BS ISO 16525-9:2014

BSI Standards Publication

Adhesives — Test methods for isotropic electrically conductive adhesives

Part 9: Determination of high-speed signal-transmission characteristics

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National foreword

This British Standard is the UK implementation of ISO 16525-9:2014.

The UK participation in its preparation was entrusted to Technical Committee PRI/52, Adhesives.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Adhesives — Test methods for isotropic electrically conductive adhesives —

Part 9: Determination of high-speed signal-transmission characteristics

Adhésifs — Méthodes d'essai pour adhésifs à conductivité électrique isotrope —

Partie 9: Détermination des propriétés de transmission de signal à haute vitesse

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

TThe committee responsible for this document is ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

ISO 16525 consists of the following parts, under the general title *Adhesives — Test methods for isotropic electrically conductive adhesives*:

— *Part 1: General test methods*

— *Part 2: Determination of electric characteristics for use in electronic assemblies*

— *Part 3: Determination of heat-transfer properties*

— *Part 4: Determination of shear strength and electrical resistance using rigid-to-rigid bonded assemblies*

— *Part 5: Determination of shear fatigue*

— *Part 6: Determination of pendulum-type shear impact*

— *Part 7: Environmental test methods*

— *Part 8: Electrochemical migration test methods*

— *Part 9: Determination of high-speed signal-transmission characteristics*

Adhesives — Test methods for isotropic electrically conductive adhesives —

Part 9: Determination of high-speed signal-transmission characteristics

SAFETY STATEMENT — Persons using this part of ISO 16525 should be familiar with normal laboratory practice. This part of ISO 16525 does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any regulatory conditions.

IMPORTANT — Certain procedures specified in this part of ISO 16525 might involve the use or generation of substances, or the generation of waste, that could constitute a local environmental hazard. Reference should be made to appropriate documentation on safe handling and disposal after use.

1 Scope

This part of ISO 16525 specifies test methods to investigate the high-speed signal-transmission characteristics in the bonded portions of an isotropic electrically conductive adhesive, which joins the terminals of a surface mounted device (SMD) and the land grid patterns of a printed circuit board. It also investigates the characteristics of wiring with an isotropic electrically conductive adhesive, which can be applied on the printed circuit board.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 472, *Plastics — Vocabulary*

IEC 60194, *Printed board design, manufacture and assembly — Terms and definitions*

IEC 61190-1-2, *Attachment materials for electronic assembly — Part 1-2: Requirements for solder pastes for high-quality interconnections in electronics assembly*

IEC 61192-1, *Workmanship requirements for soldered electronic assemblies — Part 1 General*

IEC 61249-2-7, *Materials for printed boards and other interconnecting structures — Part 2-7: Reinforced base materials clad and unclad — Epoxide woven E-glass laminated sheet of defined flammability (vertical burning test), copper-clad*

IEC 61249-2-8, *Materials for printed boards and other interconnecting structures — Part 2-8: Reinforced base materials clad and unclad — Modified brominated epoxide woven fibreglass reinforced laminated sheets of defined flammability (vertical burning test), copper-clad*

IEC 61760-1, *Surface mounting technology — Part 1: Standard method for the specification of surface mounting components (SMDs)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and IEC 60194 and the following apply.

3.1
characteristic of high-speed signal transmission
characteristic of the deflection of an output signal, which is measured according to eye pattern

3.2
eye pattern
eye of the trapezoidal clock wave pattern used to check the transmission characteristics of digital signals

3.3
characteristic impedance of transmission line
specific impedance of the transmission line with its cross-sectional profile, which meets the signal transmission direction

3.4
scattering parameter
transmission energy at output port (port 2) and reflection energy at input port (port 1) under the electromagnetic energy of the sine wave at a certain frequency input form port 1

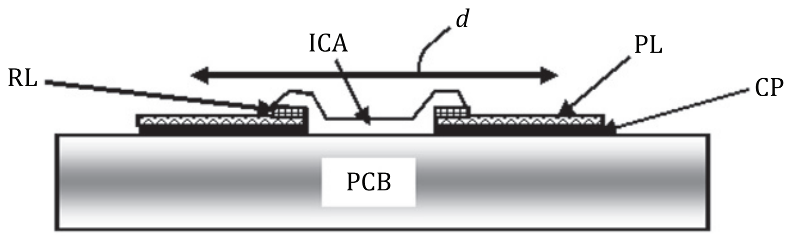
3.5
ball grid array package
BGA package
array of electrodes formed on the reverse side of, and connected to, the printed circuit using ball-like bumps of solder

4 Principle

There are two methods to investigate high-speed signal-transmission characteristics. In one method, a signal-transmission pattern is printed on a circuit board using an isotropic electrically conductive adhesive and then, the high-speed signal-transmission characteristics of the heat-hardened transmission pattern with an isotropic electrically conductive adhesive is measured. In the other method, the terminals and electrodes of SMDs are bonded to the land grid patterns of the printed circuit board using an isotropic electrically conductive adhesive. For reference, a lead-free solder is also used, and the high-speed signal transmission characteristics of the bonded portions is measured. The dimensions of the line and bonded portions with an isotropic electrically conductive adhesive are shorter than that of the copper line that is commonly used in circuit boards and SMDs. Therefore, the influence of the copper line on measurement is unavoidable, and it is difficult to extract the characteristics of the isotropic electrically conductive adhesive.

Therefore quantitative test methods need to be specified for showing the high-speed signal characteristics of wiring and bonded portions without the influence of copper lines.

NOTE These test methods are not intended for the high-speed signal properties of SMDs or printed circuit boards. Printed and bonded portions to be investigated are illustrated in Figure 1 (the X-Y plane) and Figure 2 (the Z-direction). Conditions of the isotropic electrically conductive adhesive in Figures 1 and 2 are intended to be according to the procedures (surface treatments, printing and curing) recommended by adhesive manufacturers.



Key

ICA isotropic electrically conductive adhesive

CP copper pattern

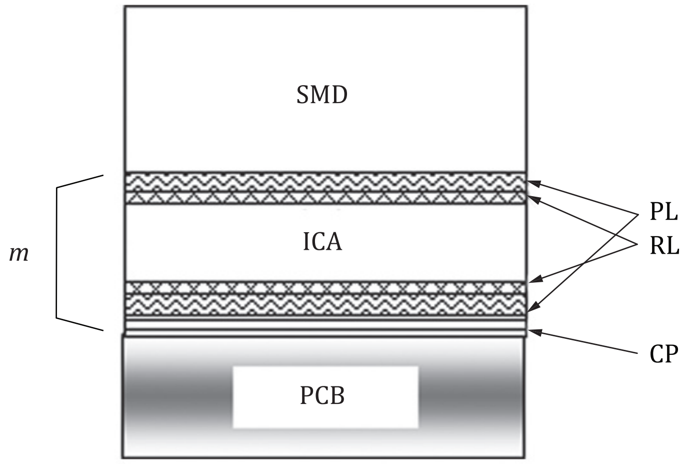
PCB printed circuit boards

d direction of signals

PL plating layer

RL reactive layer

Figure 1 — Illustration of circuit to be investigated (X-Y plane)



Key

ICA isotropic electrically conductive adhesive

CP copper pattern

PCB printed circuit boards

m measurement area

PL plating layer

RL reactive layer

SMD surface mounted device

Figure 2 — Illustration of bonded portions under investigation (Z-direction)

5 Apparatus and test circuit board

5.1 Apparatus for measuring digital signals, capable of measuring signal integrity using the eye patterns of the output signal, which is generated when clock-synchronizing random digital signals. It consists of two devices described in 5.1.1 and 5.1.2. For measurement, a standard circuit board should be screwed directly to each device using a coaxial cable. A typical eye pattern of the output signal is shown in Figure 3.

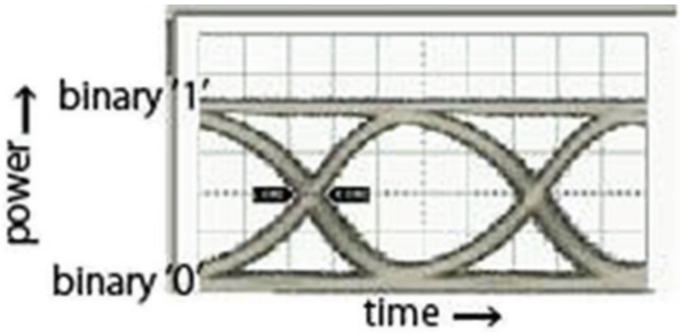


Figure 3 — A typical eye pattern

5.1.1 Random pulse generator, capable of generating digital random pulses, and which is connected to the input port of a standard circuit board. A random pulse generator with an output capacity from 0,05 Gbps to 12 Gbps is recommended.

5.1.2 Oscilloscope, used to measure the eye patterns of random waveforms generated through the output terminal of a test circuit board. It is connected to the output terminal of a test circuit board using a coaxial cable. An oscilloscope with a band up to 18 GHz is recommended.

5.1.2 Coaxial cable and a subminiature type A (SMA) connector, and an **SMA connector** with a band up to 20 GHz.

5.2 Apparatus for characteristic impedance measurement, consisting of a transmission line, used to measure the high-frequency characteristic. The transmission line shows characteristic impedance, and therefore the test circuit board is designed so that it can match the internal impedance of a measuring apparatus. A general value of the internal characteristic impedance of a test apparatus is 50 Ω. The apparatus is used to check whether or not the test standard circuit boar adapts to such internal impedance.

5.2.1 TDR-mode oscilloscopes, of high frequency, and equipped with the time domain reflection (TDR) mode for measurement. Firstly, match the y-axis with impedance and examine a reflection state of the step wave pattern. Then, examine the output value and profile to judge whether or not the characteristic impedance of the standard test circuit board has been matched with the designed one. Figure 4 shows an example of typical measurement. Apparatus with the rise time of step waveform 30 ps or shorter is recommended.

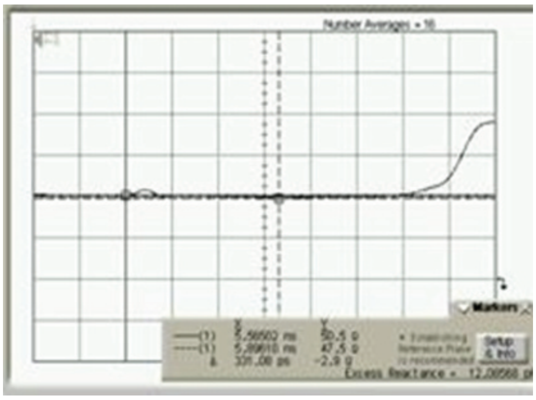
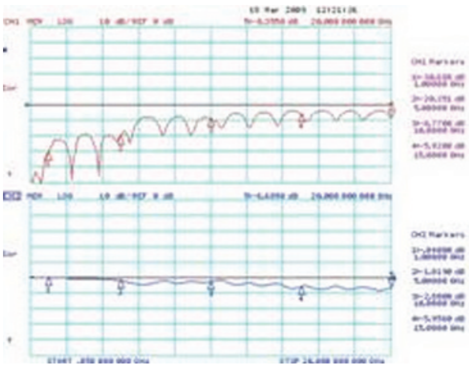


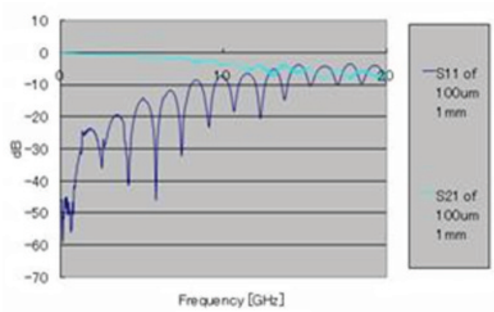
Figure 4 — Example of typical profile of the characteristic impedance measured in the TDR mode

5.3 Apparatus for measuring frequency characteristic. A digital signal is a composite wave that consists of sine waves, and in signal transmission it is essential not to change the ratio of such composite waves. Therefore after measuring the characteristic of wide-ranging frequencies of sine waves, the maximum level of the measured wave should be confirmed.

5.3.1 Network analyser, capable of measuring the scattering parameter, starting with calibration of the copper line pattern (on the test circuit board described in 5.4), whose line is identical in length to that of the standard test circuit board. By subtracting the measured value of the copper line pattern from that of the standard pattern, the characteristic of the line can be cancelled. This means that only the characteristic of the printed or bonded portion can be extracted. Connect the test circuit board to the network analyser using a coaxial cable. Figure 5 shows an example of typical measurement of S21 and S11. Apparatus with a measurement range from 50 MHz to 40 GHz is recommended. The range of measurement is usually from 100 MHz to 30 GHz (or 20 GHz depending on the relevant purpose).



a) Before subtraction



b) After subtraction

Key

X frequency (GHz)

Y signal (dB)

Figure 5 — Example of typical measurement of the scattering parameter

5.4 Test circuit boards, with the following specifications.

a) **Material of substrate**

Glass fabric-based epoxy resin copper-clad laminate with a double-sided (the X-Y plane), three-layer conductor (the Z-direction) substrate, as specified in IEC 61249-2-7.

b) **Thickness of substrate**

1,6 ± 0,2 mm (the X-Y plane) and 1,0 ± 0,15 mm (the Z-direction) as specified in IEC 61249-2-7.

c) **Dimensions of substrate**

As specified in 5.4 d). The substrate should be screwed to the test apparatus with its end-face soldered to an SMA connector (18 GHz).

Both ends of the board are connected to the SMA. Therefore, it is recommended that the dimensions of the ends of the substrate and the pattern comply with the drawing.

d) **Pattern and its dimensions**

Circuit pattern as outlined in Figure 6 (for a standard test circuit board for measurement of the X-Y plane) and Figure 7 (for a standard test circuit board for measurement of the Z-direction). Details are specified in Figure A.3. These dimensions are designed to minimize the influence of wiring and are therefore recommended.

e) **Plating**

Various substrates, according to the applications and specifications (recommended by the manufacturer) of isotropic electrically conductive adhesives, if their specifications conform to those in 5.4 d). Variation will be reflected in the high-speed signal transmission characteristic of printed and bonded portions. In other words, measured values will contain the characteristics of the interface of the bonded portions.

Dimensions in millimetres

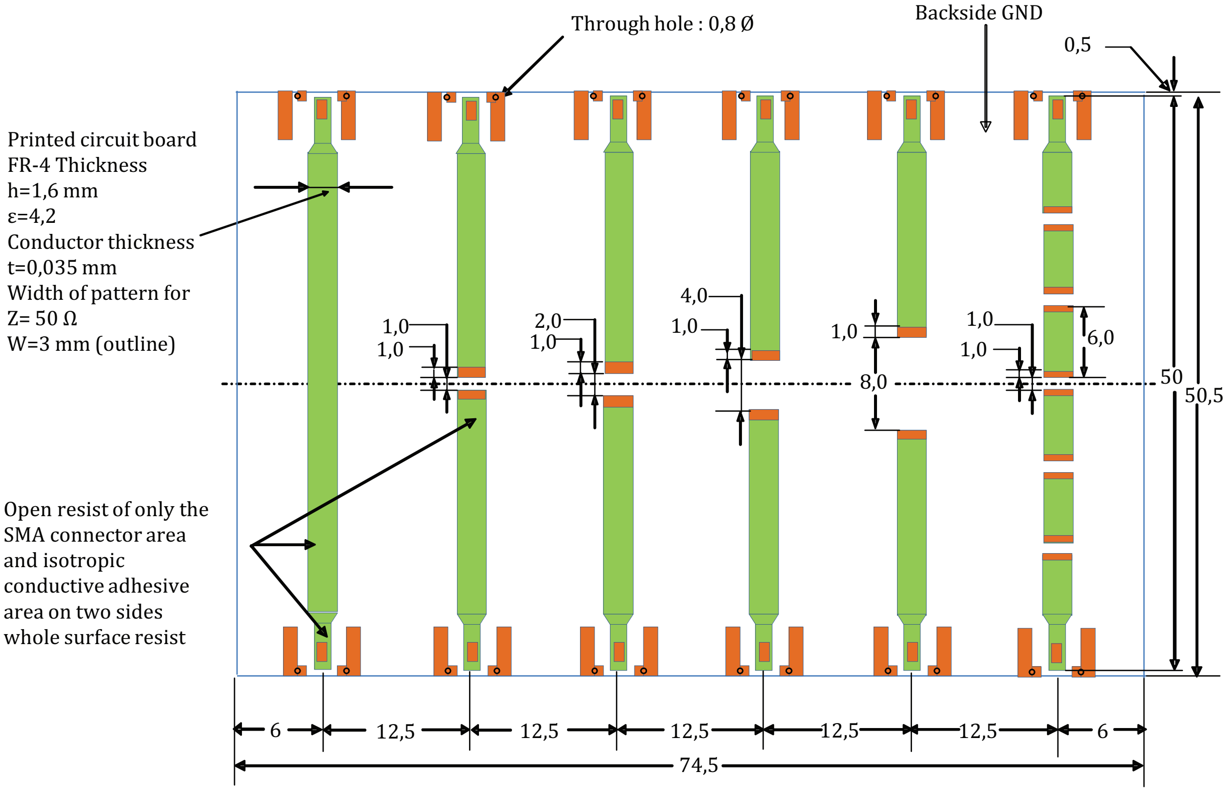
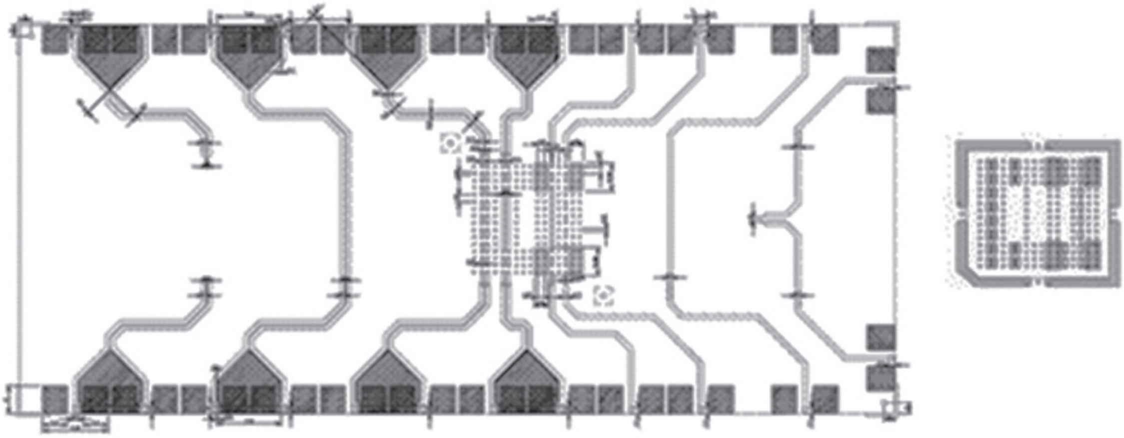


Figure 6 — Surface pattern of a test circuit board (in the X-Y plane)



The corresponding pattern of BGA package is shown on the right-hand side.

