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Method for evaluating electronic characteristics of ultrasonic test instruments

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal of revision of Japanese Industrial Standard submitted by The Japanese Society for Non-destructive Inspection (JSNDI)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS Z 2351:1992** is replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, applications for a patent after opening to the public or utility model rights. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, applications for a patent after opening to the public or utility model rights.

Method for evaluating electronic characteristics of ultrasonic test instruments

Introduction

This Japanese Industrial Standard has been prepared based on the first edition of ISO 12710 published in 2002, with some modifications of the technical contents to enable smooth management of this Standard based on the status of implementation of JIS Z 2351 : 1992 in Japan.

The portions with dotted underlines and Annex JA are the matters not contained in the corresponding International Standard. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard establishes the procedures for measuring, by means of electronic measuring instruments, the electrical characteristics of ultrasonic test instruments that are equipped with a manually operated display unit using the pulse-echo technique.

NOTE : The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 12710 : 2002 *Non-destructive testing — Ultrasonic inspection — Evaluating electronic characteristics of ultrasonic test instruments* (MOD)

The symbols which denote the degree of correspondence in the contents in the corresponding International Standard and JIS are IDT (identical), MOD (modified) and NEQ (not equivalent) according to ISO/IEC Guide 21-1.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS Z 2300 *Terms and definitions of nondestructive testing*

JIS Z 8103 *Glossary of terms used in measurement*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in JIS Z 2300 and JIS Z 8103 and the following apply.

3.1 pulse square wave ratio

factor that evaluates the quality of a square wave transmission waveform

3.2 time resolution

ability to separate and discriminate between adjacent signals

3.3 independent gate

gate with the ability to control only the gain in a gate independently

3.4 control position

adjusted value of all the knobs that affect displays such as gain, pulse width and rejection

3.5 number of waves

number of cycles counted taking one cycle of a sinusoidal wave as a base unit

3.6 accuracy

accuracy of a measuring instrument that is expressed by limits of error under the specified condition (see JIS Z 8103)

4 Items of principal performance

The mandatory assessment items of principal performance are as follows. The assessment items other than the following principal items, their contents and ranges shall be subject to the agreement between the parties concerned with delivery.

- a) The items for transmitter part are specified in 5.1.1, 5.1.2, 5.1.3, 5.1.4 and 5.1.6.
- b) The items for receiver part are specified in 5.2.1, 5.2.2, 5.2.3 and 5.2.5.
- c) The item for time base part is specified in 5.3.1.
- d) The item for time resolution is specified in 5.3.2.

5 Methods of performance assessment

5.1 Performance of transmitter part

5.1.1 Output impedance

The measurement of output impedance of the transmitter part shall be as follows.

- a) **Apparatus** The apparatus used shall be as follows.
 - 1) **Oscilloscope** The frequency bandwidth shall be 100 MHz or over, and the apparatus shall be calibrated before use.
 - 2) **Terminating resistor** The resistor shall be 50 Ω of non-inductive.
 - 3) **High voltage probe** An oscilloscope for observation of high voltage signals.
- b) **Measurement method** The measurement method shall be as follows.
 - 1) Open the output terminal of the transmitter part of the ultrasonic test instrument as shown in figure 1, measure the voltage of the transmitted pulse with an oscilloscope, and record it as V_i .

- 2) Connect the terminating resistor R_0 to the output terminal as shown in figure 2, measure the voltage of the transmitted pulse across the terminal with an oscilloscope, and record it as V_2 .

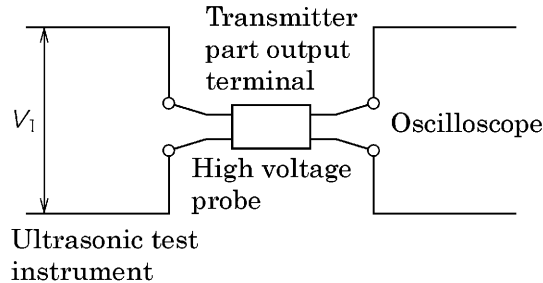


Figure 1. Setup of apparatuses for measurement of transmitted pulse voltage when output terminal is opened.

