

# JIS

**JAPANESE INDUSTRIAL STANDARD**

**Measuring methods for ferrite  
cores for  
microwave device**

**JIS C 2565—1992**

**Translated and Published**

**by**

**Japanese Standards Association**

Printed in Japan



**Documents**

Document Sharing Hub

In the event of any doubt arising,  
the original Standard in Japanese is to be final authority.

## JAPANESE INDUSTRIAL STANDARD

J I S

Measuring methods for ferrite cores for  
microwave device

C 2565-1992

1. Scope

This Japanese Industrial Standard specifies testing methods for ferrite cores to be used for microwave devices in which gyromagnetic phenomenon is utilized (hereafter referred to as cores).

Remarks: The following Standards are cited in this Standard:

JIS B 7725-Vickers Hardness Testing Machines

JIS C 2501-Methods of Test for Permanent Magnet

JIS C 3202-Enameled Winding Wires

JIS Z 2244-Method of Vickers Hardness Test

JIS Z 8703-Standard Atmospheric Conditions for Testing

2. Definitions and symbols

For the purpose of this standard the following principal definitions and symbols shall apply.

- (1) saturation magnetization  $M_s$  The maximum magnetization which can be achieved by a core.
- (2) complex permittivity  $\underline{\epsilon}$  The complex quantity given below which shows the relation between vector quantity expressing a.c. electric displacement and vector quantity expressing a.c. electric field strength.

$$\underline{\epsilon} = \frac{1}{\epsilon_0} \left( \frac{\underline{D}}{\underline{E}} \right) \dots\dots\dots (1)$$

where,  $\epsilon_0 = 8.854 \times 10^{-12}$ : absolute permittivity of vacuum (F/m)

$\underline{E}$  : a.c. electric field strength in vector expression (V/m)

$\underline{D}$  : a.c. electric flux density in vector expression (C/m<sup>2</sup>)

If real component and imaginary component of complex permittivity are denoted as  $\epsilon'$  and  $\epsilon''$  respectively, then  $\underline{\epsilon}$  is expressed as follows:

$$\underline{\epsilon} = \epsilon' - j\epsilon'' \dots\dots\dots (2)$$

- (3) complex permeability  $\underline{\mu}$  The complex quantity given below which shows the relation between vector quantity expressing a.c. magnetic field strength and vector quantity expressing a.c. magnetic flux density.

$$\underline{\mu} = \frac{1}{\mu_0} \left( \frac{\underline{B}}{\underline{H}} \right) \dots\dots\dots (3)$$

where,  $\mu_0 = 4\pi \times 10^{-7}$  : absolute permeability of vacuum (H/m)

$\underline{H}$  : a.c. magnetic field strength in vector expression (A/m)

$\underline{B}$  : a.c. magnetic flux density in vector expression (T)

If real component and imaginary component of complex permeability are denoted as  $\mu'$  and  $\mu''$  respectively, then  $\underline{\mu}$  is expressed as follows:

$$\underline{\mu} = \mu' - j\mu'' \dots\dots\dots (4)$$

- (4) gyromagnetic resonance linewidth  $\Delta H$  The difference between two applied d.c. magnetic fields which pass two points on a uniform gyromagnetic resonance absorption curve where the loss is 1/2 of the maximum value.

- (5) effective Landé factor  $g_{eff}$  This means such value that the ratio of the frequency to the effective resonant magnetic field ( $H_0$ ), in magnetic resonance, is divided by  $176 \times 10^2$ . It is calculated from the formula (5).

$$g_{eff} = \frac{f}{176 \times 10^2 \times H_0} \dots\dots\dots (5)$$

where,  $f$  : frequency (Hz)

$H_0$  : effective resonant magnetic field (A/m)

- (6) spin-wave resonance linewidth  $\Delta H_k$  The difference between two applied d.c. magnetic fields which pass two points on a spin-wave magnetic resonance absorption curve where the loss is 1/2 of the maximum value.

### 3. Temperature of test environment

Unless otherwise specified, the temperature of test environment shall be  $23 \pm 2^\circ\text{C}$ . If the measured value is not dependent to temperature or no specific temperature is required, the test may be carried out at 5 to  $35^\circ\text{C}$  (the ordinary temperature specified in JIS Z 8703).

