

Takada RF Labs, Inc. Technology Databook (Rev.4.0)

Takada RF Labs, Inc.

This document describes technology outline of products that Takada RF Labs, Inc provide to customers. In Chapter 1, fundamental technologies that are commonly applied for various products made by Takada RF Labs, are described. Chapter 2 and later chapters describe concrete application examples of these technologies to make various type of RF modules such as general RF modules, evaluation board and test fixture for RF devices and high frequency probe-card.

Table of contents

Chapter 1	Fundamental Technologies	2
Section 1	RF connector.....	2
Section 2	Substrate base material	5
Section 3	Transmission line.....	6
Subsect.1	Planar transmission line.....	6
Subsect.2	Thin semi-rigid coaxial cable.....	9
Section 4	Assembly.....	11
Section 5	Design.....	11
Section 6	Measurement	11
Chapter 2	RF module fabrication	12
Section 1	Procedure of RF module fabrication	12
Section 2	RF module configuration	12
Section 3	RF performance of module	13
Subsect.1	Baud rate increase activity	13
Subsect.2	Channel count increase activity	16
Section 4	Other Examples of RF module.....	18
Chapter 3	Evaluation board and test fixture of high frequency (speed) devices.....	21
Section 1	Evaluation board	21
Section 2	Test fixture for high frequency devices.....	22
Subsect.1	Basic structure of test fixture	22
Subsect.2	Contactors with spring pin base vertical contact probe.....	24
Subsect.3	Contactors with anisotropic conductive sheet.....	25
Subsect.4	Metal-rod vertical multi-contact pin probe (MRP) as contactor.....	26
Chapter 4	High frequency probe-card using MRP.....	28

Chapter 1 Fundamental Technologies

Section 1 RF connector

We use following connectors depending on requirements of operating frequency, module size and RF signal pin count.

0.8mm, 1.0mm(W), 1.85mm(V), 2.92mm(K), SMA, SMB, SMP(GPO), SMPM(GPPO), G3PO(SMPS), QSFP card edge, FPC connector, CEC (Cable Edge Connector)