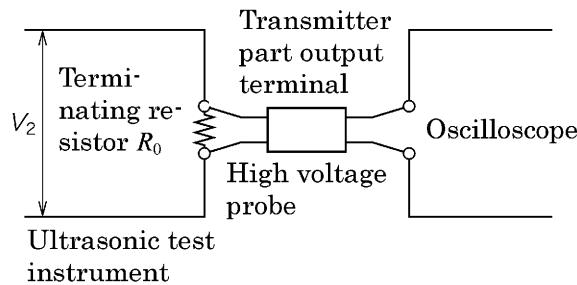


Figure 2. Setup of apparatuses for measurement of transmitted pulse voltage when output terminal is terminated

- 3) Measure the voltage at the peak value.
- 4) If the instrument is provided with a pulse energy adjustor, measure at energy (maximum) and (minimum). If the impedance switching function is provided, measure at each impedance.
- 5) Obtain the transmitted output impedance Z_0 (Ω) by the following formula :

$$Z_0 = \frac{R_0 \times (V_1 - V_2)}{V_2}$$

where, R_0 : terminating resistor value (Ω)
 V_1 : transmitted pulse voltage when output terminal is opened (V)
 V_2 : transmitted pulse voltage when output terminal is terminated (V)

5.1.2 Repetition frequency of transmitted pulse

The measurement of repetition frequency of transmitted pulse shall be as follows.

- a) **Apparatus** The apparatus specified in **5.1.1 a)** shall be used.
- b) **Measurement method** The measurement method shall be as follows.
- 1) The setup of the ultrasonic test instrument and the apparatus shall be as shown in figure 2.
 - 2) Display two or more transmitted pulses on the screen of the oscilloscope, and measure the time interval T between two adjacent pulses.
 - 3) For the ultrasonic test instrument provided with a setting function of the transmitted pulse repetition frequency, measure the repetition frequency at the control position at the lowest and highest frequencies.
 - 4) Observe the change in the amplitude of transmitted pulse when the pulse repetition frequency is changed and record it.
 - 5) Obtain the pulse repetition frequency according to the following formula :

$$PRF = 1/T$$

where, PRF : pulse repetition frequency (Hz)
 T : time interval of transmitted pulses (s)

5.1.3 Rise time of transmitted pulse

The measurement of rise time of transmitted pulse shall be as follows.

- a) **Apparatus** The apparatus used shall be in accordance with **5.1.1 a)**.
- b) **Measurement method** The measurement method shall be as follows.
- 1) The setup of the ultrasonic test instrument and the apparatus shall be as shown in figure 2.
 - 2) Display transmitted pulse on the screen of the oscilloscope.
 - 3) Measure the time interval T_m between 10 % and 90 % of peak of the transmitted pulse on the leading edge of the transmitted pulse as shown in figure 3.
 - 4) If this time is influenced by the adjustment of pulse energy, measure this time under pulse energy controls set at the maximum and minimum.
 - 5) **Correction of the measured values** Correct the measured values according to the following formula :

$$T_R^2 = T_m^2 - T_S^2$$

where, T_R : rise time of corrected transmitted pulse (ns)
 T_m : rise time of measured transmitted pulse (ns)
 T_S : corrected time determined by the frequency bandwidth B_w of oscilloscope, obtained by the following formula (ns) :

$$T_S = 350/B_w$$

where, B_w : frequency bandwidth of the oscilloscope used for measurement (MHz)

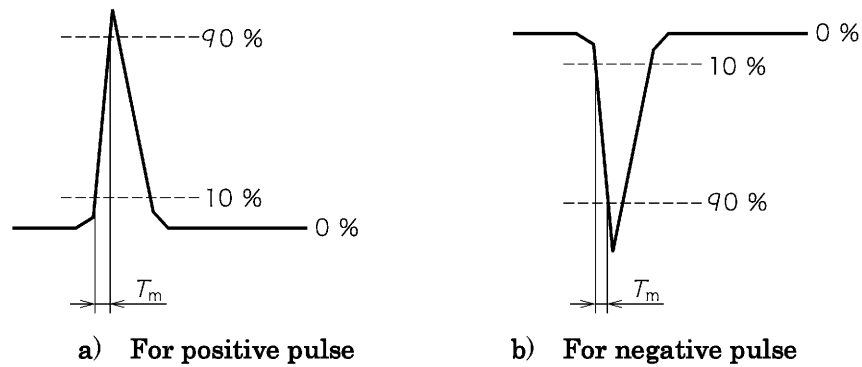


Figure 3 Measurement of rise time of transmitted pulse

5.1.4 Transmitted pulse width

The measurement of transmitted pulse width shall be as follows.