Figure 7 — Surface pattern of a test circuit board (in the Z-direction) and its corresponding pattern of BGA package

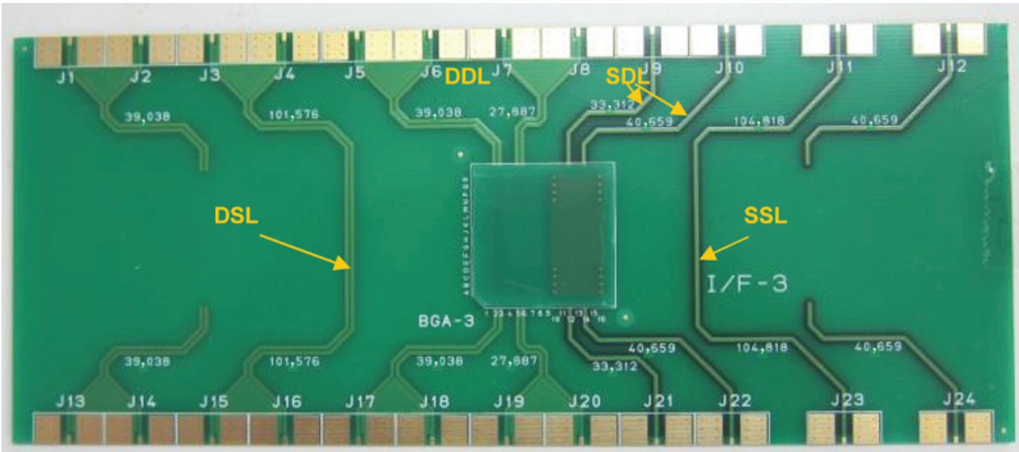
5.5 Isotropic electrically conductive adhesive, consisting of a paste material, containing an organic binder, generally a heat-curing resin, in which metal particles or flakes are dispersed. The isotropic electrically conductive adhesive is applied to the circuit board or package electrode by screen printing, potting by a dispenser, or inkjet spraying as wiring material, connection terminal, or bonding agent for LSI chips.

If necessary, heat is applied it after the secondary processing (assembly) to harden for the final procedure to create a test circuit board (see Annex B). The test circuit board is classified in two types: one for investigating the characteristics of the X-Y plane (i.e. wiring) and the other for investigating the characteristic of the Z-direction (i.e. connecting terminals or adhesive). This part of ISO 16525 uses the isotropic electrically conductive adhesive for the two types of standard test circuit board (see Figures 6 and 7).

6 Preparation of test circuit board

Assemble a standard test circuit board (see Figures 6 and 7) as follows: apply an isotropic electrically conductive adhesive to the test circuit board in accordance with the procedure described in 5.5, then solder an SMA connector (18 GHz) to the standard test circuit board (see Annex B). Figure 8 (the X-Y plane) and Figure 9 (the Z-direction) show the appearance of an assembly.

Figure 8 — Assembly of standard test circuit board for measurement in the X-Y plane



Key

BGA ball grid array

DDL differential daisy lines

DSL differential standard line

SDL single end daisy lines

SSL single end standard line

Figure 9 — Assembly of standard test circuit board for measurement in the Z-direction

7 Set-up

Set up the measuring apparatus by connecting one end of a coaxial cable with an SMA connector (attenuation 1,5 dB/m, 18 GHz) to the SMA connector (18 GHz) of the test circuit board, and the other end to the test apparatus using a 0,9 N·m torque wrench. Figures 10 and 11 show examples of set-up.

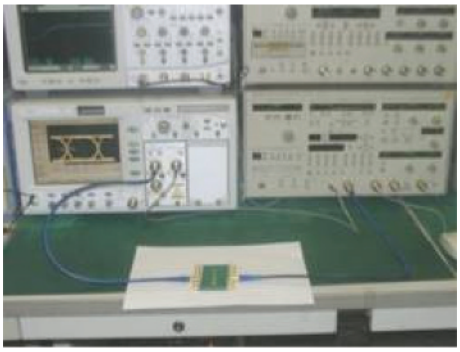


Figure 10 — Example of set-up for measurement of eye patterns

Figure 11 — Example of set-up for measurement of the scattering parameter

8 Tests

8.1 Test procedure

8.1.1 Measurement of the characteristic impedance on the TDR mode

Details of TDR measurement are specified in Annex C. An outline of TDR measurement is as follows: connect one end of the transmission line to be measured to the oscilloscope, leaving the other end unconnected; choose the TDR mode of the oscilloscope; with impedance indicated on the y-axis, and record the result. Since an isotropic electrically conductive adhesive will be applied to the centre of each standard test circuit board, set the marker at the midpoint between the input port of profile SMA and the output port of SMA. Get the value of the characteristic impedance at the marker position indicated. An example of typical measurement is shown in Figure 4 (as described in Clause 5).

8.1.2 Measurement of the digital signal characteristic

Details of measurement are specified in Annex C. An outline of the measurement procedure is as follows: connect one end of the transmission line to be measured to the pulse generator, and the other to the oscilloscope (see Figure 10); to match triggers, connect the output terminals of the pulse generator to the input terminal of the oscilloscope using a coaxial cable (see Figure 10).

a) As the first step of measurement, choose the 1 GHz clock-generating mode with the rise and fall time of the pulse generator, for example, at 35 ps (time between 10 % and 90 % of the voltage level) or shorter, the output waveform shall be recorded on the oscilloscope it. Set the measurement system so that values of the rise and fall time and Vamp (or VAMP, the voltage at the end of rise) can be recorded.

b) The random–pulse generating mode of the pulse generator shall be used to output pulses by clock frequency. Measure output waveforms using a satisfactory oscilloscope, and record the results. Set the measurement system so that values of eye height, eye width, intensity ratio of signal to noise (S/N) of the eye-pattern, and jitter root-mean-square (RMS) amplitude can be recorded.

8.1.3 Measurement of the scattering parameter

a) Details of measurement are specified in Annex C. Preparation for measurement starts with calibration of the network analyser. A coaxial cable with an 18-GHz SMA connector with attenuation 1,5 dB/m or lower is recommended. Connect one end of the coaxial cable to port 1 of the network analyser, and carry out SOLT calibrations (see Annex D). Connect the transmission line to be measured to the input and output ports (see Figure 11). Set the sweep frequency range of the network analyser to 50 MHz to 20 GHz, for example, measure the characteristics of S11 (reflection) and S21 (transmission), and record the results. Record the results at 1 GHz, 3 GHz and 20 GHz in order to check the differences in phases. Calculate the characteristics of the bonded vector portions (see Annex D).

b) For the standard circuit board for measurement of the X-Y plane, calibrate the network analyser using SOLT (see Annex D) (the copper line in the test circuit board for measurement in the X-Y plane) standards adjusted in accordance with Annex B. As in 8.1.3 a), connect the transmission line to be measured to the input and output ports (see Figure 11). Set the sweep frequency range of the network analyser to 50 MHz to 20 GHz, for example, measure the characteristics of S11 (reflection) and S21 (transmission), and record the results. Record the results at 1 GHz, 3 GHz, 10 GHz and 20 GHz in order to check the differences in phases. Caluculate the characteristics of the bonded vector portions (see Annex D).

8.2 Judgement

8.2.1 General

Criteria for judgement vary, according to the intended purposes; therefore, they cannot be expressed as values. An example is described as guidelines in Annex D. General criteria for judgement include the following.

8.2.2 Measurement of the characteristic impedance in the TDR mode

Compare the value of the characteristic impedance at the marked position in the standard pattern with that in the test circuit board.

8.2.3 Measurement of the digital signal characteristics

a) Compare the rise and fall times and VAMP (voltage after a rise is finished: called voltage amplitude) of the standard pattern with those of the test circuit board. The smaller the difference, the higher the high-speed performance.

b) Compare the eye pattern data, such as eye height, eye width and jitter RMS of the standard pattern with those of the test circuit board. Regarding S/N of the standard eye pattern, the smaller the difference, the higher the high-speed performance.

8.2.4 Measurement of the scattering parameter

The S parameter obtained as a result of vector operation is the extracted datum of the connection port. The high-speed performance is higher, as S11 is minimized and S12 is maximized against the sweep frequency.

9 Test report

The test report shall contain the following items. Some items may be selected from items b) to f) upon agreement between the delivering and receiving parties:

a) a reference to this part of ISO 16525, i.e. ISO 16525-9;

b) the name of the isotropic electrically conductive adhesive and its data, including the kinds of resin, filler material, manufacturer's code and lot number;

c) the method of preparation of the test circuit board, including the method of application, curing temperature, setting time, temperature, applied pressure and the procedures of adhesion;

d) the dimensions of the test circuit board, including the material and dimensions of the substrate, the pattern and dimensions of the circuit, and the number of substrates or samples;

e) the type of surface treatment for the electrode of the test circuit board;

f) the date, institution and atmospheric conditions (temperature and humidity) of the measurement;

g) the calculation conditions, such as voltage and current, of electrically volume resistivity and interfacial contact resistivity.

Annex A
(normative)

Sample structure used for the examination

A.1 General

This annex specifies the detailed requirements for measurement of the X-Y plane and the Z-direction of a standard test circuit board using an isotropic electrically conductive adhesive.

A.2 Material structure

The structure of the material, circuit boards (hereinafter a substrate) is in accordance with FR-4 in UL/ANSI, and GE4F in JIS. The thickness of the substrate, the soldering resistance and the copper foil are 1,6 mm, 20 µm and 35 µm, respectively.

A.3 Detailed dimensions of a standard test circuit board for measurement of the X-Y plane

Dimensions in millimetres

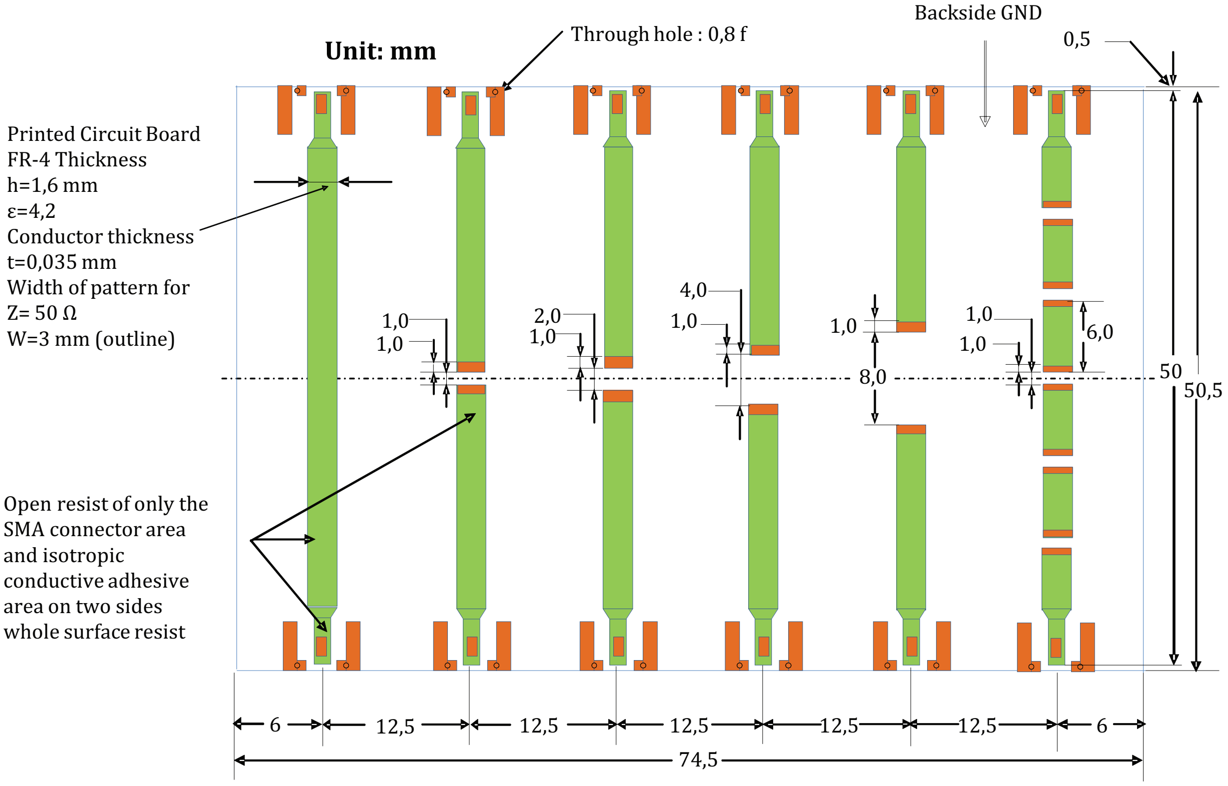
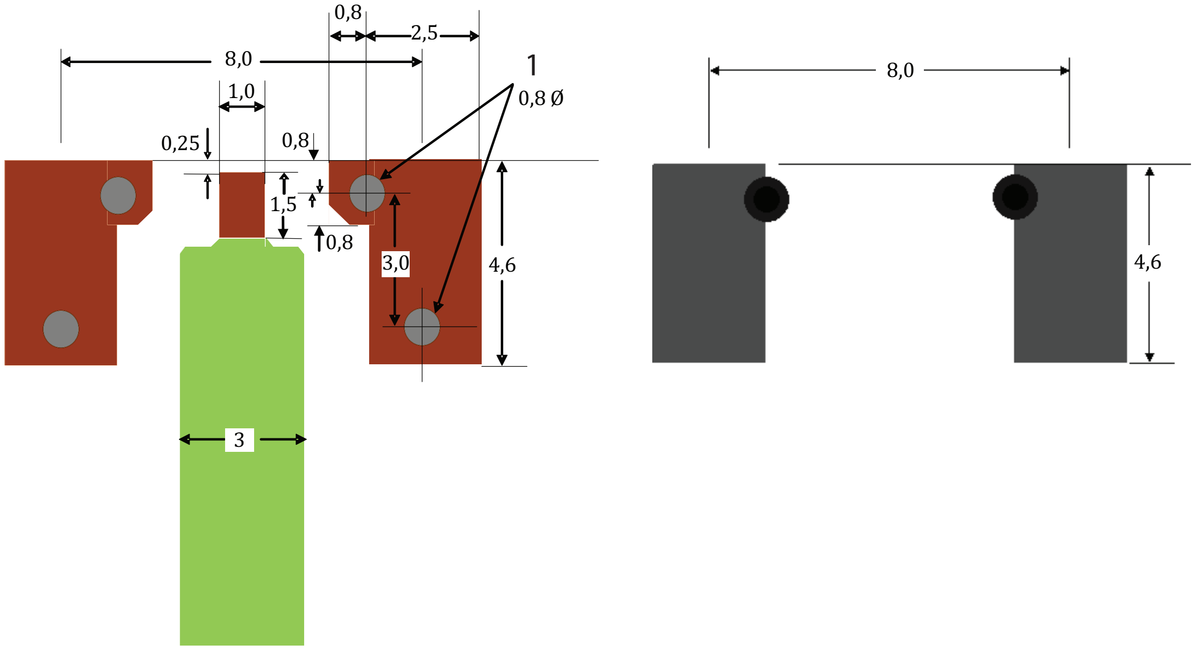


Figure A.1 — Plane dimensions of a standard test circuit board for measurement of the X-Y plane

Figure A.1 describes the plane dimensions of a standard test circuit board for measurement of the X-Y plane. The leftmost light grey pattern stands for copper pattern, and soldering resistance is applied to the entire surface without the leftmost copper pattern. This is used as a standard pattern without an isotropic electrically conductive adhesive. The next pattern has the same dimensions toward the right. There is a 1-mm cut line in the central portion. The end of the cut line, in other words, the positions indicated in dark grey are the opening sections of the copper (Cu) pattern without soldering resistance. These are connecting electrodes overlapping with the isotropic electrically conductive adhesive paste, which are printed afterwards. The right pattern indicates that the intervals of the upper and lower cut lines are widened in series and become a long pattern with an isotropic electrically conductive adhesive. The oblong cut line has six patterns from the left, which are 0 mm (no printing), 1 mm, 2 mm, 4 mm, 8 mm and 1 mm × 5 with 1,6 mm width. The dark grey portion on the upper and lower ends is the pattern for soldering an SMA connector, and this is a soldering register opening section. This end electrode matches with the interface of the characteristic impedance, and the details are described in Figure A.2. It is recommended to comply with the dimensions as well as the location of the through hole. The rear surface is the ground plane pattern and all the surfaces are covered by soldering resistance except for the circular area in black to the right-hand side of Figure A.2.