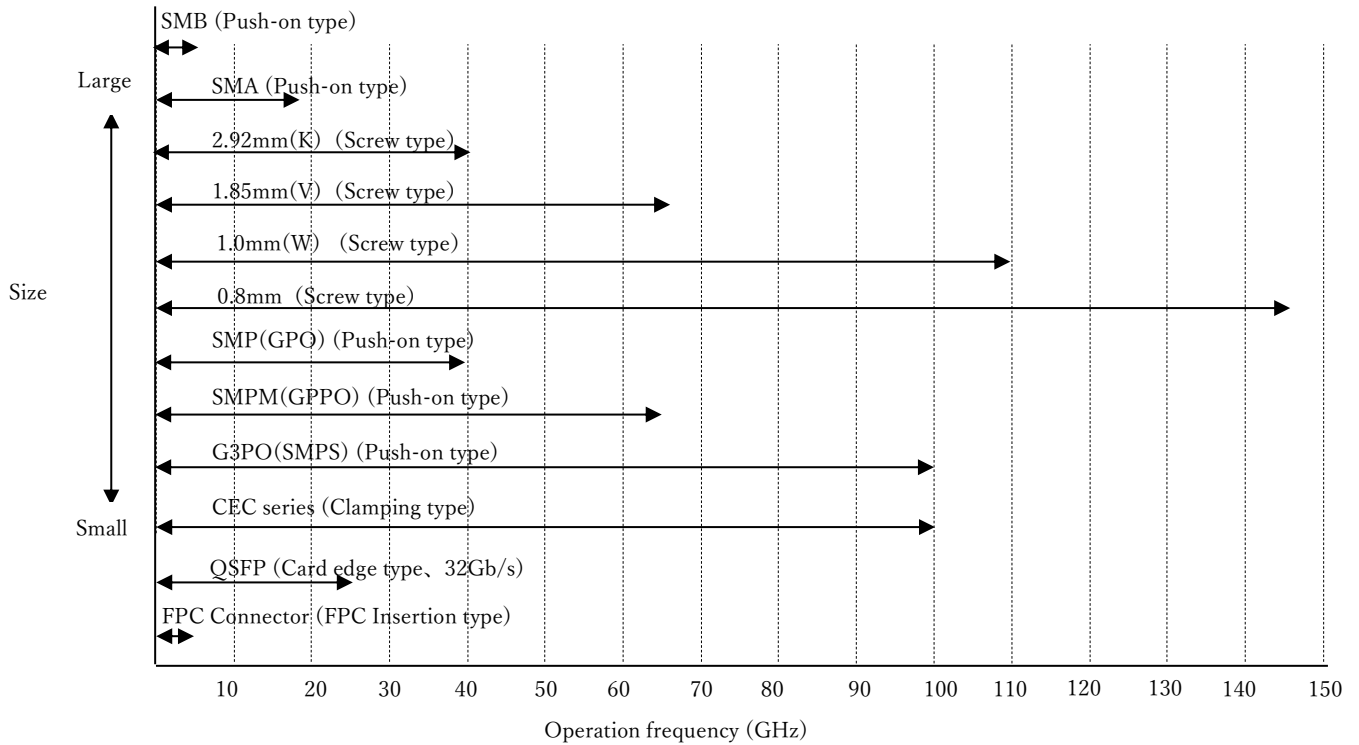


Fig. 1-1 Operating Frequency and size for connectors

Followings are Takada RF Labs, Inc.'s original connector lineup.

- 1) 1mm-coaxial end launch connector, 1MMEL02 series

Photographs for 1MMEL02P and 1MMEL02J are shown in Fig. 1-2. These are used by mounting at end launch portion of RF substrate.

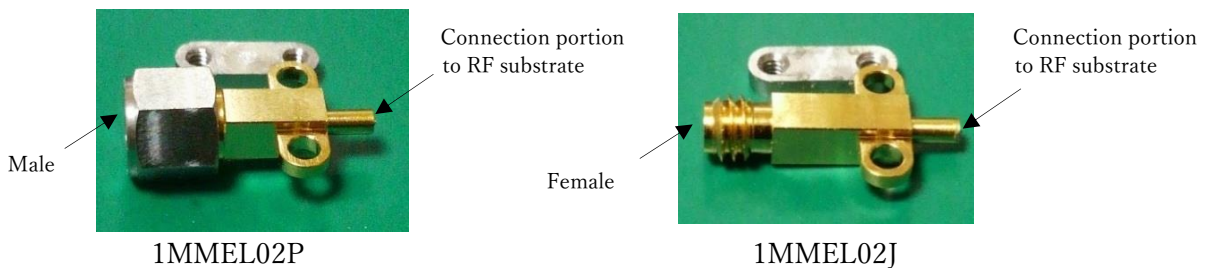


Fig. 1-2 Photograph of 1mm-coaxial end launch connector 1MMEL02 series

Back to back connector (B2B) was made to evaluate 1MMEL02 series performance. B2B has structure that two 1MMEL02s are jointed each other at the connection portion to RF substrate. S-parameter of B2B is shown Fig. 1-3.

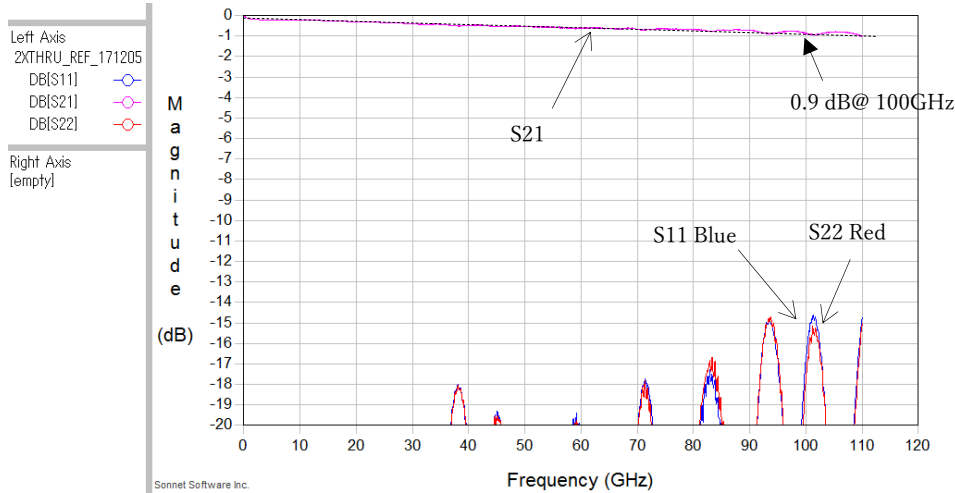


Fig. 1-3 S-parameter of B2B

From Fig. 1-3, we know that insertion loss of one 1MMEL02 is 0.45 ($=0.9/2$) dB at 100 GHz.