- a) **Apparatus** The apparatus used shall be as specified in 5.1.1 a).
- b) **Measurement method** The measurement method shall be as follows.
 - 1) The setup of the ultrasonic test instrument and the apparatus shall be as shown in figure 2.
 - 2) Display only one transmitted pulse on the screen of the oscilloscope.
 - 3) Measure the time T_w between 10 % of the peak of the transmitted pulse on the leading edge and 10 % of the peak on the trailing edges as shown in figure 4.
 - 4) Remove the terminating resistance and repeat the measurement above.
 - 5) If the ultrasonic test instrument is provided with a pulse energy adjustor, the measurement shall be performed with the pulse energy adjusted at its maximum and minimum.

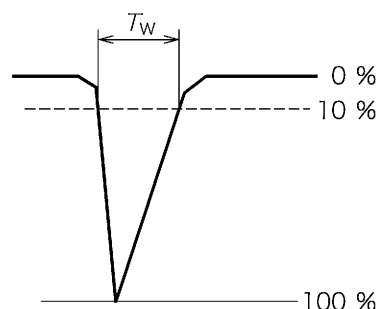


Figure 4 Measurement of transmitted pulse width

5.1.5 Pulse square wave ratio

When the waveform of a transmitted pulse is square, the following measurement shall be performed.

a) **Apparatus** The apparatus used shall be as specified in 5.1.1 a).

b) **Measurement method** The measurement method shall be as follows.

- 1) The setup of the ultrasonic test instrument and the apparatus shall be as shown in figure 2.
- 2) Display only one transmitted pulse on the screen of the oscilloscope.
- 3) As shown in figure 5, measure the pulse widths T_{W20} and T_{W80} at 20 % and 80 % of the peak of the transmitted pulse, respectively.
- 4) Calculate the pulse square wave ratio SR (%) according to the following formula :

$$SR = \frac{T_{W80}}{T_{W20}} \times 100 \text{ (%)}$$

where, T_{W80} : pulse width at 80 % level of the peak (μs)
 T_{W20} : pulse width at 20 % level of the peak (μs)

- 5) When more than one transmit frequencies can be set, measure at each frequency.

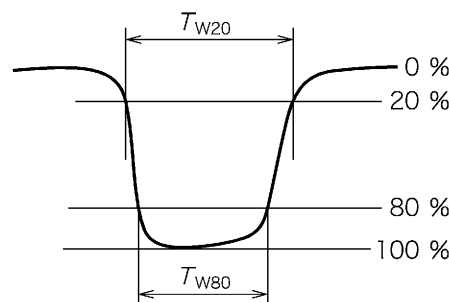


Figure 5 Measurement of pulse square wave ratio

5.1.6 Amplitude of transmitted pulse

The measurement of amplitude of transmitted pulse shall be as follows.

a) **Apparatus** The apparatus used shall be as specified in 5.1.1 a).

b) **Measurement method** The measurement method shall be as follows.

- 1) The setup of the ultrasonic test instrument and the apparatus shall be as shown in figure 2.
- 2) Display the transmitted pulse on the screen of the oscilloscope.
- 3) Measure the voltage of the peak value of the transmitted pulse.
- 4) If the amplitude is changed by the pulse energy adjustor, measure the amplitude under pulse energy controls set at the maximum and minimum.
- 5) Remove the terminating resistance and repeat the measurement in 3) and 4) above.

5.1.7 Frequency spectrum of transmitted pulse

The measurement of frequency spectrum of transmitted pulse shall be as follows.

a) **Apparatus**

- 1) **Frequency analyzer** A spectrum analyzer or FFT analyzer (a FFT analyzer refers to a device that analyzes the frequency component of a signal using a computer.)
- 2) **Attenuator** The attenuator used shall fulfill the following conditions.
 - 2.1) **Operating frequency range** DC to 100 MHz or over
 - 2.2) **Attenuation range** 0 to 80 dB or over, variable in steps of 0.2 dB or under
 - 2.3) **Impedance** 50 Ω
 - 2.4) **Accuracy** Within ± 0.3 dB per 20 dB
- 3) **Terminating resistor** 50 Ω non-inductive resistance

b) **Measurement method**

- 1) The setup of the ultrasonic test instrument and the apparatus shall be as shown in figure 6.
- 2) Set the attenuation at 40 dB or over. When the frequency analyzer has limitations of input voltage, perform setting of the attenuator within the limitations.
- 3) In the case of an analyzer in which the transmitted pulse width of the ultrasonic test instrument can be changed, perform the measurement with the pulse width set at its maximum and at its minimum.