Dimensions in millimetres



Key

1 through hole

Figure A.2 — Dimensions of connector mounting polar zone at both surfaces

Apply the isotropic electrically conductive adhesive as described in Figure 8. Firstly, it is screen-printed on six designated patterns. After curing under the recommended conditions, it is soldered to the SMA connector using the minimum amount of solder with which the fillet is formed. The dimension of the connector is h = 1,7 mm.

Dimensions in millimetres

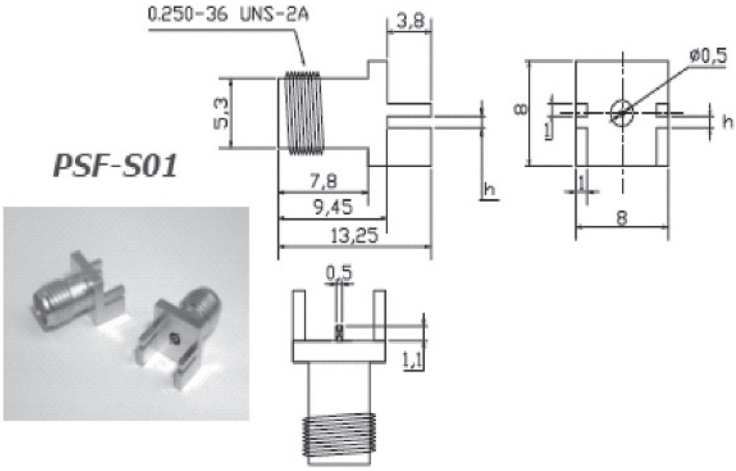
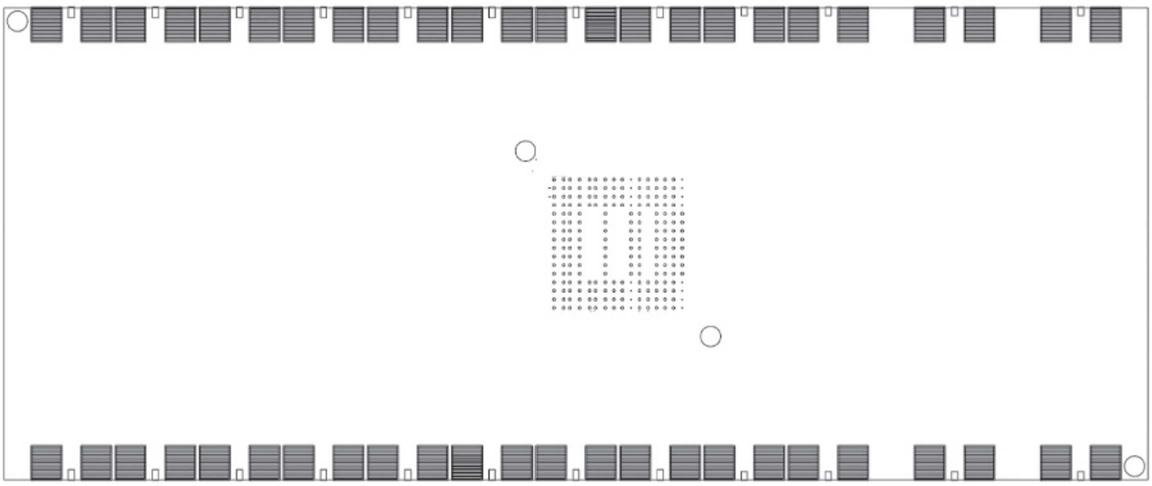


Figure A.3 — Dimensions of connector

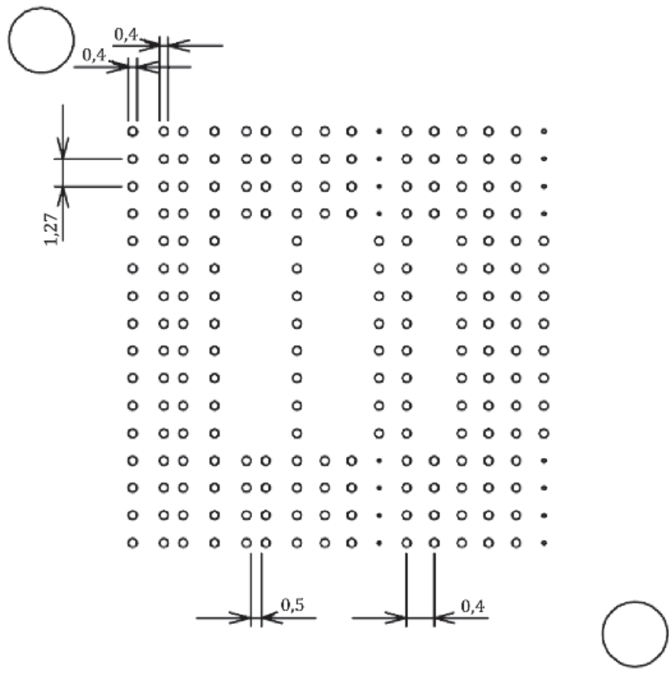
A.4 Detailed dimensions of a standard test circuit board for measurement of the Z-direction

The dimensions of surface of circuit board (substrate) for Z-direction measurement are shown in Figure A.4. The size of the substrate is 170 × 70 mm and the through hole diameter is 0,3 mm. Figures A.4 to A.9 show the pattern of each layer from the top layer. The wiring has three layers, which are indicated as L1, L2, and L3, respectively. Although the inner layer, L2 is ground, it should be noted that the pattern is according to L1, is required to avoid crosstalk. These dimensions are designed for high-speed signals and are therefore recommended. The drawing shall be enlarged when viewing.

Dimensions in millimetres



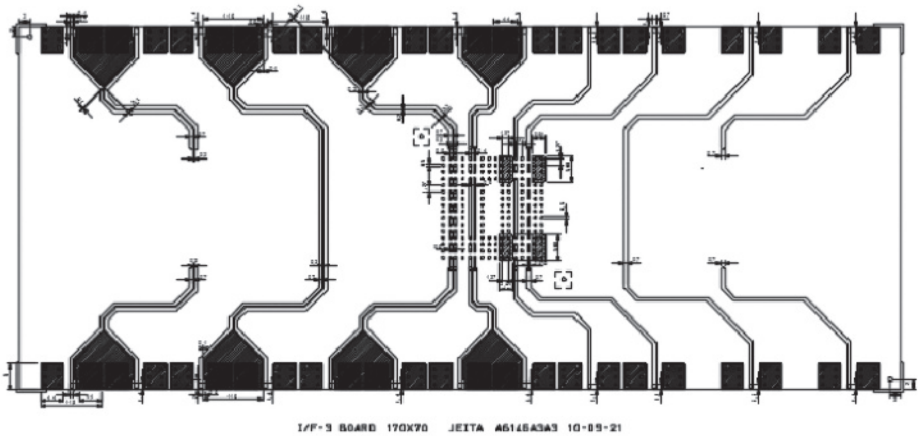
a) Resistance pattern



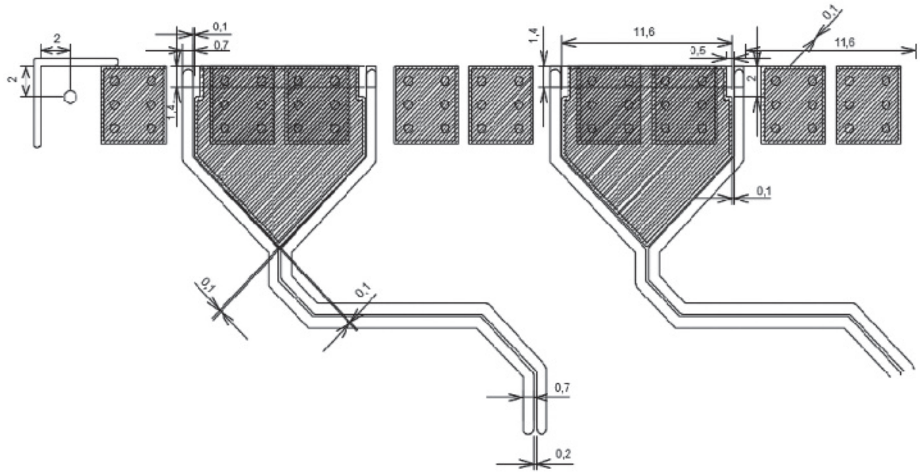
b) Centre section

Figure A.4 — Surface layer resistance pattern

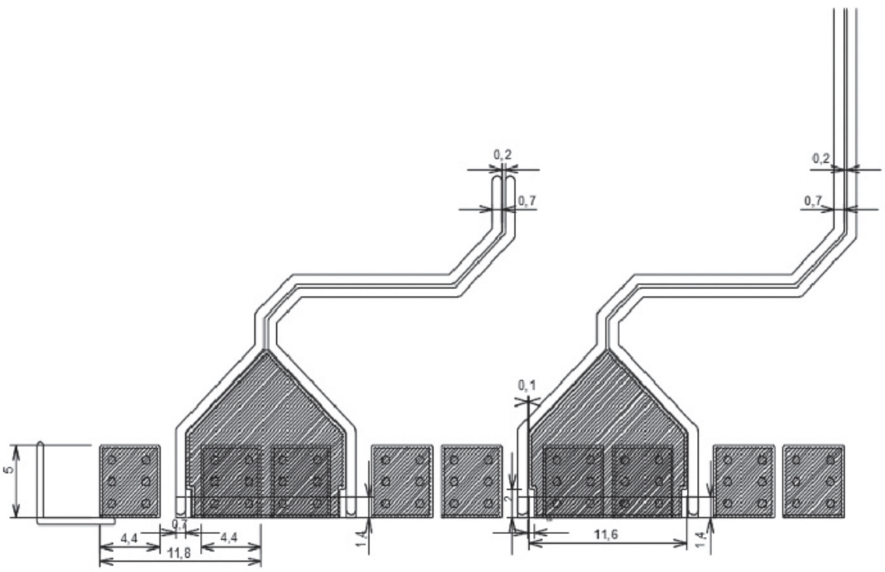
Dimensions in millimetres



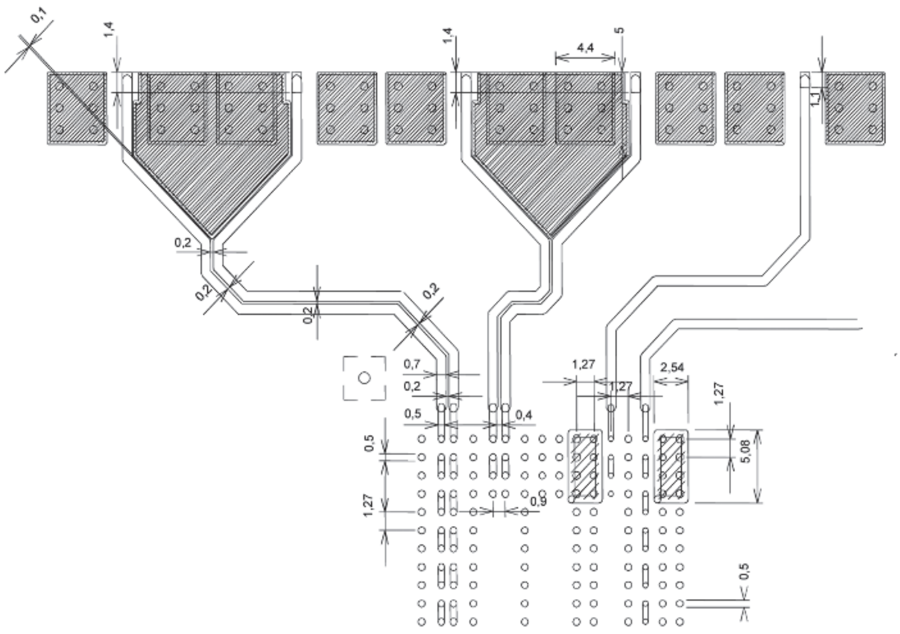
a) First layer pattern



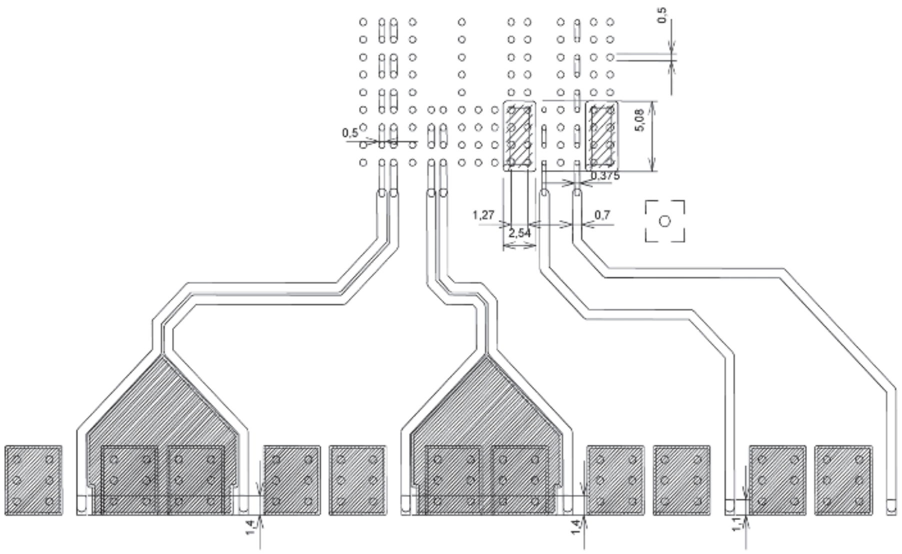
b) Upper left-hand side



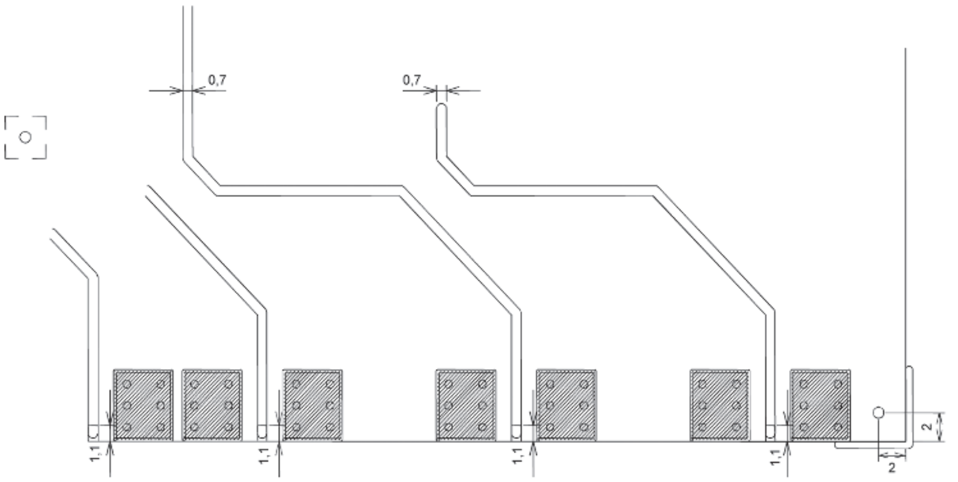
c) Lower left-hand side



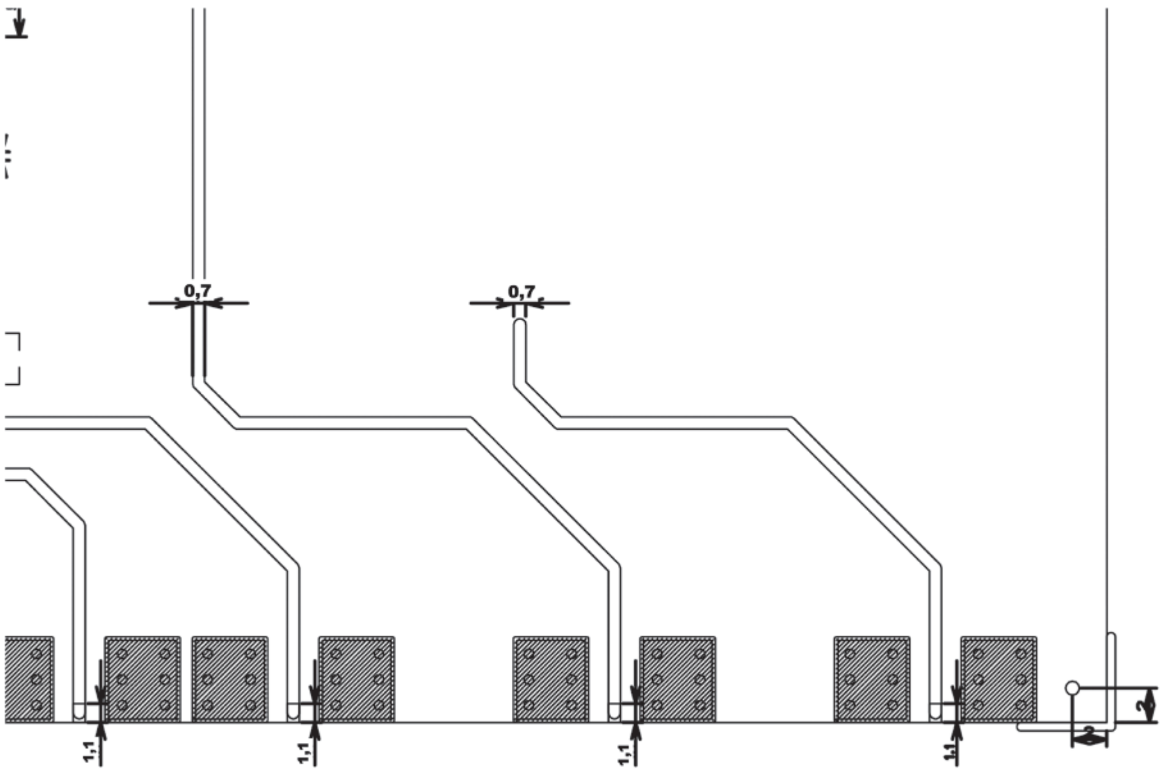
d) Upper centre section



e) Lower centre section



f) Upper right-hand side



g) Lower right-hand side

Figure A.5 — First layer pattern of substrate (Z-direction)