2) 8-channel Cable Edge Connector, CEC8

This was developed in collaboration with Shin-Etsu Polymer Co.,Ltd. for applying to 8-channel RF module interface. The structure of CEC8 is shown in Fig. 1-4.

8 of contactors are inserted into 8 holes of contactor holder and fixed.

Contactors are made by rubber sheet with coaxial structure, that is, outer and central portion is conductive and medium portion is non-conductive.

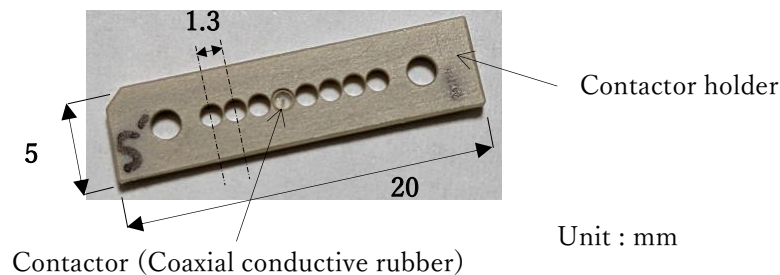


Fig. 1-4 Structure of CEC8

Figure 1-5 shows a test fixture to evaluate CEC8 RF performance. In this test fixture, CEC8 is sandwiched by two cable edge receptacles that fix the semi-rigid coaxial cables of which outer diameter is 1.2mm ϕ . Cable edges of two coaxial cables push the contactor inside CEC8 from one side and from another side, and electrical signal connection of two coaxial cables is performed.

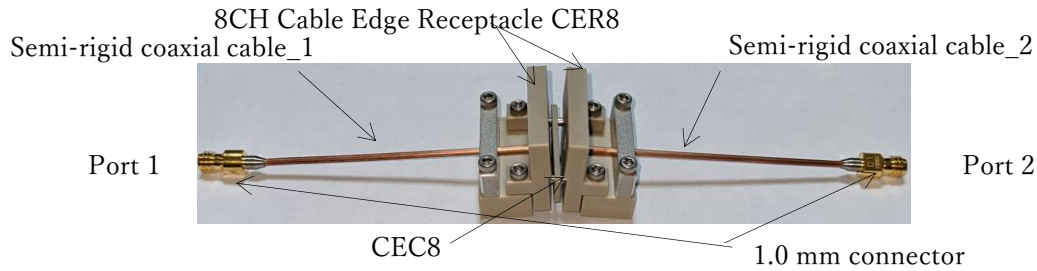


Fig. 1-5 Test fixture of CEC8

When we apply this connector CEC8 for RF modules, CER8s are mounted at I/O portion of each modules of module_1 and module_2, for example. RF signal connection of module_1 and module_2 is performed by following way.

CEC8 is inserted between CER8 of module_1 and CER8 of module_2. When CER8s of module_1 and CER8 of module_2 are attached mutually by screws, cable end of semi-rigid coaxial cables push the contactor in CEC8 then RF signal connection is performed.

Features of connector CEC8 are below.

- a) Small RF signal pitch : 1.3 mm

Signal pitch is less than half of 2.79 mm signal pitch of 4CH SMPS that may be smallest in multi-channel connectors so far,

- b) High RF performance :

S21: typ. > -0.9 dB @ DC-100GHz

S11, S22: typ. < -19 dB @DC-50GHz, typ. < -13 dB@ DC-100GHz

S-parameter measured using Fig.1-5 test fixture is shown in Fig. 1-6. Red line shows insertion loss from port 1 to port 2 and blue line shows sum of insertion loss of semi-rigid coaxial cable_1 and cable_2. Difference of two lines shows insertion loss of CEC8.