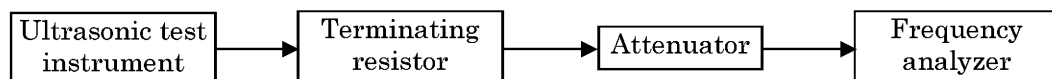


Figure 6 Setup of ultrasonic test instrument and apparatuses for frequency spectrum measurement

- 4) **Peak frequency** Measure the frequency F_{TP} at the maximum amplitude.
- 5) **Upper limit frequency** Measure the frequency F_{TU} in the high frequency side that shows 70.8 % (– 3 dB) of the maximum amplitude.
- 6) **Lower limit frequency** Measure the frequency F_{TL} in the low frequency side that shows 70.8 % (– 3 dB) of the maximum amplitude.
- 7) **Centre frequency** Obtain the centre frequency F_{TC} according to the following formula from the values of upper limit frequency and lower limit frequency obtained in 5) and 6), respectively.

$$F_{TC} = \frac{(F_{TU} + F_{TL})}{2}$$

where, F_{TC} : centre frequency (MHz)

F_{TU} : upper limit frequency (MHz)
 F_{TL} : lower limit frequency (MHz)

5.2 Performance of receiver part

5.2.1 Frequency characteristics

The measurement of frequency characteristics shall be as follows.

a) Apparatus

- 1) **Pulse generator** The pulse generator used shall be provided with the function of setting back the output pulse freely by 3 μ s or more immediately after the trailing edge of the transmitted pulse.
- 2) **Burst wave signal generator** The burst wave signal generator used shall be provided with the function of generating optional frequency and optional number of waves by receiving trigger signals from the pulse generator.
- 3) **Oscilloscope** The oscilloscope used shall be 100 MHz or over in frequency bandwidth, and shall have been calibrated before use.
- 4) **Attenuator** The attenuator used shall be as specified in 5.1.7 a) 2).
- 5) **Terminating resistor** The terminating resistor used shall be of 50 Ω non-inductive resistance.
- 6) **Protection circuit** The protection circuit shall be a circuit for preventing the input of the pulse generator from being damaged due to the transmitted signal of an ultrasonic test instrument.

b) Measurement method

- 1) The setup of the ultrasonic test instrument and the apparatuses shall be as shown in figure 7.
- 2) Perform the measurement according to the following procedure.
 - 2.1) Set the selector of the ultrasonic test instrument to “double probe technique”.
 - 2.2) The input signal to the ultrasonic test instrument shall be at the level obtained when, after making adjustment to provide a 5 cycle sine wave burst and setting the output at the peak voltage (p-p) = 1 V, the attenuator is set to 20 dB attenuation.
 - 2.3) Set the receiver reject control to “O” or “OFF”.

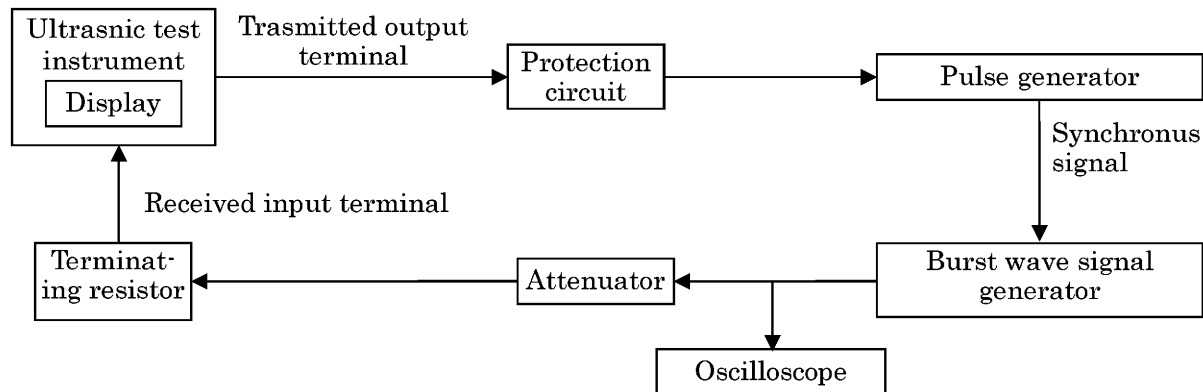


Figure 7 Setup of apparatuses for performance measurement using burst wave signal