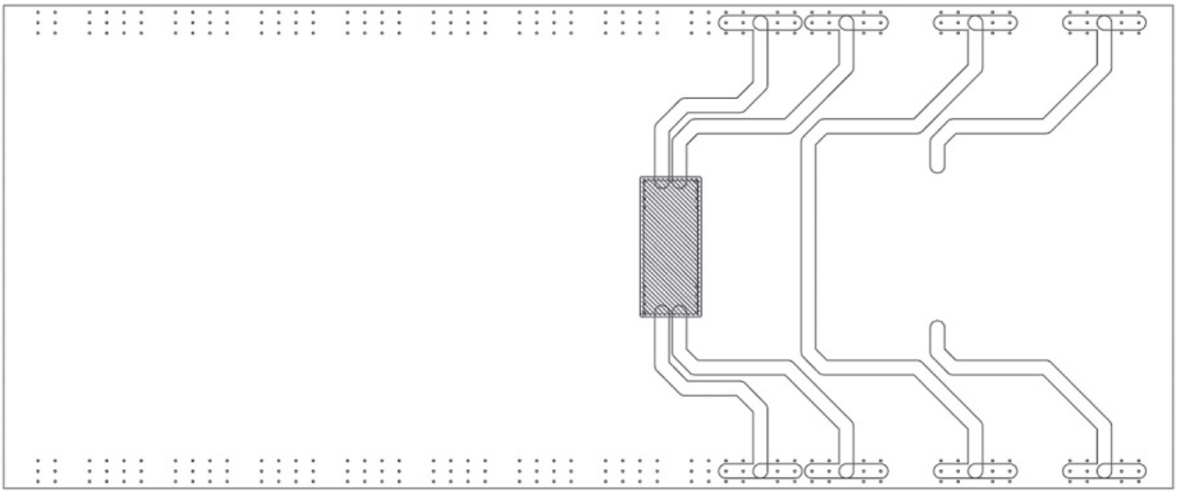


Figure A.6 — Second layer (inner layer) pattern

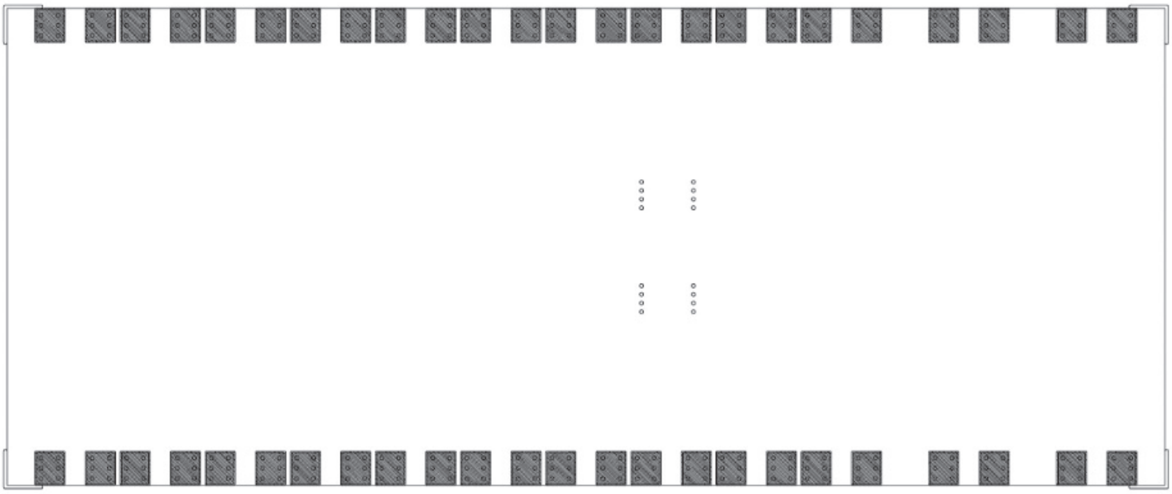


Figure A.7 — Third layer (rear surface) pattern

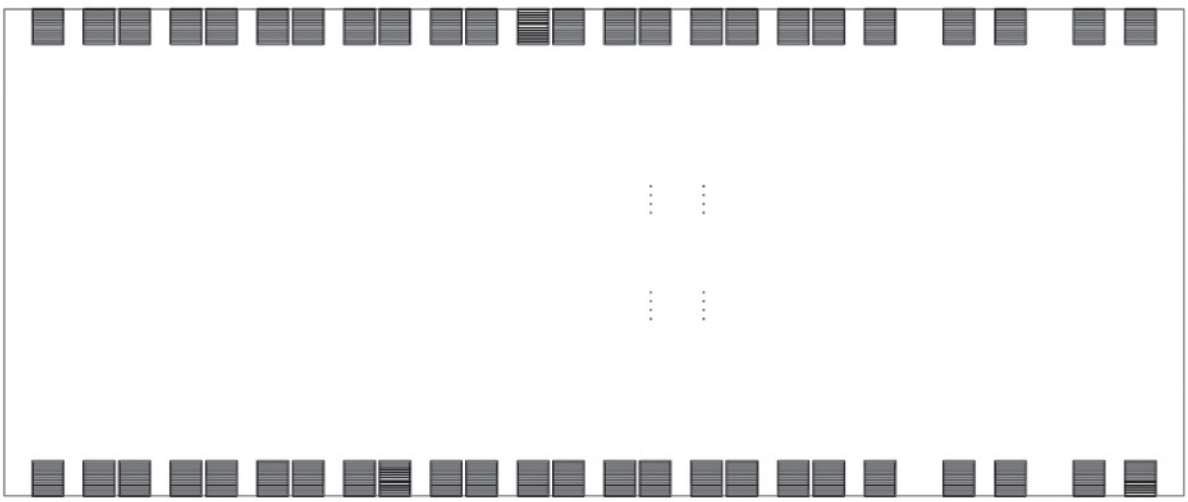
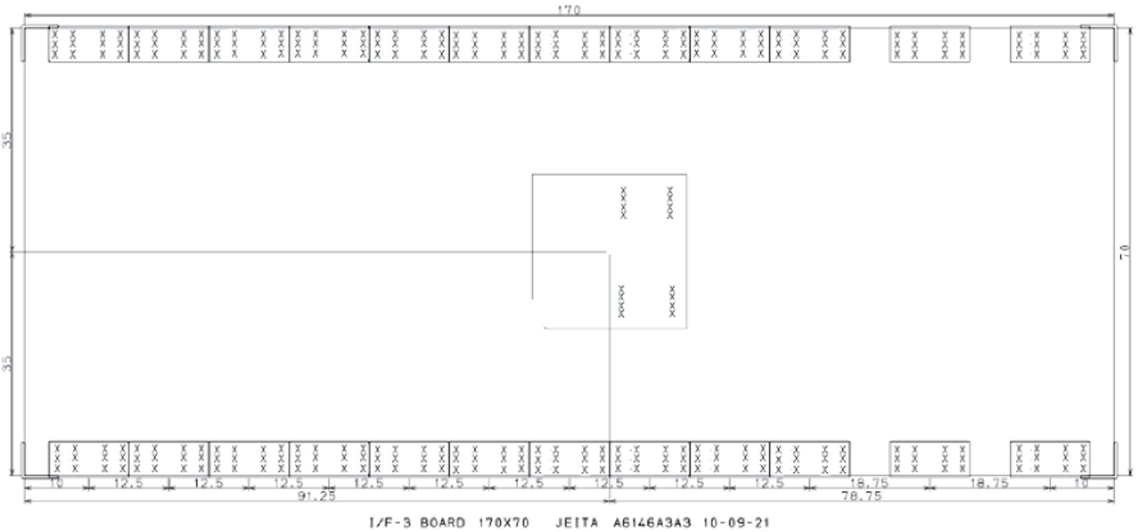


Figure A.8 — Rear surface layer resistance pattern

Dimensions in millimetres



The centre of the letter symbol “X” is the through hole position.

Figure A.9 — Indication of position of through hole

Figures A.4 to A.9 show the pattern of a standard test circuit board for measurement of the Z-direction, and Figures A.10 to A.15 show pattern diagrams of each layer for the corresponding BGA. Although these drawings are for multi-pattern printing, the number is arbitrary. In these cases, the BGA are equipped test circuit boards for the Z-direction with an 8 daisy chain or 16 daisy chain. The left and right substrate patterns are formed only with copper wiring and the same shape and length of wiring. This is the standard pattern to measure the high-frequency characteristics of the wiring only with no daisy chain connection. Single end signal (microstrip line as shown on the right half of Figure A.1) and differential signal (as shown on the left half of Figure A.1) create measurable patterns for each connection.

Figure A.13 shows the bonded surface pattern of a standard 23,5 × 23,5 mm BGA package. The pattern is labelled from the rear surface layer to the layer facing the standard substrate and it is exactly the same layer as the standard substrate.

The important points are the wiring of the BGA as shown in Figure A.5 d), and the 0,5mm-long wiring of the daisy chain, where the wiring length of the outer side is less than 0,7 mm due to adjustment of the impedance in the BGA overlap section. Although the diameter of the opening in the bonded portions is 0,4 mm, it is recommended to use 0,4 mm to 0,6 mm in diameter of isotropic electrically conductive adhesive. In order to compare the data with soldering, it is recommended that the thickness of the bonded portions be the same as that of the solder.

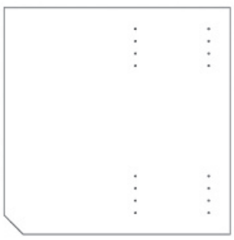


Figure A.10 — BGA surface layer resistance pattern

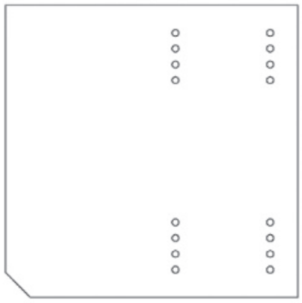


Figure A.11 — BGA surface layer pattern

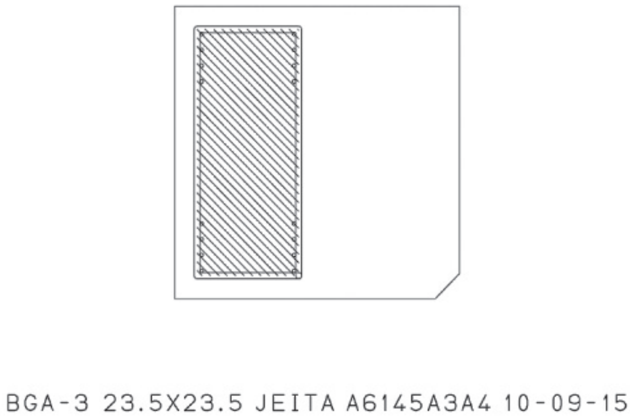


Figure A.12 — BGA inner layer pattern

Dimensions in millimetres

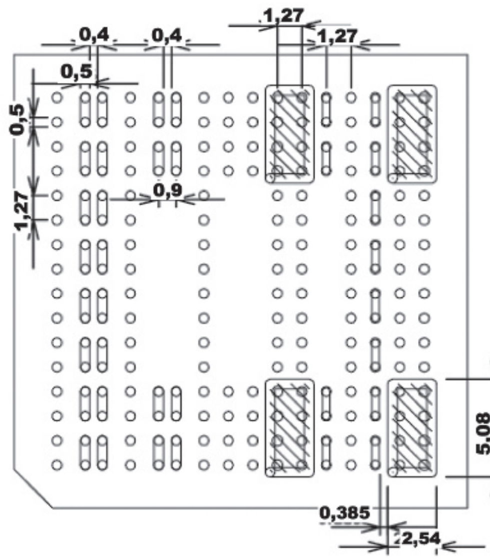


Figure A.13 — BGA bonded surface wiring pattern

Dimensions in millimetres

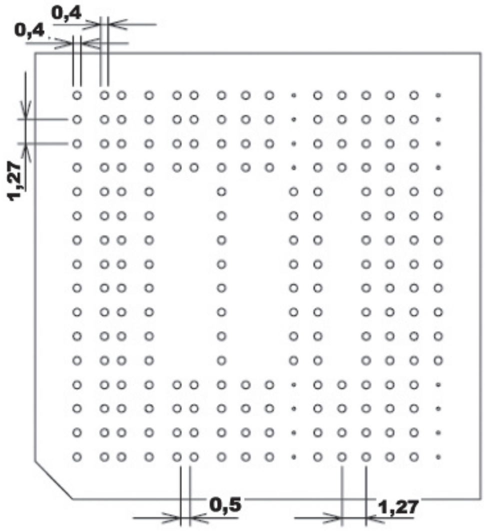
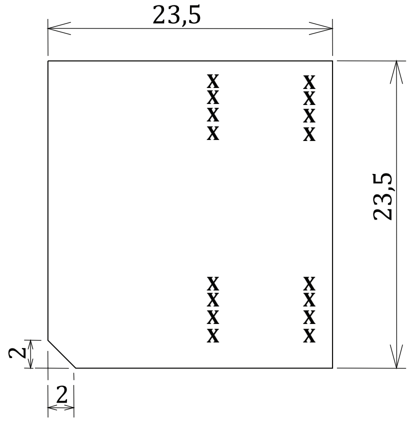


Figure A.14 — BGA bonded surface resistance pattern

Dimensions in millimetres



BGA-3 23,5 X 23,5 JEITA A6145A3A4 10-09-15

Figure A.15 — Indication of position of BGA through hole

Figure A.16 shows the cross-section structure when connected. The thickness of the substrate and that of BGA are exactly the same. The thickness of the insulating layer on the ground surface of the inner layer is 0,4 mm, which is the same as the thickness of both the substrate and BGA. It is recommended that these dimensions be used.

Dimensions in millimetres

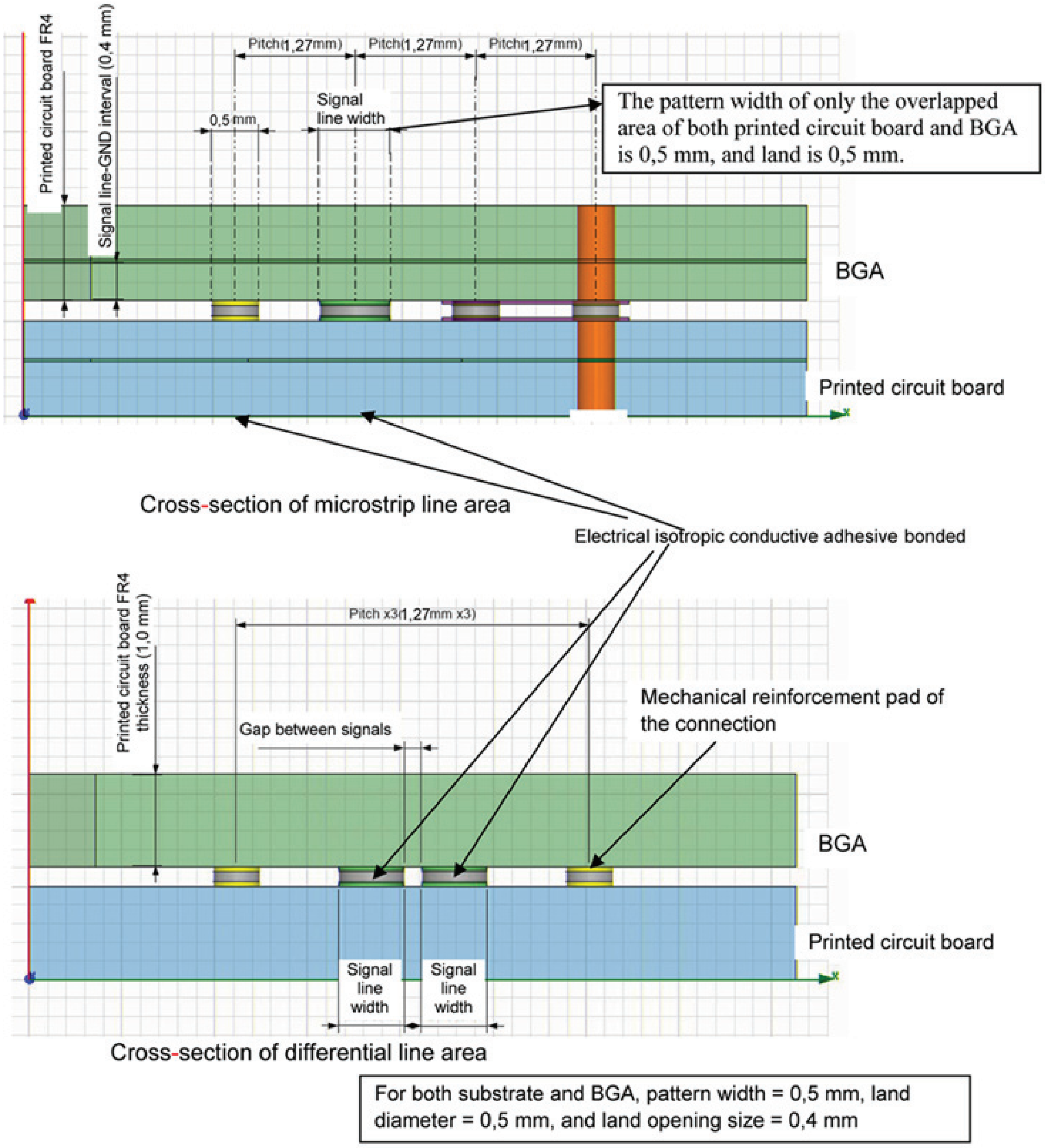


Figure A.16 — Structure and dimensions of thickness direction after a standard test circuit board for measurement of Z-direction and standard BGA to be connected

The pads, other than those indicated as a signal line in Figure A.16, are mechanical reinforcement pads. The plan view of the 16 daisy chain bonded portions of the single end (microstrip) line and the same bonded portions of the differential line are described in Figure A.17.