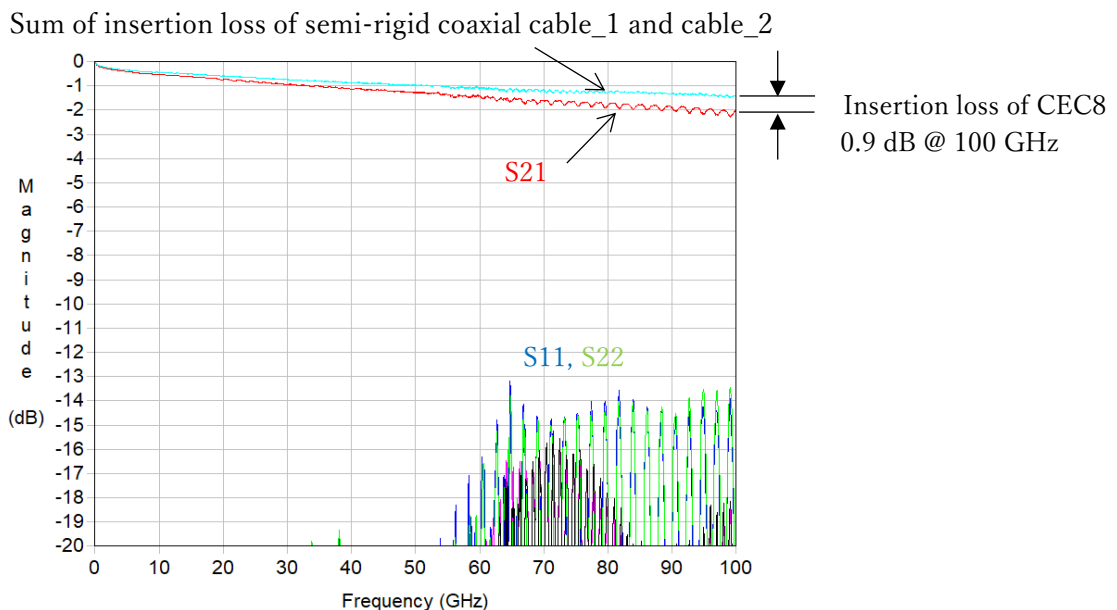


Fig. 1-6 S-parameter of CEC8

3) 16-channel Cable Edge Connector, CEC16

In order to realize optical transceiver modules with Tera-bit class data speed by increasing channel count, we are now trying to develop 16-channel Cable Edge Connector. For detail, See Subsect.2, Section3 in Chapter 2.

Section 2 Substrate base material

For making RF modules, we use following substrate materials depending on requirements of operating frequency, module size and RF signal pin count.

Organic substrate base materials:

Rogers RO4350B, Panasonic R-5775 (MEGTRON6), Teflon, FR4, FPC

These are used to make printed multi-layer circuit board, PCB.

Non-organic substrate base materials:

99.5% Alumina, Quartz, Aluminum nitride

These are used to make thin film circuit.

Features of materials are summarized in Table 1-1.

Table 1-1. Feature of substrate base material

Substrate base material	Relative dielectric constant Er	Loss tangent Tan δ @10GHz	Thermal conductivity (W/m · k)	Bending strength (MPA)	Thermal expansion Coefficient (1/K)	Avairav ility of resistor	Metal peeling resistance	Standard Substrate thickness (mm)	Minim um L/S (mm)	Minimum VIA diameter (mm)
RO4350B	3.66	0.0037	50	255	50 x 10 ⁻⁶	No	Strong	0.10, 0.17		
MEGTRON6	3.6	0.004			14-16 x 10 ⁻⁶	No	Strong	0.05, 0.10	0.08/0.08	0.25 ϕ
Tefron (CH2868D)	2.28 @12GHz	0.0015@12 GHz				No	Strong	0.221	0.05/0.05	No VIA
99.5 % Alumina	9.8	10 ⁻⁴	32	440	8 x 10 ⁻⁶	Yes	Strong	0.25, 0.38, 0.635, 1.0	0.02/0.015	0.1 ϕ (@0.25t)
Aluminum nitride	8.8 @1MHz	5 x 10 ⁻⁴ @1MHz	170, 200, 230	330	4.6 x 10 ⁻⁶	Yes	Strong	0.15, 0.2, 0.25, 0.38	0.02/0.015	
Quartz	3.8	10 ⁻⁴	1.4	60	0.5 x 10 ⁻⁶	Yes	Not so strong	0.1, 0.15, 0.2, 0.25, 0.38	0.02/0.015	0.1 ϕ (@0.25t)

Section 3 Transmission line

In RF module, we use both planar transmission line that is made on RF substrate and thin semi-rigid coaxial cable.