- 2.4) Adjust the gain of the ultrasonic test instrument so that the signal height of the burst wave signal generator reaches 80 % on the display scale of the instrument.
- 2.5) Record the frequency F_{RP} as the peak frequency when the signal height is at the maximum.
- 2.6) Vary the frequency of the burst wave signal toward both the upper and lower sides, and record it when it has fallen 3 dB below the maximum signal height. The frequency at the upper side is taken as F_{RU} , and that at the lower side, as F_{RL} .
- 3) Obtain the bandwidth ΔF_R according to the following formula and record it :

$$\Delta F_R = F_{RU} - F_{RL}$$

where, ΔF_R : bandwidth (MHz)
 F_{RU} : frequency in the high frequency side at the height that has fallen 3 dB below the maximum signal height (MHz)
 F_{RL} : frequency in the low frequency side at the height that has fallen 3 dB below the maximum signal height (MHz)

- 4) Obtain the centre frequency F_{RC} according to the following formula and record it :

$$F_{RC} = \frac{(F_{RU} + F_{RL})}{2}$$

where, F_{RC} : centre frequency of the bandwidth (MHz)

- 5) In the ultrasonic test instrument that can select received frequency, measure the peak frequency, centre frequency and bandwidth in each selected state by the same method, and record the results.

5.2.2 Sensitivity

5.2.2.1 General

The measurement of sensitivity shall be performed by one of the following methods.

5.2.2.2 Method using the reference output level and equivalent input noise levels

The measurement of sensitivity using the reference output level and equivalent input noise levels shall be as follows.

- a) **Apparatus** The apparatus used shall be as specified in 5.2.1 a).
- b) **Measurement method** The measurement method shall be as follows.
 - 1) The setup of the ultrasonic test instrument and the apparatuses shall be as shown in figure 7.
 - 2) Separate the receiver part from the transmitter part by setting the selector of the ultrasonic test instrument to “double probe technique”. As shown in figure 7, use the protection circuit to protect the pulse generator from high voltage transmitted pulse of the ultrasonic test instrument. Synchronize the pulse generator with the instrument, and generate burst wave signal at a delayed position from the transmitted pulse. Apply the output signals from the burst wave signal generator to the input terminal of the receiver part of the instrument through the attenuator and the terminating resistor of $50\ \Omega$.
 - 3) Set the reject control of the ultrasonic test instrument to “0” or “OFF”.
 - 4) Set the frequency of burst wave signal generator with received centre frequency (or test frequency), and with number of waves of 5 to 10.
 - 5) Perform the measurement according to the following procedure.
 - 5.1) Set the output level of the burst wave signal generator, as shown in figure 8 a), to $V_{p-p} = 1\text{ V}$, on the oscilloscope. Set the value of the attenuator to 60 dB.

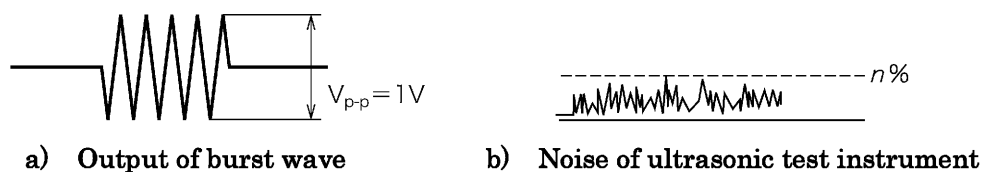


Figure 8. Signal height

- 5.2) Adjust the height of the burst wave signals on the display to 50 % of full scale of the graticule by gain controls of the ultrasonic test instrument, and read the value of the gain controls as $A\text{ dB}$. Use the part of constant amplitude of the burst wave to read the signal height on the display.
- 5.3) Disconnect the attenuator from the terminating resistor. Adjust the gain controls under the condition that only the terminating resistor is connected to the input terminal of the receiver part of the ultrasonic test instrument to make the noise level on the display 50 % and read the value of the gain controls as $N\text{ dB}$.
- 5.4) In case where the noise level does not reach to 50 % even when gain controls are maximized, read the noise level height as $n\%$ as shown in figure 8 b) and the corresponding gain controls value $M\text{ dB}$

6) Obtain the sensitivity S dB of the ultrasonic test instrument by the following formula and record it.