The dimensions shown are optimized and it is, therefore, recommended that they be used.

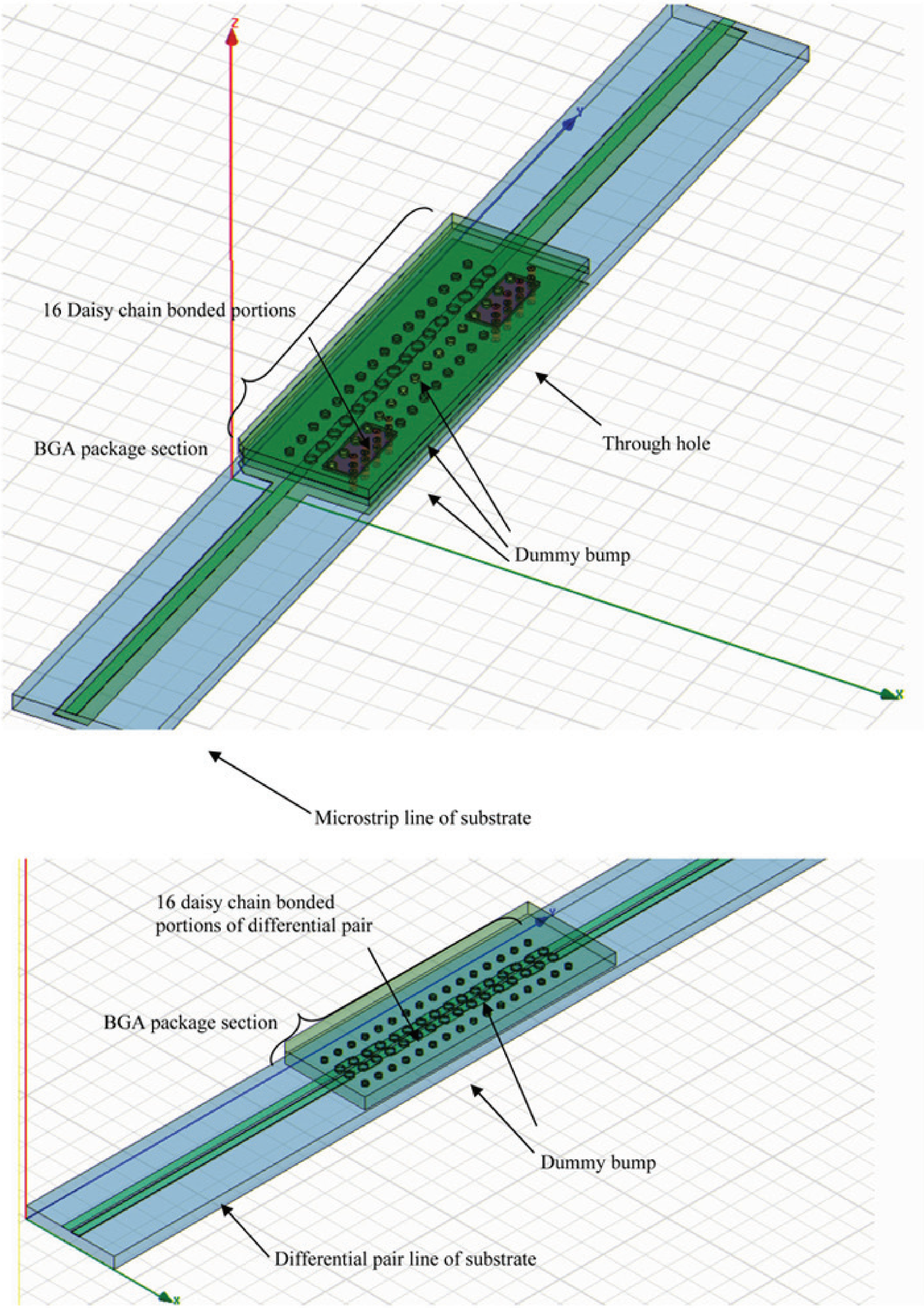


Figure A.17 — Plan view of the 16 daisy chain bonded portions of the single end line and the same bonded portions of the differential line

Annex B
(normative)

Test procedure

B.1 General

This annex specifies the measuring procedure for determining the electric high-frequency characteristics of the object.

B.2 Measuring procedure using a circuit board for measurement of the X-Y plane

a) Prepare several printed circuit boards for measurement of the X-Y plane described in A.3.

b) Prepare the isotropic electrically conductive adhesive paste to be measured.

c) Select and carry out the procedure for coating the bonded portions of the substrate with an isotropic electrically conductive adhesive film by means of screen printing mask or inkjet dispensing. The thickness of the adherend depends on the purpose of the target under test.

d) After coating, cure the isotropic electrically conductive adhesive. The curing depends on the purpose or the recommended condition of the isotropic electrically conductive adhesive.

e) After curing, solder the electrodes of the substrate and the SMA connector which matches the thickness of the substrate. It is recommended to use a connector with characteristics of 18 GHz or more. The fillet of the solder should look as if it were wet with liquid in order not to rise like a bump.

f) Place the substrate on which the isotropic electrically conductive adhesive and SMA connector are mounted, in front of the measuring machine. Connect the coaxial cable which ends in the SMA, and connect the other side of the cable to the measuring machine. The substrate should not be placed directly on a conductive mat as an electrostatic discharge (ESD) object, but on an insulating sheet or a plate on the mat.

g) Measure the substrate according to 8.1. As specified in Figure 6, the substrate has six lines. The leftmost line is a standard with copper wiring.

h) Input the measurements into the computer for analysis. The data are frequently judged by differentiating them from standard wiring. Follow the method of analysis in Annex D, and the criteria for judgement in 8.2.

B.3 Measuring procedure using a circuit board for measurement of the Z-direction

Prepare several substrates for measurement of the Z-direction and BGAs, which are matched in patterning to these substrates as described in A.4.

a) Prepare the isotropic electrically conductive adhesive paste to be measured.

b) Select and carry out the procedure for coating the bonded portions of the substrate with an isotropic electrically conductive adhesive film. For example by screen printing or by dispensing and inkjet selection. The thickness of the adherend depends on the purpose of the target under test.

c) After coating, cure the isotropic electrically conductive adhesive, adjusting the height of BGA to the specified position. Curing conditions depend on the purpose or the recommended condition of the isotropic electrically conductive adhesive. When the viscosity decreases, put the spacer between the substrate and the BGA in order to maintain the space.

d) After curing, solder the electrodes of the substrate and the SMA connector which matches the thickness of the substrate. It is recommended to use a connector with characteristics of 18 GHz or greater. The fillet of the solder should appear wet with liquid in order not to rise like a bump.

e) Place the substrate with the isotropic electrically conductive adhesive and SMA connector in front of the measuring machine. Connect the coaxial cable (attenuation is 15 dB/m or lower, 18 GHz specification) which ends in the SMA, and connect the other side of the cable to the measuring machine. The substrate should not be placed directly on a conductive mat as an ESD object, but on an insulating sheet or a plate on the mat.

f) Measure the substrate according to 8.1. As specified in Figure 7, the substrate has six lines. The rightmost line(single end wiring) and the leftmost line(differential wiring) are standards with copper wiring only.

g) Input the measurements into the computer for analysis. The data are frequently judged by differentiating from this standard wiring. Follow the analysis method described in Annex D and the criteria for judgement in 8.2.

Annex C
(normative)

Test equipment and example of implementation of the test

C.1 General

This annex specifies the test equipment for measuring the electrical high-frequency characteristics of the target and the example of implementation of the test.

C.2 Measurement of X-Y plane

C.2.1 General

The measurement of X-Y plane is only for single end wiring.

C.2.2 Measurement of the characteristic impedance in the TDR mode

Equipment: TDR scope (The specification required for the equipment is on a performance of step wave slew rate less than 35 ps.) as characteristic impedance measurement equipment. An example of implementation of the test is described below.

a) A TDR scope is very easily broken down by static electrical charge. Therefore, be sure to install the scope on the spot where the anti-static measurement is taken; while operating the equipment, an anti-static strap is required as protective clothing.

b) Install SMA cable to the cable connector of the TDR scope.

   Use a torque wrench to install the SMA cable and ensure that the cable is not loose.

c) Install the opposite end of the above b) cable to the SMA connector of the transmission line of the substrate. Use a torque wrench and ensure that the installation was carried out without any looseness.

d) Set the TDR scope in accordance with this document, as below. Firstly, set the time resolution of the x-axis of the scope (time/div) to 100 ps or 200 ps. Adjust the starting time of the TDR scope, referring to 3 ps for adjustment of the step generator. Next, set the marker. Adjust the position of the TDR waveform between the position of the SMA connector of the substrate output end after passing through the transmission line (daisy chain) and that of the substrate input end. Set the position of the waveform so that the middle point comes to the centre of the coordinate on the display. At this point, display two markers on the screen. Carry out a test by setting up the first marker on the connector input end and the second at the centre of the display so that each characteristic impedance value (Ω) can be measured by the marker and complete preparation of the data capturing (hard copy).

C.2.3 Digital signal characteristics measurement

a) Pulse pattern generator (PPG) output section and the input section of the sampling oscilloscope can be damaged by static electrical charge. Therefore, wear an anti-static strap when operating the equipment.

b) In general, most of the products can switch the output of PPG at Gigabits per second (Gbps) class on/off. Check that PPG output is off in advance and install the PPG pulse output connector to the SMA cable. In addition, install the separate SMA cable to PPG trigger output connector. Use a torque wrench to install the SMA cables and ensure that the cable is not loose.

c) Install the opposite end of the SMA cable, which is connected to the PPG pulse output to the SMA connector of the transmission line of the substrate. Use a torque wrench and ensure that the installation is properly carried out without any looseness.

d) Install the SMA cable to the SMA connector of the opposite side of the transmission line of the substrate. Use the torque wrench for installation in the same manner as c) above.

e) Install the opposite end of the SMA cable of the substrate to the signal input connector of the sampling oscilloscope. In addition, install the opposite side of the SMA cable of PPG trigger output connector to the trigger input connector of the sampling oscilloscope. Use the torque wrench for installation in the same manner as c) and d) above.

f) Set parameters for selecting each low and high voltage of PPG, bit rate, and RZ/NRZ (Return-to-zero for single wave form/Non-return-to-zero for eye pattern wave form). Switch the PPG output on, switch the sampling oscilloscope to the normal waveform observation mode and start the observation. Adjust the delay time so that the rise or fall section of the observation waveform is located in the centre of the display and adjust the time resolution (time/div.) so that the inclination of rise and fall can be observed. Use the measurement utility of rise and fall time, Vamp, which are embedded in the sampling oscilloscope and set each measurement value so that it can be recorded. When the measurement of the rise and fall waveform and rise and fall time, and VAMP is completed, stop recording, and obtain the observation data by saving the hard copy to the sampling oscilloscope display.

g) Start observation by switching the sampling oscilloscope to eye-measurement mode. Adjust the time axis of the sampling oscilloscope so that the waveform of just one cycle (unit interval: UI) can be displayed. Use the measurement utility of eye height (eye-open height), eye width (eye-open width), and VAMP (voltage amplitude), which are embedded in the sampling oscilloscope and set each measurement value so that it can be recorded. Because the sampling oscilloscope records eye waveform by overwriting repeatedly, stop recording when the repeating reaches the limit count (50 times in this example of the procedure) and obtain the observation data by saving the hard copy to the sampling oscilloscope display.

C.2.4 S-parameter characteristics measurement

a) Vector network analyser (VNA) input/output section can be damaged by static electrical charge; therefore, install the scope where the anti-static measurement is taken with an anti-static strap when operating the equipment.

b) For VNA use, calibration task (calibration: CAL) is necessary prior to measurement. In this test, the same axis cable with SMA connector may be used for connecting and wiring to the object being measured; therefore, use the same axis connection system for CAL. Carry out short-open-load-through (SOLT) CAL of Full 2 (for single end) when measuring the S-parameter with which the reverse direction of input/output can be measured because the object to be measured has a pair of input/output ends as a transmission line. In order to carry out SOLT CAL, use the calibration kit (CAL kit), which is provided separately by the VNA equipment manufacturer. Although there are SMA connectors (e.g. APC 3,5 mm connector), whose size usually matches, substitutes may be used and various types of high-frequency coaxial connectors (e.g. N-shaped connectors, K-shape connectors and APC 7 mm connectors), take care to use the same type of connector as that used for the object to be measured. The looseness of the portion where the connector is installed can significantly affect the value of the high-frequency measurement. Therefore, in order to measure with high-accuracy, the torque wrench shall be used for setting the connector.

c) Prior to calibration and characteristics evaluation measurement, set the frequency range (start/stop frequency), Measurement point (measurement score within the frequency range), RBW (Resolution Band Width: receiving detector bandwidth limitation width) and other values to be measured in VNA. Set the trigger for measurement to “continuous” to continue sweeping the frequency.

d) Carry out the calibration by operating VNA. Carry out Full 2 Port CAL (SOLT) by referring to the manuals/handbooks of each device to find the procedures of Full 2 Port CAL. For CAL operation, it is preferable to use the torque wrench for setting a SMA connector and it is important to confirm that the connector is not loose when carrying out tasks. When the CAL is completed, store the calibration data in the device's internal memory and prepare for starting the measurement.

e) Measure the characteristic (S-parameter) of the object with the VNA. Use the torque wrench and connect the opposite end surface of the cable extended from VNA to the SMA connector of the object to be measured. Select S11 (reflection characteristic) and S21 (transit characteristic) for S-parameter data which the VNA displays. In addition, switch the display format to frequency characteristic display (LOG MAG, etc.) of decibels, and set the standard level (0 dB) and the line position of the standard level (normally, for vertical 10 scales, the second from the top) and amplitude interval (10 db/div) arbitrarily by VNA operation. When saving S-parameter characteristic as a chart, use the hard copy saving function on the VNA screen. When saving the S-parameter for each measured frequency, as ASCII data, obtain the data by operating VNA as the saving function in touchstone format. Carry out these operations by referring to the operating manuals/handbooks of each device.

C.3 Z-direction measurement

C.3.1 Measurement of the characteristic impedance in the TDR mode

Equipment: TDR scope (The specification required for the equipment is on a performance of step wave slew rate less than 35 ps.) as characteristic impedance measurement equipment. An example of implementation of the test is described below.

C.3.1.1 Measurement of single end mode case

a) A TDR scope can be damaged by static electrical charge; therefore, install the scope where the anti-static measurement is taken; while operating the equipment, an anti-static strap is required as protective clothing.

b) Install an SMA cable to the cable connector of the TDR scope. Use a torque wrench to install the SMA cable and ensure that the cable is not loose.

c) Install the opposite end of the above-mentioned cable [see b)] to the SMA connector of the transmission line of the substrate. Use the torque wrench and ensure that the installation is properly carried out without any looseness.

d) Set a TDR scope in accordance with this part of ISO 16525 as follows. Firstly, set the time resolution of x-axis of the scope (Time/Div) to 100 ps or 200 ps. Switch the y-axis of the scope to impedance value display (Ω) and set the longitudinal centre to 50 Ω. Adjust the starting time of the TDR scope, referring to 3 ps for adjustment of the step generator. Next, set the marker. Adjust the position of the TDR waveform between the position of the SMA connector of the substrate output end after passing through the transmission line (daisy chain) and that of the substrate input end. Set the position of the waveform so that the middle point comes to the centre of the coordinate on the display. At this point, display two markers on the screen. Carry out a test by setting up the first marker on the connector input end and the second at the centre of the display so that each characteristic impedance value (Ω) can be measured by the marker and complete preparation of the data capturing (hard copy).

e) Conduct a test.

C.3.1.2 Measurement of differential mode case

Use the above-mentioned procedures for single end measurement of basic equipment operation etc. However, for differential measurement, the cable connection shall be twice the single end measurement, using a cable with the same length (physical length/electric length / electric character). Furthermore, because it is necessary to adjust the subtle phase difference up to the cable connecting point (skew adjustment), carry out the adjustment by referring to the operating manuals/handbooks of the devices being used.

C.3.2 Digital signal characteristic measurement

C.3.2.1 General

Equipment: PPG as a random pulse generator: Repetitive sampling oscilloscope as an eye pattern measurement device. An example of implementation of the test is described below.