Subsect.1 Planar transmission line

Most of cases, planar transmission lines are conveniently used since surface mount devices are easily assembled and high speed bare dies are wire-bonded. 4 kind of transmission lines shown below are used depending on application.

CPW (Coplanar waveguide):

Signal line and GND pattern are formed on the surface of substrate normally.

GCPW (Grounded coplanar waveguide):

Ground-plane with wide enough width than signal line width is additionally formed at back side of substrate of CPW. Ground plane at surface and Ground plane at back side are electrically connected by VIA holes.

MSL (Microstrip Line) :

Signal line is formed on surface of substrate and ground plane with wide enough width is formed at back side of substrate.

nMSL(narrowed MSL) :

This is kind of MSL but substrate width is narrowed to close to the width of signal line. This is our company original structure invented to enhance frequency characteristics keeping micro strip mode.

RF characteristics of the planar transmission lines depend on material and thickness of substrate. In addition, line patterning accuracy is important design parameter.

Easiness to have good match to connectors should also be considered in design.

We choose optimum solution depending on application from our experience and perform design verification by circuit simulation and 2D or 3D electromagnetic field simulation.

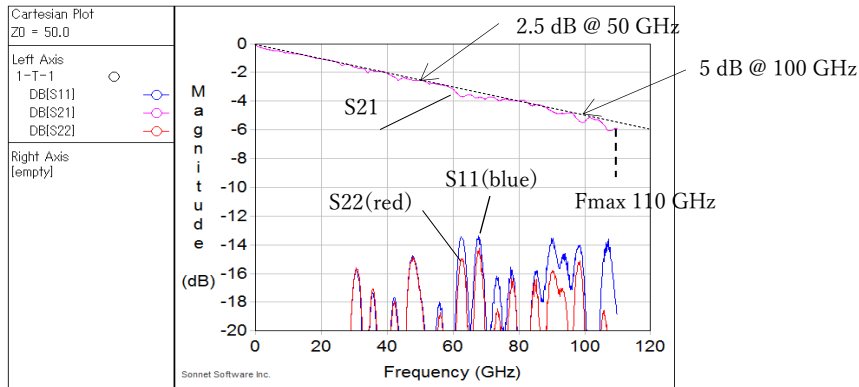
As one of examples, RF characteristics of CPW using Megtron6 is described below for the cases of using 1mm connector and SMPM.

Characteristics of CPW (using 1mm connector)

Measured S-parameter of 8 mm length CPW transmission line on Megtron6 substrate with 1mm-connector at the both end of substrate is shown in Fig. 1-4. S21 is varied almost linearly up to the frequency F_{max} at which S21 value start to depart from approximate line drawn by dashed line. In this case, F_{max} is about 110GHz that is close to guaranteed maximum frequency of 1mm-connector. Sum of Insertion loss of 8 mm length CPW line and two 1mm-connectors is 5 dB@ 100GHz. Since insertion loss of two 1mm-connector is 0.9 dB@100GHz, insertion of 8mm CPW line is 4.1 dB@100 GHz.

Insertion loss per 1mm @ 100 GHz, which we use as “ Figure of merit “ of transmission

line, is calculated to $0.51 (=4.1/8)$ dB/mm @100GHz



connector loss of two 1mm connector : 0.9 dB @ 100 GHz

CPW line loss is calculated to 0.51 dB/mm @100GHz

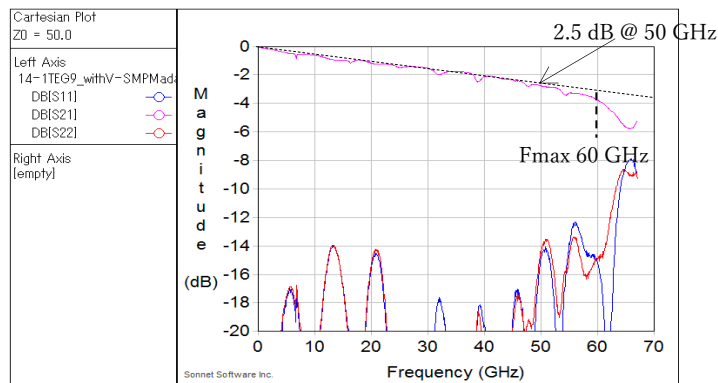
Fig. 1-4 S-parameter of CPW(MEGTRON6, 1.0mm-connector) 8mm length THRU line