### 4. Testing machinery, apparatus and device

The testing machinery, apparatus and device shall be previously calibrated and shall have enough accuracy.

### 5. Electrical and magnetic performance tests

#### 5.1 Saturation magnetization

5.1.1 Vibration type magnetometer method The vibration type magnetometer method shall be as specified below.

- (1) Test specimen The test specimen shall have a shape maximum of almost spherical block or powder. A block specimen with maximum diameter of about 3 mm or powder specimen of 20 to 30 mg is fixed by a suitable method in a capsule of about 5 mm outer diameter, about 3 mm inner diameter and about 6 mm length.

Remarks: The test specimen shall have a size capable of being accommodated in the specimen container of the vibration type magnetometer.

- (2) Measuring conditions The magnetic field strength for this measurement shall be not less than  $4 \times 10^5$  A/m, and the measurement shall be carried out at 2 points one of which corresponds to the originally established magnetic field strength and the other corresponds to 110 % or over thereof.
- (3) Measurement The respective masses of the test specimen (before fixed in the case of powder) and the reference specimen ( $m$ ,  $m_0$ ) are weighed (to three significant figures) and the respective densities ( $d$ ,  $d_0$ ) are also measured. The test specimen (fixed one in the case of powder) and the reference specimen are individually placed in a vibration type magnetometer, the respective induced voltages ( $e$ ,  $e_0$ ) are measured under a constant amplitude, constant frequency and constant position, and then the saturation magnetization  $M_s$  is calculated from the formula (6).

$$M_s (\text{A/m}) = \frac{edm_0}{e_0d_0m} M_{s0} \dots\dots\dots (6)$$

where,  $e$  : induced voltage by test specimen (V)  
 $e_0$  : induced voltage by reference specimen (V)  
 $d$  : density of test specimen ( $\text{g/cm}^3$ )  
 $d_0$  : density of reference specimen ( $\text{g/cm}^3$ )  
 $M_{s0}$  : saturation magnetization of reference specimen (A/m)

Nickel sphere of 99.95 % or more in purity and about 3 mm in diameter is used as the reference specimen, and the following values apply.

$$d_0 = 8.90 (\text{g/cm}^3)$$

$$M_{s0} = 490.8 (\text{kA/m})$$

5.1.2 Magnetic balance method The magnetic balance method shall be as specified below.

- (1) Test specimen The sample material is powdered by a mortar or the like, classified by a sieve of about 100 mesh and the passed powder is taken as the test specimen.
- (2) Measuring conditions The conditions specified in 5.1.1 (2).

- (3) Measurement The respective masses ( $m$ ,  $m_0$ ) of test specimen and reference specimen are measured (to 3 significant figures), and the respective densities ( $d$ ,  $d_0$ ) are measured.

The test specimen and reference specimen are individually placed on a magnetic balance, respective forces ( $F$ ,  $F_0$ ) which the specimens receive at a certain position is measured, and then the saturation magnetization  $M_s$  is calculated from the formula (7).

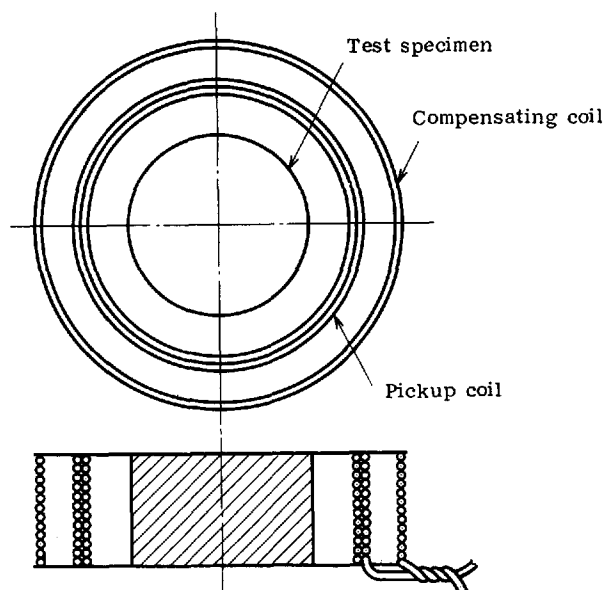
$$M_s (\text{A/m}) = \frac{F d m_0}{F_0 d_0 m} M_{s0} \dots \dots \dots (7)$$

where,  $F$  : force received by test specimen (N)  
 $F_0$  : force received by reference specimen (N)  
 $d$  : density of test specimen ( $\text{g/cm}^3$ )  
 $d_0$  : density of reference specimen ( $\text{g/cm}^3$ )  
 $m$  : mass of test specimen (g)  
 $m_0$  : mass of reference specimen (g)  
 $M_{s0}$  : saturation magnetization of reference specimen (A/m) [similar to 5.1.1 (3)]

