}r \frac{2\pi}{\lambda} d \quad \text{④}$$

where

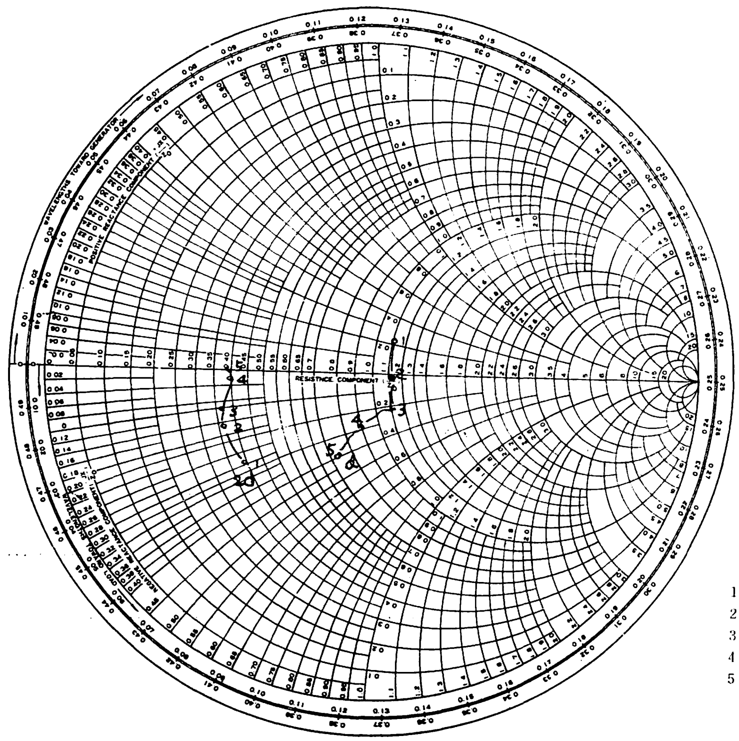
$$w = j \frac{2\pi}{\lambda} \sqrt{\dot{\varepsilon}r \, \dot{\mu}r} \, d$$

It is desirable that the thickness of the absorber satisfies Eq. ④ under

$$d \ll \lambda \quad \text{⑤}$$

3. MEASUREMENT

To calculate complex relative permeability and permittivity of an absorber, we must know its input impedance.



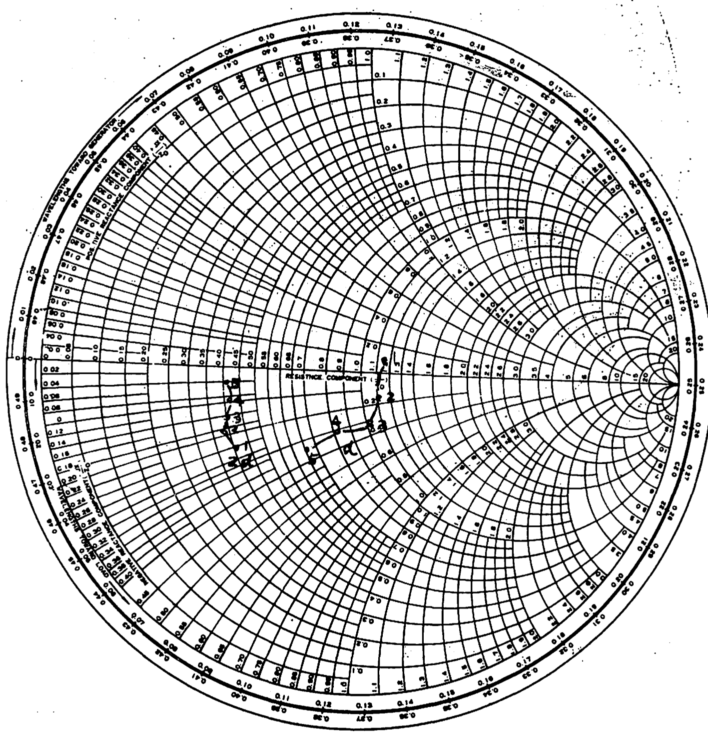
d = 5.15mm
SAMPLE A

1. 4.5GHZ
2. 5.0 〃
3. 5.5 〃
4. 6.0 〃
5. 6.5 〃

Fig. 3

3. 1 MEASUREMENT OF INPUT IMPEDANCE

Rubber-ferrite sample is put in WX−2OD coaxial slotted line as in Fig. 2. Measurement was done on (d = 5.15mm, d = 10.3mm) of the same sample, aiming 5 GHZ, 6 GHZ band absorber. Fig. 3～5, Table. 1～3 show input impedance of sample A, B, C.