Characteristics of CPW (using SMPM)

In case that we want to make small size RF module, push-on type small size connectors such as SMPM are used instead of screw type of connectors.

Measured S-parameter of 8 mm length CPW transmission line on Megtron6 substrate with SMPM at the end of substrate is shown in Fig. 1-5. S21 is varied almost linearly up to the frequency Fmax at which S21 value start to depart from approximate line drawn by dashed line. In this case, Fmax is about 60GHz that is close to guaranteed maximum frequency of SMPM.

Sum of Insertion loss of 8 mm length CPW line and two SMPM is 2.5 dB@50GHz. Since insertion loss of two SMPM is 0.54dB@50GHz, insertion of 8mm CPW line is 1.96dB@50 GHz. Insertion loss per 1mm @ 50 GHz, which we use as “ Figure of merit “ of transmission line, is calculated to $0.245 (=1.96/8)$ dB/mm @50GHz



connector loss of two SMPM : 0.54 dB @ 50GHz

CPW line loss is calculated to 0.245 dB/mm @50GHz

Fig. 1-5 S-parameter of CPW(MEGTRON6, SMPM) 8mm length THRU line

Not limited to CPW, insertion loss (IL) of planar transmission lines formed on RF substrate gradually increases almost linearly as increasing frequency. When increasing to one frequency, IL value starts to increase drastically implying that IL value departs from the linear line. We call this frequency “ Fmax” . Fmax as well as unit length insertion loss at 100 GHz (L100G) or unit length insertion loss at 50 GHz (L50G) becomes “ Figure of merit” to show performance of planar transmission lines. Fmax is 100 GHz in Fig. 1-4 and 60 GHz in Fig. 1-5, for example. Sometimes, IL increases at Fmax then changes to decrease at over Fmax. We call this characteristics “Dip”. In order to get broad-band characteristics of RF modules, it is necessary to let the RF module operate in the frequency region at less than Fmax.

Table 1-2 shows Fmax and L50G or L100G for various type transmission lines of various substrate materials with various connectors that were experimentally obtained by Takada RF Labs, Inc. , so far.

Table 1-2 Fmax and L50G or L100G

基板材料	項目	線路形態			
		CPW	GCPW	MSL	nMSL
RO4350B (Er:3.66), Connector : SMPM	Fmax			40 (GHz)	
	L100G			0.43 (dB/mm)	
MEGTRON6 (Er:3.6), Connector : 1.0mm(W) end launch	Fmax	110 (GHz)			
	L100G	0.49 (dB/mm)			
MEGTRON6 (Er:3.6), Connector : SMPM	Fmax	60 (GHz)			
	L100G	0.49 (dB/mm)			
Tefron (CH2868D) (Er:2.28), Connector : G3PO	Fmax	>50 (GHz)			
	L50G	0.5 (dB/mm)			
99.5 % Alumina, 0.25t (Er:9,8), Thin semi-rigid coaxial cable (SX-09I) with 1.85 mm(V) connector is directly soldered to substrate.	Fmax		100 (GHz)		
	L100G		0.31 (dB/mm)		
99.5 % Alumina, 0.25t (Er:9,8), Wide width line (W/S=0.17/0.165 mm) Connector: 1.85mm(V) glass bead	Fmax		67 (GHz)		
	L50G		0.06 (dB/mm)		
99.5 % Alumina, 0.25t (Er:9,8), Medium width line (W/S=0.1/0.08 mm) Connector: 1.85mm(V) glass bead	Fmax		67 (GHz)		
	L50G		0.075 (dB/mm)		
9.5 % Alumina, 0.25t (Er:9,8), Connector: 1.85mm(V) glass bead Narrow width line (W/S=0.055/0.0275 mm)	Fmax		67 (GHz)		
	L50G		0.12 (dB/mm)		
9.5 % Alumina, 0.25t (Er:9,8), Connector : hermetically sealed type G3PO	Fmax				65 (GHz)
	L100G				0.32 (dB/mm)
Quartz 0.5t (Er:3.8) Thin semi-rigid coaxial cable (SX-09) with 1.0 mm(W) connector is directly soldered to substrate.	Fmax	>110 (GHz)			
	L100G	0.33 (dB/mm)			
Quartz 0.25t narrow width line (W/S=0.08/0.025 mm) Connector : 1.0mm(W) end launch	Fmax		>110 (GHz)		
	L100G		0.35 (dB/mm)		
Quartz 0.25t Medium width line (W/S=0.1/0.02 mm) Connector : 0.8 mm(W) end launch	Fmax		TBD		
	L100G		0.125 (dB/mm)		