5.1.3 Yoke method The yoke method shall be as specified below.

- (1) Test specimen The style of test specimen is square or circular column, the length is 10 to 20 mm and the diameter or the length of one side is 10 to 15 mm.
- (2) Measuring conditions As specified in 5.1.1 (2).
- (3) Measurement The test specimen and the coaxial compensating and searching coil shown in Fig. 1, are set up between magnetic poles of a magnetizer specified in JIS C 2501, the magnetic flux is measured by ballistic galvanometer method or a recording flux-meter, and the  $M_s$  is calculated from the formula (8).

Fig. 1. Coaxial compensating and searching coil



$$M_s (\text{A/m}) = \frac{\phi}{(n_1 - n_2) A \cdot \mu_0} \dots \dots \dots (8)$$

where,  $\phi$  : magnetic flux measured with fluxmeter (Wb)  
 $n_1$  : number of turns of pickup coil  
 $n_2$  : number of turns of compensating coil  
 $A_1$  : sectional area of pickup coil ( $\text{m}^2$ )  
 $A_2$  : sectional area of compensating coil ( $\text{m}^2$ )  
 $A$  : sectional area of test specimen ( $\text{m}^2$ )  
 $\mu_0$  : absolute permeability of vacuum =  
 $4\pi \times 10^{-7} (\text{H/m}) = 4\pi \times 10^{-7} (\text{T} \cdot \text{m/A})$

In the compensating and searching coil assembly, the pickup coil and compensating coil are connected in series so that the electro-motive forces of the 2 coils negate each other, and the coil is so adjusted that the following equations hold.

$$n_1 A_1 = n_2 A_2$$

$$A < A_1 < A_2$$

Further, the inner diameter of pickup coil is made as close to the diameter of test specimen.

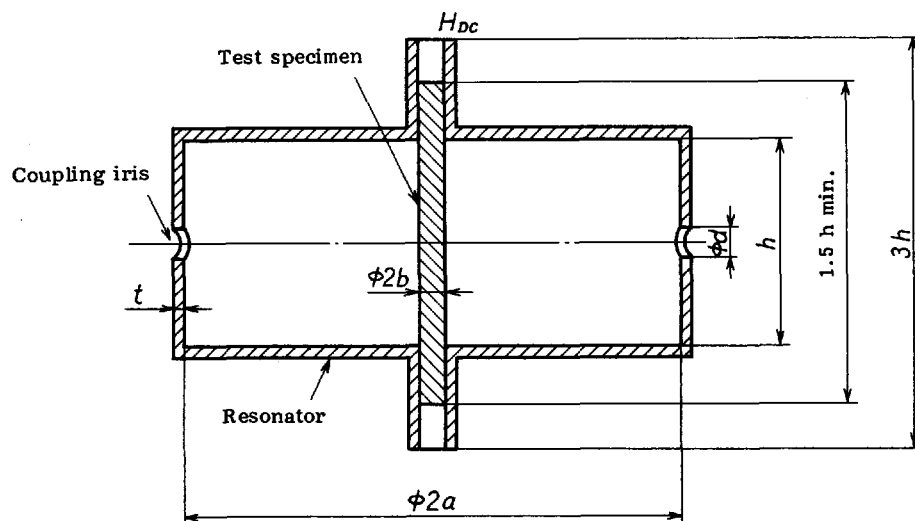
## 5.2 Complex permittivity

**5.2.1 Test specimen** The style of test specimen shall be cylindrical. The diameter of test specimen shall be 0.060 to 0.075 times the inner diameter of resonator, the tolerances shall be  $\pm 0.01$  mm and the length shall be not less than 1.5 times the height  $h$  of resonator (see Fig. 2).