d = 5.15 mm
SAMPLE B

1. 4.5GHZ
2. 5.0 〃
3. 5.5 〃
4. 6.0 〃
5. 6.5 〃

Fig. 4

3. 2 CALCULATION OF $\dot{\mu}r$ AND $\dot{\varepsilon}r$

Let $\dot{Z}_1$, $\dot{Z}_2$ be normalized input impedance

$$\left.\begin{aligned} \dot{Z}_1 &= \dot{Z}c\ tanh\dot{r}d \\ \dot{Z}_2 &= \dot{Z}c\ tanh2\dot{r}d = \dot{Z}c\ \frac{tanh\dot{r}d}{1+tanh^2\dot{r}d} \end{aligned}\right\} \quad \cdots\cdots ⑥$$

where

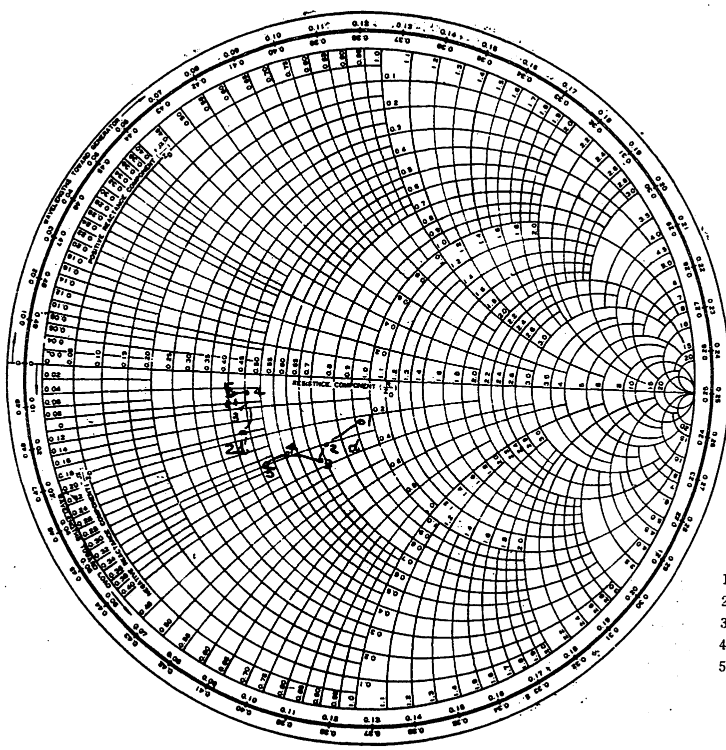
$$\dot{Z}c = \sqrt{\dot{\mu}r\,/\,\dot{\varepsilon}r}$$

$$\dot{r} = j\,\frac{2\pi}{\lambda}\sqrt{\dot{\mu}r\ \dot{\varepsilon}r}$$

d : thickness of sample

then from above equation ⑥, we obtain

$$\left.\begin{aligned} \dot{Z}c &= \frac{\dot{Z}_1}{\sqrt{\dfrac{2\dot{Z}_1}{\dot{Z}_2}-1}} \\ tanh\dot{r}d &= \sqrt{\frac{2\dot{Z}_1}{\dot{Z}_2}-1} \end{aligned}\right\} \quad \cdots\cdots ⑦$$



d =5.15mm

SAMPLE C

1. 4.5GHZ
2. 5.0 〃
3. 5.5 〃
4. 6.0 〃
5. 6.5 〃

Fig. 5

and

$$\left.\begin{aligned}\dot{\mu}r &= \mu r' - j\mu r'' = \mu r'(1 - j\tan\delta\mu) = \frac{\dot{Z}c\dot{r}}{j\frac{2\pi}{\lambda}} \\ \dot{\varepsilon}r &= \varepsilon r' - j\varepsilon r'' = \varepsilon r'(1 - j\tan\delta\varepsilon) = \frac{\dot{r}}{\dot{Z}c\left(j\frac{2\pi}{\lambda}\right)}\end{aligned}\right\} \quad \cdots\cdots (8)$$

Table 1

SAMPLE A

FREQUENCY (GHZ)	D = 5.15mm		D = 10.3mm	
	N・IMPEDANCE	IMPEDANCE	N・IMPEDANCE	IMPEDANCE
4.5	1.1 + j 0.23	55 + j 11.5	0.39 − j 0.275	19.5 −j13.75
5.0	1.3 − j 0.1	65 − j 5	0.37 − j 0.155	18.5 − j 7.75
5.5	1.1 − j 0.22	55 − j 11	0.37 − j 0.10	18.5 − j 5
6.0	0.89− j 0.28	44.5− j 14	0.40 − j 0.025	20 − j 1.25
6.5	0.73− j 0.39	36.5− j 19.5	0.38 + j 0.015	19 + j 0.75

*1 CHARACTERISTIC IMPEDANCE : 50 〔Ω〕
*2 N・IMPEDANCE : NORMARIZED IMPEDANCE

Table 2

SAMPLE B

FREQUENCY (GHZ)	D = 5.15mm		D = 10.3mm	
	N・IMPEDANCE	IMPEDANCE	N・IMPEDANCE	IMPEDANCE
4.5	1.15+ j 0.1	5.75+ j 5	0.41 − j 0.24	20.5− j 12
5.0	1.10− j 0.15	55− j 7.5	0.39 − j 0.17	19.5− j 8.5
5.5	1.03− j 0.30	51.6− j 15	0.405− j 0.15	20.2− j 7.5
6.0	0.80− j 0.32	4.0− j 16	0.42 − j 0.085	21 − j 4.25
6.5	0.65− j 0.34	32.5− j 17	0.65 − j 0.34	32.5− j 17