We can say followings from the Table 1-2,

- 1) Fmax of transmission lines of CPW and GCPW formed on both organic substrate base materials and non-organic substrate base materials is over 100 GHz if they are well designed.
- 2) There is no possibility that Fmax becomes higher than maximum recommended frequency of connectors that are connected to transmission lines.
- 3) GCPW by Alumina substrate is used for the frequency region of DC to less than 67 GHz. Insertion loss depends on signal line width, that is, wider line width has smaller insertion loss. L5G for wide width line (W/S=0.17/0.165 mm) that are used for main signal line is 0.06(dB/mm)@50 GHz.
- 4) GCPW with Quartz substrate is used for the frequency region of DC to over 110GHz. L100G of medium width line (W/S=0.1/0.02 mm) is 0.125 dB /mm @100GHz
- 5) CPW by organic substrate base materials can also be worked at up to 110 GHz, however, L100G of around 0.5 dB/mm @ 100GHz (implying L50G of 0.25 dB/mm @50 GHz) is about 4 times larger than Alumina substrate and Quartz substrate.

Subsect.2 Thin semi-rigid coaxial cable

As mentioned above, planar transmission lines formed on the substrate are normally used in RF modules. However, we often use thin semi-rigid coaxial cable line in addition to planar transmission lines. The main purpose of using thin semi-rigid coaxial cable lines is to decrease total insertion loss of RF module. Since unit length insertion loss of thin semi-rigid coaxial cable is much smaller than that of planar transmission lines as explained later, implementation of thin semi-rigid coaxial cables drastically enhances the performance of RF modules.

We usually use thin semi-rigid coaxial cable (privately called as LDC08) having outer diameter of about 0.787 mm ϕ . Figure 1-6 shows frequency dependency of unit length transmission loss (L) of LDC08. L at 100 GHz (L100G) is 0.0162 dB/mm which is about 1/8 small that of lowest loss planar transmission line (Quartz 0.25t Medium width line) of 0.125 dB/mm.

By the way, maximum operating frequency of coaxial cable is determined by higher order moding frequency F_c . F_c of LDC08 is 180 GHz.