C.3.2.2 Measurement of single end mode case

a) PPG output section and the input section of the sampling oscilloscope can be damaged by static electrical charge; therefore, install the scope where the anti-static measurement is taken; while operating the equipment, an anti-static strap is required as protective clothing.

b) In general, most of the products can switch the output of PPG at Gigabits per second (Gbps) class on/off. Check that PPG output is off in advance and install the PPG pulse output connector to SMA cable. In addition install the separate SMA cable to the PPG trigger output connector. Use a torque wrench to install the SMA cables and ensure that the cable is tight.

c) Install the opposite end of the SMA cable, which is connected to the PPG pulse output to the SMA connector of the transmission line of the substrate. Use a torque wrench and ensure that the installation is tight.

d) Install the SMA cable to the SMA connector of the opposite side of the transmission line of the substrate. Use the torque wrench for installation in the same manner as in c) above.

e) Install the opposite end of the SMA cable of the substrate to the signal input connector of the sampling oscilloscope. In addition, install the opposite side of the SMA cable of the PPG trigger output connector to the trigger input connector of the sampling oscilloscope. Use the torque wrench for installation in the same manner as in c) and d) above.

f) Set parameters, such as the selection of each Low and High voltage of PPG, Bit Rate, and RZ/NRZ. Switch the PPG output on, switch the sampling oscilloscope to the normal waveform observation mode and start the observation. Adjust the delay time so that the rise or fall sections of the observation waveform are located in the centre of the display and adjust the time resolution (time/div) so that the inclination of rise and fall can be observed. Use the measurement utility of rise and fall, and VAMP, which are prepared as the embedded function of the sampling oscilloscope and set each measurement value so that it can be recorded. When measurement of the rise and fall waveform and rise and fall, and VAMP is completed, stop the recording of the sampling oscilloscope, and obtain the observation data under the status. Save the observation data on the sampling oscilloscope display.

g) Start observation by switching the sampling oscilloscope to Eye measurement mode. Adjust the time axis of the sampling oscilloscope so that the waveform of just one cycle (Unit Interval: UI) can be displayed. Use the measurement utility of eye height (eye-open height), Eye width (Eye-open width), and VAMP (voltage amplitude), which are embedded in the sampling oscilloscope and set each measurement value so that it can be recorded. Because the sampling oscilloscope records eye waveform by overwriting repeatedly, stop recording when the repeating reaches the limit count (50 times in this example of the procedure) and obtain the observation data by saving the hard copy to the sampling oscilloscope display.

C.3.2.3 Measurement of differential mode case

Use the above-mentioned procedures for single end measurement, measurement of basic equipment operation, etc. However, for differential measurement, the cable connection shall be twice the single end measurement using a cable with the same length (physical length/electric length/electric character). Furthermore, because it is necessary to adjust the subtle phase difference up to the cable connecting point (skew adjustment), carry out the adjustment by referring to the operating manuals/handbooks of the devices used.

C.3.3 S-parameter characteristics measurement

C.3.3.1 General

Equipment: VNA as an S-parameter measurement device. An example of implementation of the test is described below.

C.3.3.2 Measurement of single end mode case

a) VNA input/output section can be damaged by static electrical charge; therefore, install the scope where the anti-static measurement is taken; while operating the equipment, an anti-static strap is required as protective clothing.

b) For VNA use, the CAL task is necessary prior to measurement. In the example of this test, the same axis cable with SMA connector can be used for connecting and wiring to the object to be measured; therefore, use the same axis connection system for CAL. Carry out SOLT CAL of Full 2 (for single end) when measuring the S-parameter with which the reverse direction of input/output can be measured because the object to be measured has a pair of input/output ends as a transmission line. In order to carry out SOLT CAL, use the calibration kit (CAL Kit), which is provided by the VNA equipment manufacturer. Although there are SMA connectors (e.g. APC 3,5 mm connector, whose size matches) in most cases, a substitute may be used, and various types of high-frequency coaxial connectors (e.g. N-shape connectors, K-shape connectors and APC 7 mm connectors), take care to use the same type of connector as that used for the object to be measured. The looseness of the portion where the connector is installed can significantly affect the value of the high-frequency measurement. Therefore, in order to measure with high accuracy, use the torque wrench to set the connector.

c) Prior to calibration task and characteristic evaluation measurement, set frequency range (start/stop frequency), measurement point (measurement score within the frequency range), RBW (Resolution Band Width: receiving detector bandwidth limitation width) and other values to be measured in VNA. Set the trigger for measurement to “continuous” to continue sweeping the frequency.

d) To obtain the data of the S-parameter in the BGA substrate interval, there is a function called “port extension” in the VNA operating manual, etc. This function provides the ability to move the calibration surface by moving the bonded portions of the calibration surface up to the length of electric line. Firstly, carry out port 1 CAL at the centre of the cable, which is extended from VNA port 1. Carry out port 1 CAL procedure by referring to the VNA operating manual/handbook. Next, connect the cable for which port 1 CAL was carried out to J12 (open-end pattern; make reference to Figure E.9) connector of the substrate by using the torque wrench. Set the display format of VNA measurement so that the data displayed on the Smith Chart can become S11. Operate VNA so that the port extension function can be used under this status (see the operating manual/handbook of each device used). On the operation surface of the port extension function, the delay value can be adjusted. Adjust the value so that it converges to as near to the right edge as possible of the data trace on the screen (about 100 ps as a target). After the adjustment is completed, write down the delay value. The value is equivalent to the round-trip time of the transmission line, connected to J12, to the release end. Therefore, half of the value is the time for the length of electric line up to the release end in J12. This value becomes the port extension value of the connection, which becomes the transmission line in J10 (see Figure E.9). In the same way, for port 2 of VNA, carry out the series of tasks to obtain the delay value, which is necessary for port extension of the port 2 side by adjusting the delay value after carrying out port 1 CAL and subsequently connecting the cable to J24 (other side open-end; see Figure E.9) of the substrate. Pay attention that the half value of the delay is the port extension value in J24, and at the same time, the port extension value in J22 (see Figure E.9).

e) In preparation for characteristic evaluation measurement, carry out calibration task (CAL) by operating the VNA. Firstly, for the delay operated in d) above, set 0 s (undo). Operate the VNA and carry out full 2 port CAL (SOLT). Be sure to refer to the operating manuals/handbooks of each device to be used to find procedures of full 2 port CAL. For CAL operation, it is preferable to use the torque wrench for setting the SMA connector and it is important to confirm that the connector is not loose when carrying out tasks. When CAL is completed, store the calibration data in the device's internal memory and prepare for starting the measurement.

f) Measure the characteristic (S-parameter) of the object with the VNA after CAL is completed. Firstly, carry out characteristic evaluation measurement between J10 to J22. Use the torque wrench and connect the opposite end surface of the cable extended from VNA to the SMA connector of the object to be measured. Select S11 (reflection characteristic) and S21 (transit characteristic) for S-parameter data which the VNA displays. In addition, switch the display format to frequency characteristic display (LOG MAG, etc.) of decibels, and set the standard level [0 dB], the line position of the standard level [normally, for vertical 10 scales, the second from the top] and amplitude interval [10 db/div] arbitrarily by VNA operation. S-parameter, which becomes electrical characteristics of the BGA interval section, can be measured by using the port extension function and by setting up the delay value of each port, which was defined in the procedure in d) above to each port (J10 for port 1, J22 for port 2). When saving the S-parameter characteristic as a chart, use the hard copy saving function on the VNA screen. When saving the S-parameter as ASCII data, obtain the data by operating VNA as the saving function in touchstone format. Carry out these operations by referring to the operating manuals/handbooks of each device. Next, carry out characteristic evaluation measurement between J09 and J21 (transmission line with 8 daisy chains). The transmission line to directly obtain its delay value, which is applied to the port extension between J09 and J21 (see Figure E.9 for each), is not prepared on the evaluation substrate. Therefore, obtain the ratio of the length of transmission line up to BGA interval of J09 and J21 to the length of transmission line of J12 and J24, and correct the calculation of the Delay value obtained, which was by measuring J12 and J24. This becomes port extension value of J09 and J21. The physical length of the transmission line mentioned is a given value, which the person in charge of the test can find from the silk printing of the evaluation substrate surface. The ratio of length is J09/J12 = 0,819 because the transmission line length of J12 is 40,659 (mm) (indicated on Figure E.9), and the transmission line length up to the BGA interval of J09 is 33.312 (mm) (indicated on Figure E.9). In the same way, the ratio of length becomes J21/J24 = 0,819 because the transmission line length of J24 is 40,659 (mm) (indicated on Figure E.9) and the transmission line length of J21 is 33,312 [mm] (indicated on Figure E.9). For port 1 side, enter the value, which is obtained by multiplying the port extension value at J12 (J10 is the same) by 0,819, as the port extension value, and for port 2 side, input the value, which is obtained by multiplying the port extension value at J24 by 0,819, as the port extension value, respectively. Carry out the same measurement procedures as the above-mentioned for between J10-J22 (lengths indicated on Figure E.9) when connecting J09 and J21 to other cables and saving measurement data.

C.3.3.3 Measurement of differential mode case

a) Comply with the procedures for the above-mentioned single end measurement for basic equipment operation when carrying out differential measurement. There are four VNA Ports for carry out differential measurement. Make two pairs for each port and handle them as differential port 1/port 2. The measurement is carried out by connecting input pair/output pair as a transmission line for the target to be measured. In order to avoid causing big phase difference in each pair, carry out measurement and connection with the cable of nearly the same length.

b) Use port extension functions for differential measurement and prepare for obtaining S-parameter characteristic data in the BGA interval. Handle the VNA ports 1 and 2 pair as differential port 1. In the same way, handle the ports 3 and 4 pair as differential port 2. Firstly, connect a cable to VNA port 1 and carry out port1 CAL. In the same way, carry out port 1 CAL for port 2, port 3 and port 4 in the same order. Next, connect the cable from port 1 to J01 connector (see Figure E.9) of the measurement substrate, and connect the cable from Port 2 to J02 connector (see Figure E.9). In the same way the cable from port 3 to J13 (see Figure E.9), and the cable from port 4 to J14 (see Figure E.9) by using a torque wrench respectively. Operate the VNA so that the port extension function can be used under this status (see the operating handbooks/manuals of each device used.) On the operation surface of port extension function, the delay value can be adjusted. Adjust the value so that it converges to as near the right edge as possible of the data trace on the screen. After the adjustment is completed, write down the delay value. The value is equivalent to the round-trip time of the transmission line, which was connected to J01, to the release end. Therefore, half of the value is the time for the length of electric line up to the release end in J01. This value becomes the port extension value of the connection, which becomes the transmission line in J05 (see Figure E.9). In the same way, operate the port extension function for VNA Port 2 and obtain the delay value of J02. The half value is regarded as the port extension value in J06 (see Figure E.9). Operate port 3 and port 4 with the same procedure and obtain the port extension values in J17 and J18 (see Figure E.9 each).

c) From this point, carry out CAL as a preparation for characteristic evaluation measurement. Prior to CAL operation, set all the delay values of port extension operated at each port from port 1 to port 4 to 0 s (undo). Operate VNA and carry out the differential Full 2 port CAL (SOLT). Make reference to the operating manual/handbook of each device used in order to find the procedures for the differential Full 2 port CAL. For CAL operation, it is preferable to use the torque wrench for setting SMA connector and it is important to confirm that the connector is not loose when performing the tasks. When CAL is completed, store the calibration data in the device's internal memory and prepare to begin the measurement.

d) Measure the characteristics (S-parameter) of the object to be measured with VNA, which CAL completed. Firstly, as for differential measurement, carry out characteristic evaluation of differential S-parameter for J05/J06 pair and J17/J18 pair (see Figure E.9). In order to obtain the differential S-parameter, carry out setup so that the VNA is operated in differential mode. Carry out these operations for differential mode by referring to the operating manual/handbook of each device. The S-parameter for Sdd11 (reflection characteristics in a differential mode) and Sdd21 (transit characteristic in a differential mode) are to be measured. Refer to the procedures of single end measurement for operation of the data display. When the data are displayed, specify the delay value of each port (ports 1 to 4) as in c, above by using port extension function. Then, measure the S-parameter as the electrical characteristics of the BGA interval. When saving the S-parameter characteristic as a chart, use the hard copy saving function on the VNA screen and when saving the S-parameter as ASCII data, obtain the data by operating VNA as the saving function in touchstone format. Carry out these operations by referring to the operating manual/handbook of each device. Next, carry out characteristic evaluation between J07/J08 and J19/J20 (transmission line with 8 daisy chains) (see Figure E.9 for each). The transmission line to directly obtain its delay value, which is applied to the Port Extension between J07/J08 and J19/J20, is not prepared on the evaluation substrate. Therefore, obtain the ratio of the length of transmission line up to BGA interval of each J07, J08, J19 and J20 for the length of transmission line of each J01, J02, J13 and J14, and correct the calculation of the delay value, which was obtained by measuring J01, J02, J13 and J14. This becomes port extension value of J07, J08, J19 and J20. The physical length of the transmission line mentioned is a given value (all the lengths indicated in Figure E.9 as 27,887 mm, respectively), which the person in charge of the test can find from the silk printing of the evaluation substrate surface. Because the transmission line length of each J01, J02, J13 and J14 are 39,038 [mm] each, the ratio of length becomes J07/J01 = 0,714, and the same ratio is true of J08/J02, J19/J13 and J20/J14. Multiply the ratio by the delay value as a port extension for each port, enter and set the value. In this way, carry out measurement of the S-parameter by applying the port extension function to J07, J08, J19 and J20.

Annex D
(normative)

Application procedure for isotropic electrically conductive adhesive — Example

D.1 General

This annex specifies the measurement results of electrical high-frequency characteristics of a an object, in comparison with the standard transmission lines, and the electrical characteristics of the isotropic electrically conductive adhesive or soldering connection and other technology acting as the standard, and judgement guidelines for these results.

D.2 Measurement of X-Y plane

D.2.1 Measurement of characteristic impedance in the TDR mode

Compare the characteristics of each transmission line with isotropic electrically conductive adhesive wiring and those of the basic pattern (transmission line without isotropic electrically conductive adhesive wiring), which is set up on the test substrate (X-Y plane). Because the electrical characteristics of the isotropic electrically conductive adhesive are different from the those of copper, as for the TDR profile, the value of the characteristic impedance in the isotropic electrically conductive adhesive section changes. Observe the amount of change, the wiring length of the isotropic electrically conductive adhesive section, and the length (electrical length) of the interval where the characteristic impedance is changing, by considering the correlation of each length type.

D.2.2 Digital signal characteristic measurement

Compare how each transmission line with isotropic electrically conductive adhesive wiring influences rectangular waveform and changes the electrical characteristics for the basic pattern (transmission line without isotropic electrically conductive adhesive wiring), which is set up on the test board (X-Y plane). Observe changes in the rise and fall times and amplitude (Vamp) for changes in rectangular waveform.

As for the comparison with the standard pattern, focus the attention on the change in waveform against each length of the isotropic electrically conductive adhesive section and also on how the multiple reflections, which attribute to the repeated wiring between the pattern where isotropic electrically conductive adhesive wiring is repeated and the single pattern, affect the rectangular waveform and carry out observations.

D.2.3 S-parameter characteristic measurement

Compare how the length of each isotropic electrically conductive adhesive wiring influences the S-parameter characteristic between the basic pattern (without isotropic electrically conductive adhesive) set on the test substrate (X-Y plane) and under the status when the transmission line with isotropic electrically conductive adhesive wiring is incorporated on the way. Alternatively, when observing characteristics of the S-parameter for each length of only the wiring portion of the isotropic electrically conductive adhesive (excluding the wiring pattern with repeated adhesive wiring), prepare a test substrate without applying the isotropic electrically conductive adhesive as a jig for calibration, perform set up to move calibration surface by using the port extension function of the network analyser (VNA) and transmission line pattern without isotropic electrically conductive adhesive; connect and change to the same transmission pattern of the test substrate for which the isotropic electrically conductive adhesive is applied. By doing so, the S-parameter characteristic can be observed. As an observation point of S-parameter, focus on the change of cut off frequency of the high-pass side where the difference in loss starts to become greater than the loss at the low-pass side of S21 (transit characteristic).

D.3 Z-direction measurement

D.3.1 Measurement of characteristic impedance in the TDR mode

Compare electrical characteristics between the basic pattern (transmission line without isotropic electrically conductive adhesive wiring), which is on the test substrate (Z-plane) and the transmission line with the BGA connection (many/few daisy chain connections, each transmission line). Furthermore, by means of preparing a test substrate with a soldering joint of the BGA connection, it is possible to compare the solder, which is the existing connection technology, with an isotropic electrically conductive adhesive.

D.3.2 Digital signal characteristic measurement

Compare how the rectangular waveform is affected and how electrical characteristics are changed between the standard pattern on the test substrate (Z-direction) (transmission line without BGA substrate connection) and the transmission line with the BGA connection (many/few daisy chain connection, each transmission line). Observe the rise and fall times and the amplitude (Vamp) for change in rectangular waveform. Furthermore, by means of preparing a test substrate with a soldering joint of a BGA connection, it is possible to compare the solder, which is the existing connection technology, with an isotropic electrically conductive adhesive.

D.3.3 S-parameter characteristic measurement

Compare how the S-parameter characteristics are different between the transmission line, which is a standard pattern on a test substrate (Z-direction) (transmission line without BGA substrate connection) and the transmission line with the BGA connection (many/few daisy chain connections, each transmission). Furthermore, by means of preparing a test substrate with a soldering joint of a BGA connection, it is possible to compare the solder, which is the existing connection technology, with an isotropic electrically conductive adhesive.