Table 3

SAMPLE C

FREQUENCY (GHZ)	D = 5.15mm		D = 10.3mm	
	N・IMPEDANCE	IMPEDANCE	N・IMPEDANCE	IMPEDANCE
4.5	0.93− j 0.23	46.5− j 11.5	0.42− j 0.18	21 − j 9
5.0	0.73− j 0.30	36.5− j 15	0.42− j 0.08	21 − j 4
5.5	0.67− j 0.36	33.5− j 18	0.43− j 0.10	21.5− j 5
6.0	0.57− j 0.285	28.5− j 14.25	0.44− j 0.04	22 − j 2
6.5	0.47− j 0.295	23.5− j 14.75	0.39− j 0.06	19.5− j 3

PERMEABILITY OF RUBBER−FERRITE

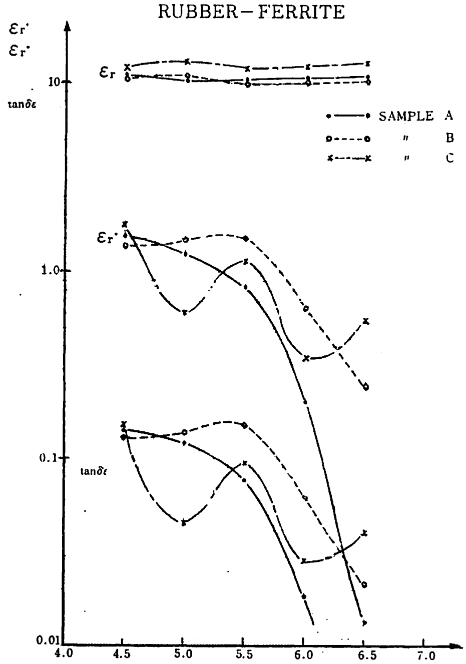


Fig. 6

PERMITTIVITYOF RUBBER−FERRITE

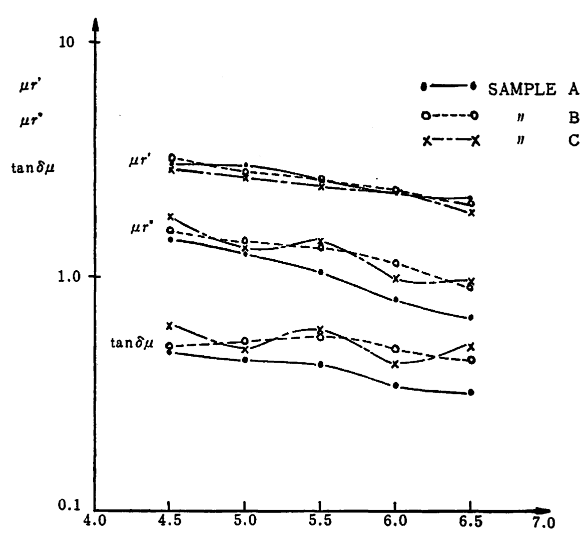


Fig. 7

4. RESULT OF EXPERIMENT

Substituting data in table 1. ～3. into Eq. ⑧, we have the result in Fig6, 7. Fig. 8 ～ 9 show vswr v•s f and B/fo v•s f characteristics of one of the absorbers.

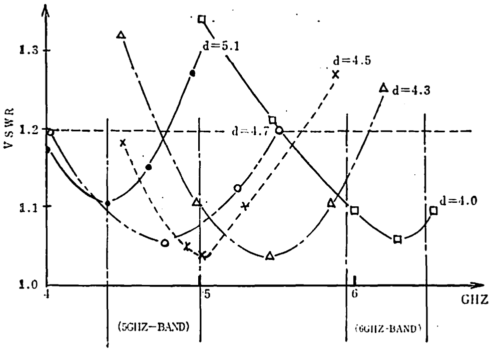


Fig. 8

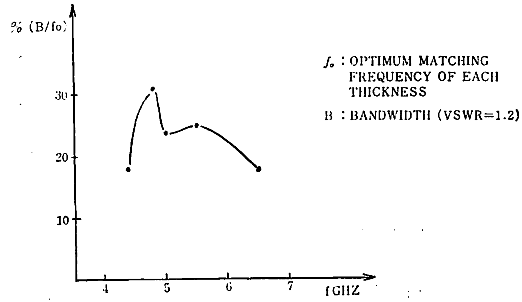


Fig. 9

5. CONCLUSION

- wide specific bandwidth is obtained
- By changing thickness, same absorber is available for both 5 GHZ and 6 GHZ band.
- Development of weather-proof rubber is necessary for long-term practical applapplication
- Technics for keeping thickness constant is necessary, as the change of thickness gives serious displacement of optimum matching frequency.

REFERENCES

- NAITO, "On the thickness of ferrite absorber" ,Trans. of Institute of Electronics an d Communication Engineers of Japan, VOL. 52 — B, No. 1, PP 21 — 25