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Development of the Measuring Technology for Dielectric Characteristics in Microwave Regions

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고주파수 영약에서의 유전특성 측정기술 개발[2)]

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요 약

극초단파 영역에서 얇은 두께의 시료를 도파 관의 한 가운데 두었을 때 진송 법과 Automatic Network Analyzer를 이용하여 산란인자를 측정하였다. 파동의 진파상수를 구하기 위하여 복소수로 되어 있는 반사계수와 투과계수를 결정하고 이것으로 초월함수를 풀어 시료의 유전특성을 구하였다.
시료를 도파 관의 한 가운데 두고 산란인자를 측정하는 이 방법은 유전체와 도파 관 사이에 생길 수 있는 간격을 줄일 수 있고 시료를 쉽게 정착할 수 있다.
이 측정 방법은 대단히 간단하고 빨리 측정할 수 있으며 실험을 재생할 수 있다는 장점이 있다.

I. INTRODUCTION

Numberous techniques for measurement of complex dielectric constants in microwave ranges have been given in the books edited by von Hippel[1-2]. The measurement methods for dielectrics can be generally divided into two

The resonance method provides the very accurate values but is applied only in frequency domain. If it is applied to a broad range of frequencies, this method is time-consuming. It is also difficult for resonance method to design the resonator.

On the other hand, the transmission-line method is suitable for broadband measurement and is applied in both frequency and time

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domains. This technique cab be also performed in the simpler experimental arrangement.

In these experiments, dielectric properties in microwave ranges are measured and calculated by the transmission-line method. Therefore, the only equations associated with the transmission-line method are described.

The governing transcendental equations for determination of dielectric properties in transmission-line method are written as the different forms depending upon geometry which dielectric materials are loaded in the rectangular waveguide[3]. The sample in rectangular waveguide is a) side-loading, b) center-loading, c) end-loading(open), d) end-loading(closed).

II. TRANSCENDENTAL EQUATION

The governing transcendental equations is also dependent on sample-loading methods. The equation in the center-loading sample is given by[4]

$$\zeta \tan\left(\frac{t}{2}\zeta\right) = \xi \cot\left(\frac{a-t}{2}\xi\right) \quad (1)$$

where t is the thickness of a sample and a is the width of a waveguide.

Both parameters, ζ and ξ in Eq.(1) are related to dielectric constants and propagation constants and are defined by

$$\zeta^2 = k^2\varepsilon + \gamma^2 \quad (2)$$

$$\xi^2 = k^2 + \gamma^2 \quad (3)$$

where complex dielectric constant, complex propagation constant, and wave number are defined by, respectively

$$\varepsilon = \varepsilon' - j\varepsilon'' \quad (4a)$$

$$\gamma = \alpha + j\beta \quad (4b)$$

$$k \equiv \frac{\omega}{c} = \frac{2\pi f}{c} \quad (4c)$$

However, since Eq.(1) is a complex transcendental equation, some approximations are applied to simplify the solution. This can be transformed with simplified variables as

$$z \tan z = M \quad (5)$$

where $$z \equiv \frac{t}{2}\zeta = x + jy \quad (6)$$

$$M \equiv \frac{t}{2}\xi\cot\left(\frac{a-t}{2}\xi\right) = A + jB \quad (7)$$

In order to find a relation between dielectric constant and propagation constant, A and B are determined as functions of x and y.

However, the relation between x or y and A or B which is only functions of the measurable quantities, k, γ, and t, should be determined from Eqs.(6) and (7). The final results are

$$\varepsilon' = \frac{1}{k^2}\left[\frac{4(x^2 - y^2)}{t^2} + \beta^2 - \alpha^2\right] \quad (8a)$$

$$\varepsilon'' = \frac{1}{k^2}\left[2\alpha\beta - \frac{8x\,y}{t^2}\right] \quad (8b)$$

III. MEASUREMENT

Dielectric characteristics are determined from two-port scattering parameters observed with automatic vector network analyzer.

The sample is loading in a home-made WR-75 waveguide with the sample holder between two ports of the network analyzer. Scattering parameters are measured with and without sample and propagation constants(Eq. 4b)are determined, thereby calculating dielectric characteristics(Eq. 8) from Eq.(4a).

Fig. 1 is one of oscillograms of the scattering parameters measured with a Automatic Network Analyzer as a function of frequency with a sample.

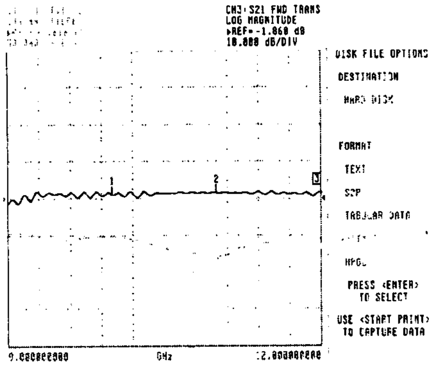

Fig. 1 an oscillogram of the scattering parameters with a sample

The upper and lower lines in the above oscillogram are corresponding respectively to transmission(S_{21}) and reflection(S_{11}) coefficients, which are scanned between 9 GHz and 14 GHz of frequency.

From these scattering parameters, the reflection and the transmission coefficients expressed with the complex numbers were determined as a function of frequency, which is used to calculate dielectric characteristics. Of course, there is no reflection($S_{11}(s)$) without the sample.

Table 1 shows the results as a function of frequency calculated by a home-made computer program or by Excel's spreadsheet through Eq.(1) ~ Eq.(8). In general, the dielectric constants and loss factors decreased with increasing frequency.

sample by the calibrated ANA and the propagation constants were calculated. Finally, a complex transcendental equation was solved by computer program or Excel's spreadsheet method, thereby determining dielectric constant and loss factor of the sample.

However, this technique is well-known to be very sensitive to sample thickness and the governing transcendental equation has multi-values. Therefore, by measuring the scattering parameters and calculating propagation constants as a function of sample thickness, a correct value of dielectric characteristics should be determined.

This technique reduces problem of the possible air gap between the dielectrics and the conducting boundaries and makes sample loading easy.

IV. Conclusion

It was found that transmission-line technique and the center-loading method in rectangular waveguide are suitable to a spectra measurement tool, Automatic Network Analyzer which the scattering parameters can be determined.

This technique was applied to preliminarily observe dielectric characteristics of a known material which is center-loaded in a home-made WR-75 waveguide.

Table 1 the calculated dielectric properties

frequency (GHz)	measurement / property	1	2
10	ε′	24.041	24.195
	ε″	2.015	1.934
12	ε′	25.189	25.029
	ε″	1.540	1.588
14	ε′	28.065	27.905
	ε″	1.347	1.360

The complex reflection and transmission coefficients were measured with and without a

Further investigation is required

V. REFERENCES

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