**5.2.2 Measuring conditions** The measuring conditions shall be as specified below.

- (1) In the measurement, transmission type circular  $TM_{010}$  style resonator is used (see Fig. 2).
- (2) As illustrated in Fig. 2, the test specimen is mounted to the center of resonator so that the axis of test specimen coincides with the axis of resonator.
- (3) During the measurement, external magnetic field ( $H_{dc}$ ) is applied in the direction of the axis of test specimen. The external magnetic field is applied until such a degree that change in the measured value is not observed even the magnetic field is changed (normally not less than  $4 \times 10^5$  A/m).
- (4) The style of resonator is as illustrated in Fig. 2.
- (5) The measuring frequency is 8.2 to 12.4 GHz.

Fig. 2. Style of resonator and test specimen



$$2a = 22.16 \text{ mm}$$

$$h = 11.08 \text{ mm}$$

$$d = 4.5 \text{ mm}$$

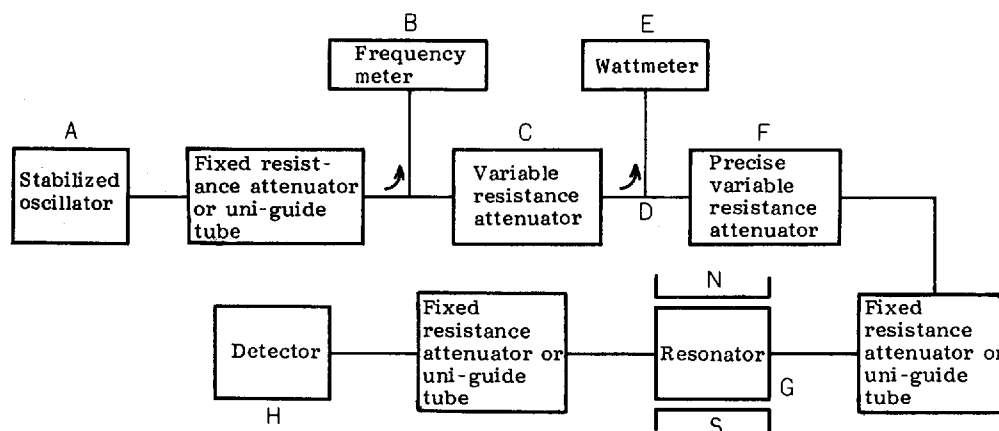
$$t = 0.5 \text{ mm}$$

$$2b = 1.4 \text{ mm}$$

**5.2.3 Measurement** The measurement shall be made as specified below.

- (1) Measuring circuit (see Fig. 3)

Fig. 3. Block diagram of measuring circuit system



- (2) **Measuring procedure** Attenuation of 3 dB is set by operating the precise variable resistance attenuator F with accuracy of 0.1 dB or so. The oscillator A is set to a frequency  $f_0$  at which the output becomes the maximum for a same input level by changing the frequency while the test specimen is not inserted in the cavity resonator G. The output at this time is read from the detector H, and the frequency  $f_0$  is measured by the frequency meter B or other suitable measuring apparatus. Next, the attenuation of the precise variable resistance attenuator F is decreased by 3 dB, then two frequencies at which the output becomes the same as that at the resonance point before the attenuation is reduced are measured, and then the difference between such frequencies  $\Delta f_0$  is obtained. The frequency meter B for use in this calculation of  $\Delta f_0$  is a heterodyne frequency meter employing frequency stabilized microwave oscillator or a frequency meter of other system having accuracy of same grade.

In this case, the  $Q$  of cavity resonator is obtained by  $Q_0 = \frac{f_0}{\Delta f_0}$ .

Next, the test specimen is inserted and the same operation is repeated, the resonance frequency  $f_1$  and the difference between frequencies at half output point  $\Delta f_1$  are measured in this operation, and  $Q_1$ , is calculated as  $Q_1 = \frac{f_1}{\Delta f_1}$ .

During the above measurements, the variable resistance attenuator C is adjusted so that the indication of the wattmeter E becomes constant (input power is constant).

- (3) **Calculation** From the above-mentioned measured values,  $\delta f = f_0 - f_1$  is obtained, the correction terms  $\epsilon'$  is obtained from the formula (10), and then  $\epsilon'$  and  $\epsilon''$  are calculated from the formulae (9) and (11).

$$\epsilon' = \epsilon' \left( 1 - 0.722 \frac{b^2}{a^2} \epsilon' \right) \dots \dots \dots (9)$$