6.1) In the case of 5.3) :

$$S = N - A + 60$$

6.2) In the case of 5.4) :

$$S = 20 \log(50/n) + M - A + 60$$

where, N : gain controls value (dB) when noise of the instrument is set to 50 % height on the display
 A : gain controls value (dB) when burst wave signal is set to 50 % height on the display
 M : gain controls (dB) when noise of the instrument is set to n % on the display
 n : height of noise of the instrument on the display (%)

5.2.2.3 Method using gate/alarm function

The measurement of sensitivity using the gate/alarm function shall be as follows.

- a) **Apparatus** The apparatus used shall be as specified in 5.2.1 a).
- b) **Measurement method** The measurement method shall be as follows.
 - 1) The setup of the ultrasonic test instrument and the apparatuses shall be as shown in figure 7.
 - 2) Set the frequency of the burst wave to the same frequency as the test frequency of the ultrasonic test instrument, and provide burst waves of the number of waves of 5 to 10.
 - 3) Set the instrument gain at mid-range.
 - 4) Adjust the burst wave signal generator and the attenuator to give 20 % burst wave height on the display of the ultrasonic test instrument.
 - 5) Trigger the gate/alarm function of the instrument, and set the alarm level at 20 %.
 - 6) Disconnect the burst wave signal generator, and adjust the instrument gain to the maximum where alarm is no longer triggered by noise.
 - 7) Reconnect the burst wave signal generator, adjust the burst wave signal generator and the attenuator such that the signal height on the display of the ultrasonic test instrument reaches 80 %.
 - 8) Measure the input signal level of the instrument at this time with the oscilloscope, and record the reading obtained as the sensitivity.
 - 9) If the input signal level is too low to read accurately, measure the output signal level of the burst wave signal generator and correct the reading with attenuation by the attenuator to obtain the input signal level of the ultrasonic test instrument, and record the result as the sensitivity.

5.2.3 Gain controls

The measurement of performance of gain controls shall be in accordance with the method in 5.2.3.1 when the gain control consists of two or more controls with different control steps, and in accordance with the method in 5.2.3.2 when the gain control consists of a single control.

5.2.3.1 Individual gain controls measurement method

a) **Apparatus** The apparatus used shall be as specified in 5.2.1 a).

b) **Measurement method** The measurement method shall be as follows.

- 1) The setup of the ultrasonic test instrument and the apparatuses shall be as shown in figure 7. The selector of the instrument shall be set to “double probe technique”.
- 2) Set the frequency of the burst wave signal with received centre frequency (or test frequency), and with the number of waves of 5 to 10.
- 3) Perform the measurement on each gain control according to the following procedure.
 - 3.1) Adjust the gain controls so that the noise level on the display of the ultrasonic test instrument is 3.3 % or under and the maximum. In this condition, adjust the attenuator and the output of the burst wave signal generator so that the signal height on the display of the instrument reaches 50 %. Read the values of the gain of the instrument and the attenuator to take them as the initial values.
 - 3.2) Select the measuring step from table 1 according to the minimum step of the gain controls of the instrument.
 - 3.3) Reduce the gain of the instrument by the measuring step selected in 3.2).
 - 3.4) Adjust the attenuator until the signal height on the display of the ultrasonic test instrument reaches 50 % and record the values of the gain controls and of the attenuator at this time.
 - 3.5) Repeat the procedures in 3.3) and 3.4), and perform the measurement through the full range of the gain controls.
 - 3.6) Make a table of gain controls settings and the attenuator settings.
 - 3.7) Read the difference between the adjusted value (change from the initial value) of the gain controls and the adjusted value (change from the initial value) of the attenuator from the table, and record it. Further, record the maximum value of the difference.