By using the port extension function of the measurement method as explained in Annex C, it is possible to measure the S-parameter of the standard pattern, as a transmission length of only the BGA interval section, and the relevant section of the transmission line with BGA connection. As an observation point of S-parameter, focus on the change of intercept frequency of the high-pass side where the difference in loss starts to become greater than the loss at the low-pass side of S21 (transit characteristic).

Annex E
(normative)

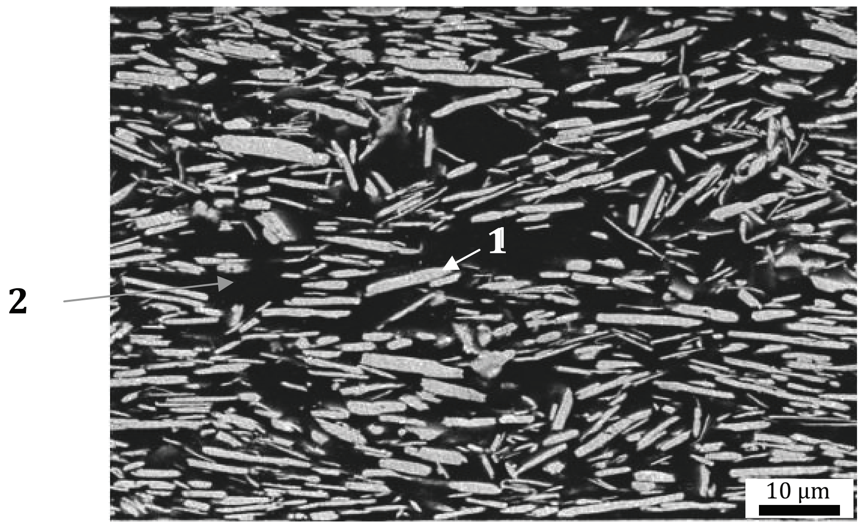
Application of isotropic electrically conductive adhesive — Measurement example

E.1 X-Y plane standard substrate measurement — Example

E.1.1 Digital signal eye pattern measurement — Example

Print an isotropic electrically conductive adhesive with cross-section structure as shown on Figure E.1 on the X-Y plane standard substrate, which is made according to Figures A.1 to A.3, and describe the measurement of inputting the digital signal for standard substrate after surface treatment. Figure E.2 shows the completed standard substrate. The length of the print is set so that six types of 0 mm (copper wiring only, comparison wiring), 2 mm, 4 mm, 6 mm, 8 mm and 2 mm × 5 can be compared except for electrode connected portion.

Dimensions in micrometres



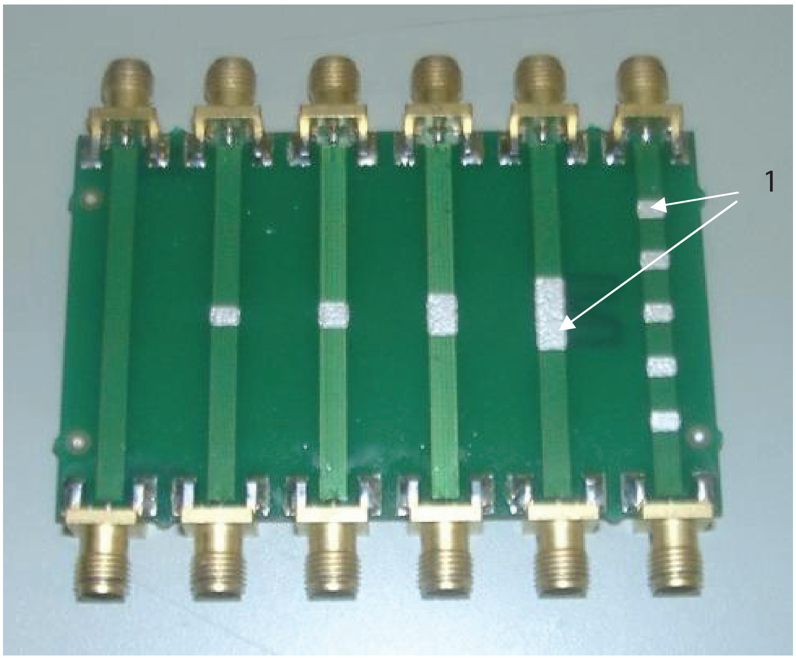
Key

1 Ag flake

2 epoxy resin

Figure E.1 — Cross-section microstructure after curing of an isotropic electrically conductive adhesive

For deposition, screen printing is used and three types of thickness, 80 µm, 100 µm and 150 µm are tested. Each DC resistance of the entire wiring is shown in Table E.1. Next, TDR measurement result is shown (see Figure E.3). The centre y-axis dashed-line is the centre of the isotropic electrically conductive adhesive printing section, and the characteristic impedance of this section is shown.



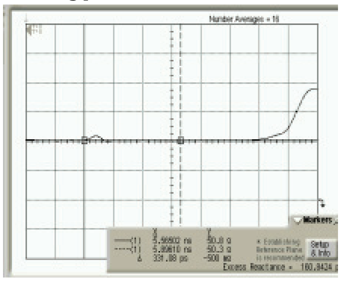
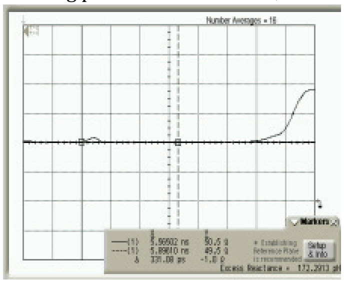
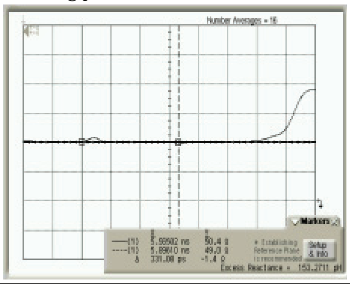
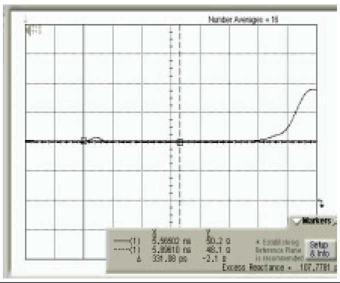
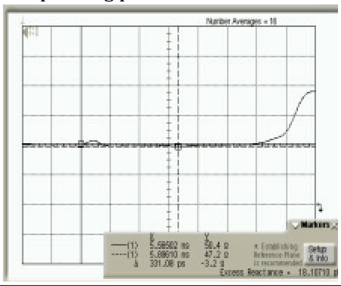
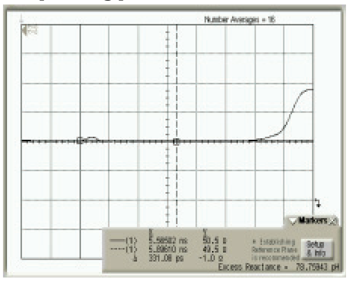
Key

1 printing portion of an isotropic electrically conductive adhesive

Figure E.2 — X-Y plane standard measurement substrate with printed isotropic electrically conductive adhesive

Table E.1 — DC resistance of entire circuit including isotropic electrically conductive adhesive printing section

Printing length /thickness	0 mm	1 mm	2 mm	4 mm	8 mm	1 mm × 5
80 µm	0,01	0,01	0,01 to 0,02	0,02	0,03	0,02
100 µm	0,01	0,01	0,01	0,02	0,02	0,02
150 µm	0,01	0,01	0,01	0,02	0,02	0,02
DC resistance is in ohm (Ω).						

Printing length = 0 mm	Printing length = 2 mm	Printing length = 4 mm
Printing portion of ICA Z_0 = 50,3 Ω 	Printing portion of ICA Z_0 = 49,5 Ω 	Printing portion of ICA Z_0 = 49,0 Ω 
Printing length = 6 mm	Printing length = 8 mm	Printing length = 2 mm × 5
ICA printing portion Z_0 = 48,1 Ω 	ICA printing portion Z_0 = 47,2 Ω 	ICA printing portion Z_0 = 49,5 Ω 

X axis: time 1ns/div., y axis: z_0 not in linear (each figure indicated marker point value)

Figure E.3 — TDR measurement result

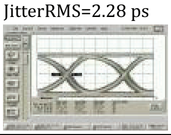
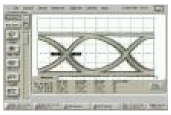
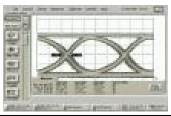
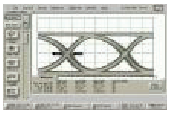
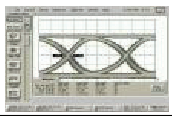
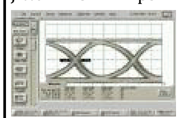
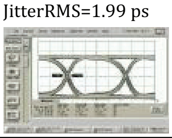
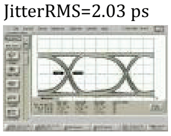
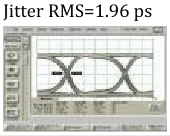
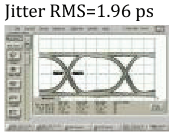
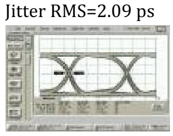
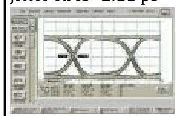
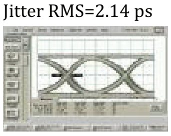
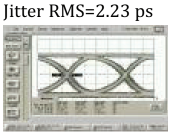
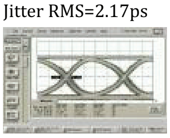
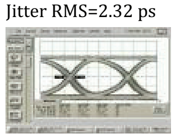
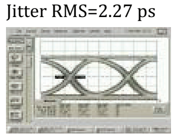
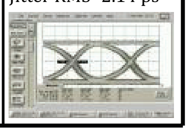
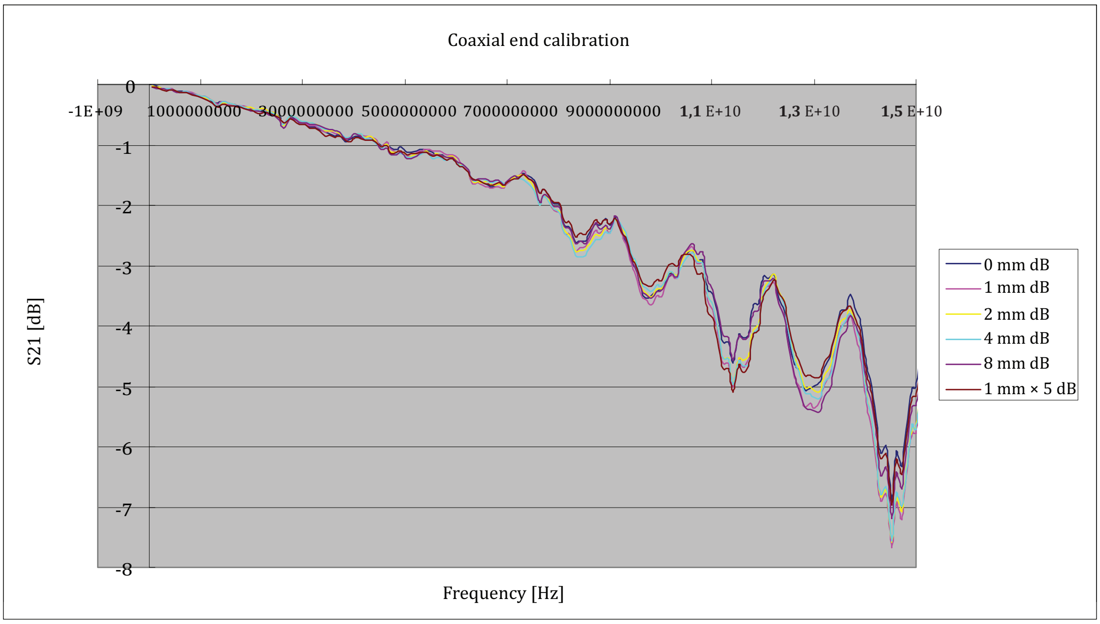
Printing thickness	Printing length					
	0 mm	1 mm	2 mm	4 mm	8 mm	1 mm × 5
80 µm Profile unit: x; 20ps/div. y; 100mV/div.	Eyeheight=304 mV Eyewidth=69,4 ps Eye S/N=11.10 JitterRMS=2.28 ps 	Eye height=301 mV Eye width=69,7 ps Eye S/N=10.80 JitterRMS=2.24 ps 	Eye height=298 mV Eye width=69,3 ps Eye S/N=10.58 JitterRMS=2.31 ps 	Eye height=298 mV Eye width=69,0 ps Eye S/N=10.60 JitterRMS=2.35 ps 	Eye height=299 mV Eye width=69,9 ps Eye S/N=10.65 JitterRMS=2.20 ps 	Eye height=302 mV Eye width=70,3ps Eye S/N=11.03 JitterRMS=2.14 ps 
100 µm First sample Profile unit: x; 20ps/div. y; 100mV/div.	Eye height=353 mV Eye width=131,1 ps Eye S/N=16.88 JitterRMS=1.99 ps 	Eye height=354 mV Eye width=130,8 Eye S/N=17.10 JitterRMS=2.03 ps 	Eye height=353 mV Eye width=131,2 ps Eye S/N=16.88 Jitter RMS=1.96 ps 	Eye height=352 mV Eye width=130,6 ps Eye S/N=16.67 Jitter RMS=1.96 ps 	Eye height=350 mV Eye width=130,5 ps Eye S/N=16.51 Jitter RMS=2.09 ps 	Eye height=352 mV Eye width=130,3 ps Eye S/N=16.73 Jitter RMS=2.11 ps 
100 µm Second sample Profile unit: x; 20ps/div. y; 100mV/div.	Eye height=301 mV Eye width=70,3 ps Eye S/N=10.94 Jitter RMS=2.14 ps 	Eye height=297 mV Eye width=69,8 ps Eye S/N=10.59 Jitter RMS=2.23 ps 	Eye height=299 mV Eye width=70,1 ps Eye S/N=10.67 Jitter RMS=2.17ps 	Eye height=297 mV Eye width=69,6 ps Eye S/N=10.52 Jitter RMS=2.32 ps 	Eye height=298 mV Eye width=69,9 ps Eye S/N=10.66 Jitter RMS=2.27 ps 	Eye height=302 mV Eye width=70,3 ps Eye S/N=11.08 Jitter RMS=2.14 ps 

Figure E.4 — 12 Gbps random digital output waveform of each X-Y direction pattern

An example of random digital output waveform is shown on Figure E.4 as a typical eye pattern format at the signal rate of 12 Gbps. The transmission characteristic of the digital waveform in the length direction of the used isotropic electrically conductive adhesive has the same characteristic as the standard wiring (0 mm) by copper.

E.1.2 Frequency characteristic measurement — Example

For the sample, the S-parameter and the Smith chart plot are measured by vector network analyser (VNA). For the VNA structure, open, short, load and through standards are calibrated at the normal coaxial cable end. The result of S21 and the Smith chart are shown on Figures E.5 and E.6, respectively.



Key

X frequency (Hz)

Y signal S21 (dB)

This figure shows coaxial end calibration.

Figure E.5 — S21 measurement profile example of X-Y plane standard substrate, measured by standard calibration

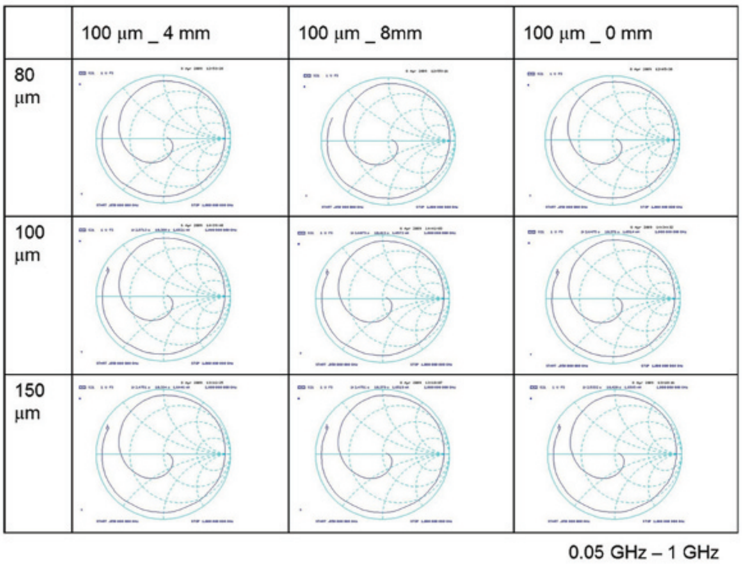


Figure E.6 — Example of Smith chart measurement of X-Y plane standard substrates, which was measured by standard calibration

Next, in order to obtain accurate frequency characteristics, use the X-Y plane standard substrate; cut it at the centre point of the copper wiring sample (0 mm), and calibrate the open, short and load standards with the copper wiring itself on through; stop the deterioration of the copper wiring characteristics, and perform the measurement. The calibration kit is shown in Figure E.7.

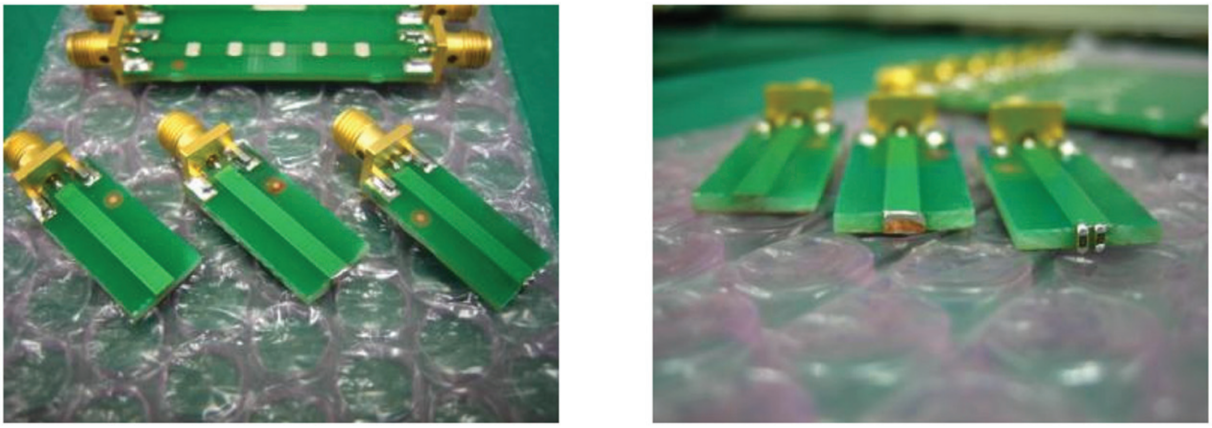


Figure E.7 — Calibration kit of open, short and load standards to cancel copper wiring characteristic

S21 parameter measured by this calibration kit is shown on Figure E.8. Figure E.8 indicates that because there is no deterioration of transit electromagnetic wave energy; the bonded sections have the characteristics of having almost no attenuation.

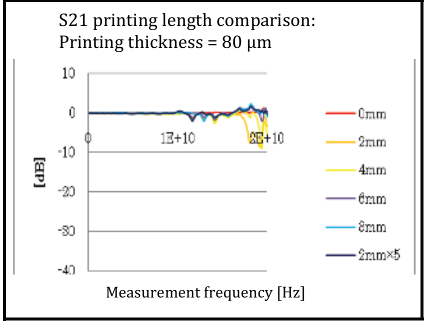
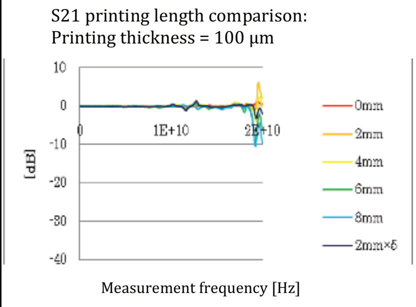
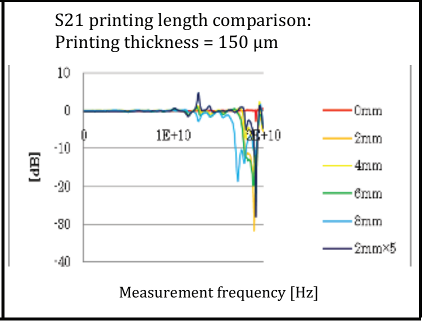
Printing thickness = 80 µm	Printing thickness = 100 µm	Printing thickness = 150 µm
		

Figure E.8 — S21 parameter profile when copper wiring characteristic is cancelled

E.2 Example of standard substrate (Z-direction) measurement

E.2.1 Digital signal eye pattern measurement — Example

For the Z-direction standard substrate shown in Figures A.5 to A.17 and the BGA, an isotropic electrically conductive adhesive pad printing as shown on Figure E.1 is carried out and Figure E.9 shows the assembled substrate after cross connection and surface treatment. As a comparison, a bonded portion was connected by soldering.,

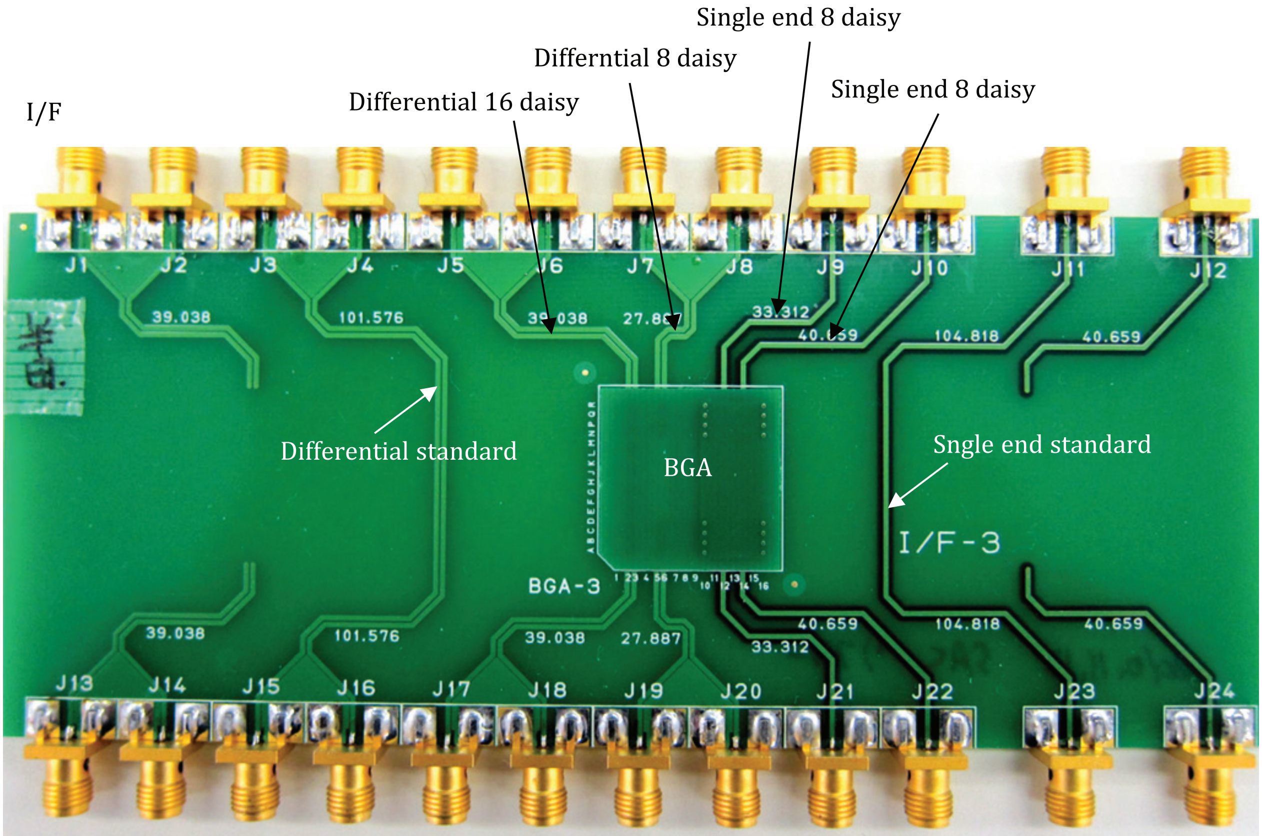


Figure E.9 — Completed chart of Z-direction standard substrate

The result of DC resistance measurement between the terminals is shown in Figure E.2 (see Table E.2). As for differential, the total of two wirings operates effectively, and therefore these values are also recorded in writing.

Table E.2 — DC resistance measurement result between terminals

<table>
<tr><td colspan="6">Differential wiring</td></tr>
<tr><td colspan="6">Solder connection</td></tr>
<tr><td colspan="2">Standard copper wiring</td><td colspan="2">Daisy 16 times</td><td colspan="2">Daisy 8 times</td></tr>
<tr><td>J3 to J15</td><td>J4 to J16</td><td>J5 to J17</td><td>J6 to J18</td><td>J7 to J19</td><td>J8 to J20</td></tr>
<tr><td>0,12</td><td>0,13</td><td>0,14</td><td>0,13</td><td>0,13</td><td>0,12</td></tr>
<tr><td colspan="2">0,25</td><td colspan="2">0,27</td><td colspan="2">0,25</td></tr>
<tr><td colspan="6">Isotropic electrically conductive adhesive</td></tr>
<tr><td colspan="2">Standard copper wiring</td><td colspan="2">Daisy 16 times</td><td colspan="2">Daisy 8 times</td></tr>
<tr><td>J3 to J15</td><td>J4 to J16</td><td>J5 to J17</td><td>J6 to J18</td><td>J7 to J19</td><td>J8 to J20</td></tr>
<tr><td>0,13</td><td>0,13</td><td>1,44</td><td>3,48</td><td>0,25</td><td>0,35</td></tr>
<tr><td colspan="2">0,26</td><td colspan="2">4,92</td><td colspan="2">0,60</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="6">Single end wiring</td></tr>
<tr><td colspan="2"></td><td colspan="2">Solder connection</td><td colspan="2"></td></tr>
<tr><td colspan="2">Standard copper wiring</td><td colspan="2">Daisy 16 times</td><td colspan="2">Daisy 16 times</td></tr>
<tr><td colspan="2">J11 to J23</td><td colspan="2">J10 to J22</td><td colspan="2">J9 to J21</td></tr>
<tr><td colspan="2">0,12</td><td colspan="2">0,14</td><td colspan="2">0,14</td></tr>
<tr><td colspan="6">Isotropic electrically conductive adhesive connection</td></tr>
<tr><td colspan="2">Standard copper wiring</td><td colspan="2">Daisy 16 times</td><td colspan="2">Daisy 8 times</td></tr>
<tr><td colspan="2">J11 to J23</td><td colspan="2">J10 to J22</td><td colspan="2">J9 to J21</td></tr>
<tr><td colspan="2">0,13</td><td colspan="2">3,07</td><td colspan="2">1,65</td></tr>
</table>

Figure E.10 shows the profile of comparison between the standard copper wiring and the output result of the differential pattern when digital random waveform is used, including the result of 16 daisy chains, where DC resistance varies widely. The measurement result shows that although connection of both solder and an isotropic electrically conductive adhesive is inferior to the standard pattern, there is no difference in connection between solder and an isotropic electrically conductive adhesive. The DC resistance does not have a great impact on an isotropic electrically conductive adhesive because it is assisted by capacitive coupling.

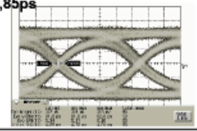
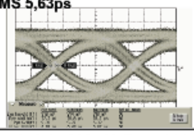
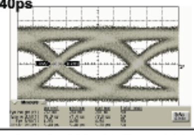
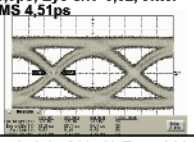
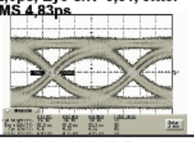
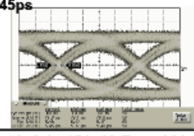
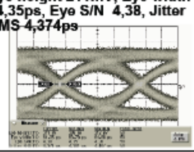
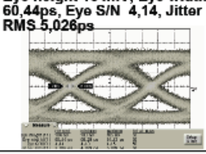
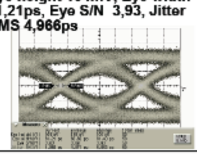
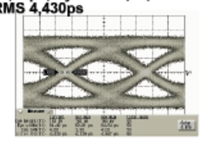
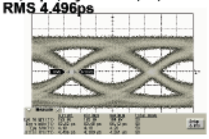
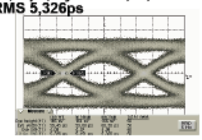
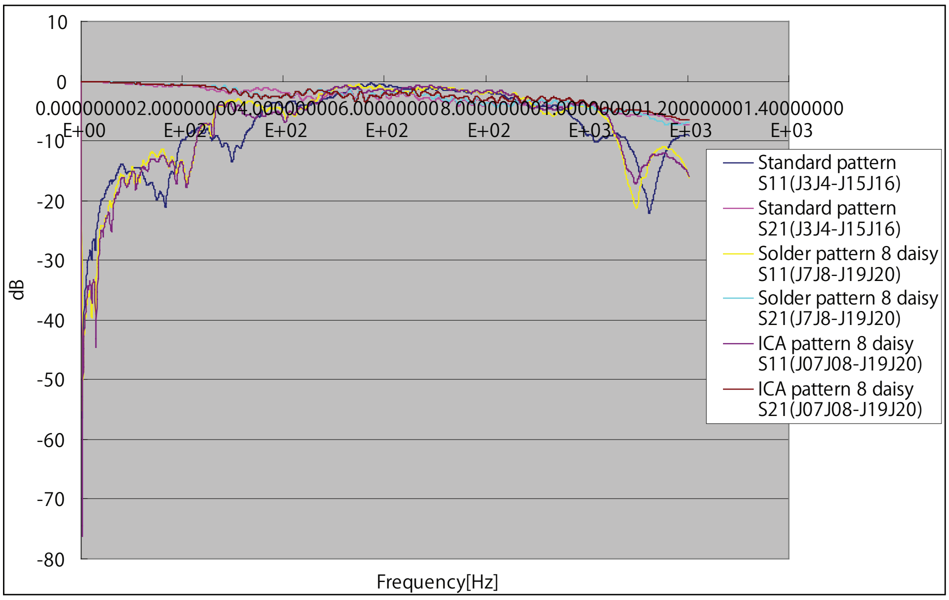
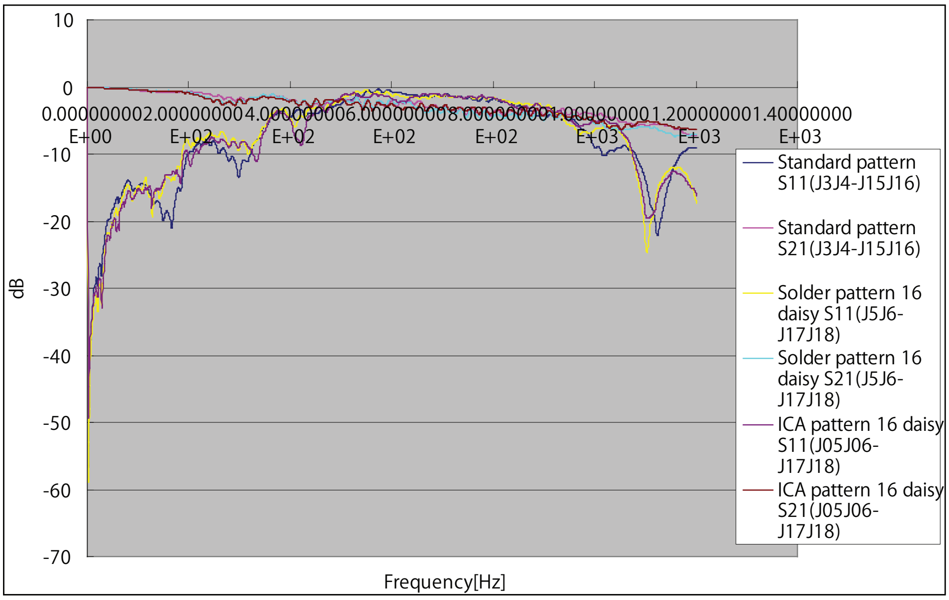
		Standard J34-J1516	Daisy 8 times J78-J1920	Daisy 16 times J56-J1718
9 Gbps Profile unit: x; 22ps /div. y; 120mV /div.	Solder connection	Eye height 317mV, Eye width 81,9ps, Eye S/N 534, Jitter RMS 4,85ps 	Eye height 318mV, Eye width 77,7ps, Eye S/N 5,31, Jitter RMS 5,63ps 	Eye height 277mV, Eye width 78,6ps, Eye S/N 4,93, Jitter RMS 5,40ps 
	Electrically isotropic conductive adhesive connection	Eye height 327mV, Eye width 83,9ps, Eye S/N 5,52, Jitter RMS 4,51ps 	Eye height 306mV, Eye width 82,0ps, Eye S/N 5,31, Jitter RMS 4,83ps 	Eye height 306mV, Eye width 78,3ps, Eye S/N 5,46, Jitter RMS 5,45ps 
11 Gbps Profile unit: x; 18ps /div. y; 120mV /div.	Solder connection	Eye height 211mV, Eye width 64,35ps, Eye S/N 4,38, Jitter RMS 4,374ps 	Eye height 184mV, Eye width 60,44ps, Eye S/N 4,14, Jitter RMS 5,026ps 	Eye height 154mV, Eye width 61,21ps, Eye S/N 3,93, Jitter RMS 4,966ps 
	Electrically isotropic conductive adhesive connection	Eye height 163mV, Eye width 64,42ps, Eye S/N 4,00, Jitter RMS 4,430ps 	Eye height 183mV, Eye width 63,62ps, Eye S/N 4,19, Jitter RMS 4,496ps 	Eye height 165mV, Eye width 59,45ps, Eye S/N 4,08, Jitter RMS 5,326ps 

Figure E.10 — Output eye pattern profile of digital random family input of differential daisy chain

E.2.2 Example of frequency characteristic measurement

Differential standard pattern, differential 8 and 16 daisy chain soldering and S-parameter measurement result of an isotropic electrically conductive adhesive connecting terminal are shown in Figure E.11. Scanning frequency is from 0,3 MHz to 8 GHz. Although S21 and S11 are crossed over at slightly lower than 5 GHz, there is almost no difference under each condition. It is too small for the diameters of connected portions at these frequencies to detect differences.





Key

X frequency (GHz)

Y signal (dB)

Figure E.11 — S-parameter measurement result of differential daisy chain pattern

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[7] UL/ANSI, FR-4 classification

[8] JIS, GE4F classification

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