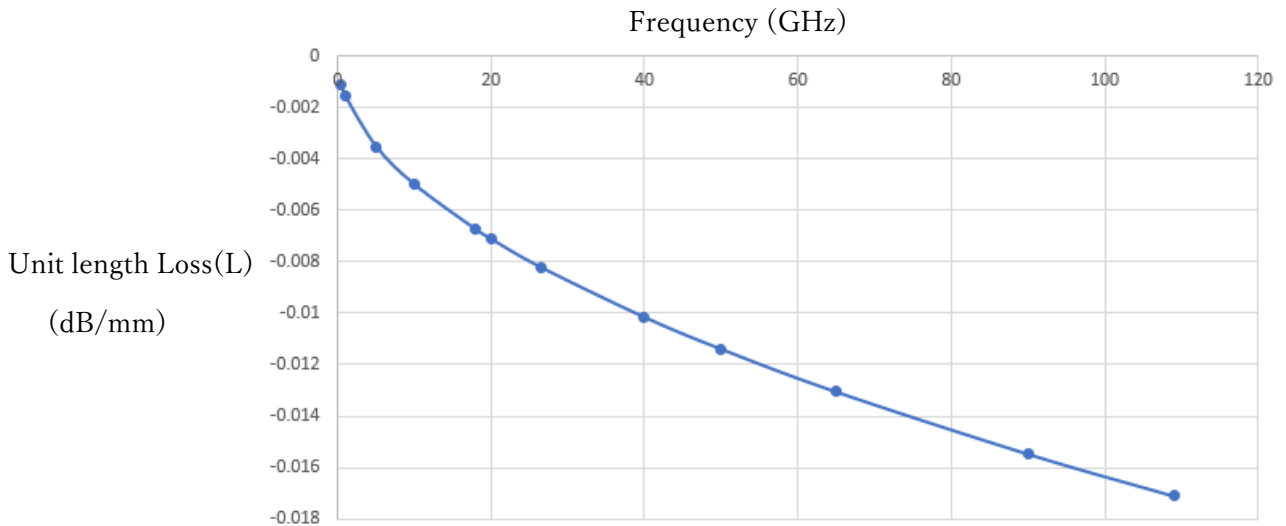


Fig. 1-6 Unit length transmission loss of thin semi-rigid coaxial cable line LDC08

While thin semi-rigid coaxial cable transmission line LDC08 has advantage that transmission loss is low, it is impossible to connect coaxial cable end to IC chip signal pad. This is because coaxial cable diameter of 0.8 mm ϕ is too much larger than GSG signal pad pitch of IC of about 0.15 mm. So, when we draw out IC signals to RF connectors as module I/Os, we use hybrid type assembly configuration in which we put planar transmission lines on RF substrate near IC chip and the planar transmission lines are spread out to wider signal pitch on the RF substrate, then thin semi-rigid cables are connected to pads with wider signal pitch as shown in Fig. 1-7. This is the case that eight GSG configuration signals are drew out to eight 1.85 mm connectors. If we use RF substrate planar transmission lines for entire portions from near IC chip to RF connector, transmission loss becomes significantly larger than the case of Fig. 1-7 because line length is long due to RF connector size bigness.

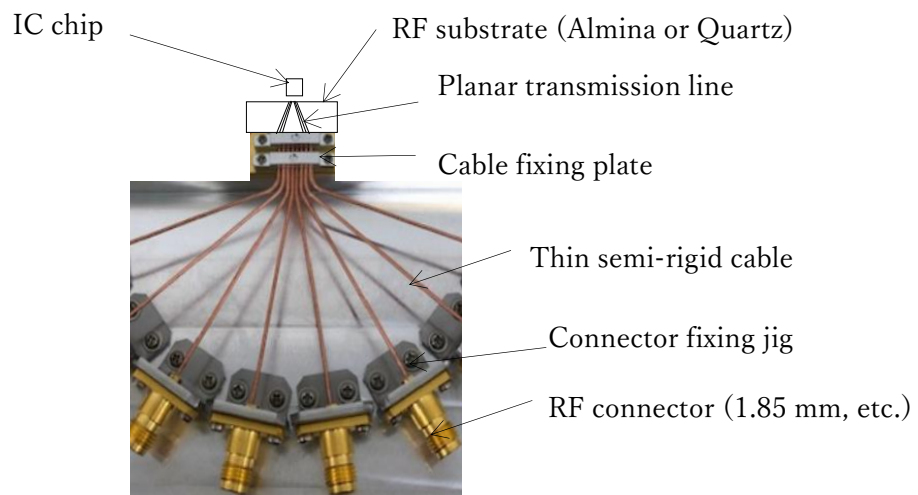


Fig. 1-7 Hybrid type assembly configuration using planar transmission line on RF substrate and thin semi-rigid coaxial cable line

We normally use the hybrid type assembly configuration for making evaluation module to evaluate RF performance of RF devices or test fixture for final product inspection

Section 4 Assembly

We are using following assembly technologies.

- 1) Pb free soldering with Reflow or using soldering iron
--- for packaged IC, multilayer-ceramic chip capacitor, chip resistor, pin header, RF connector and thin semi-rigid coaxial cable, etc.
- 2) Die bonding by AuSn or conductive epoxy
--- for IC chip, single layer capacitor, chip resistor
- 3) Au wire bonding by Au wire (25 μm ϕ or 13 μm ϕ , ultra-sonic wedge bond)
--- for pad with minimum 30 x 30 μm size
- 4) Ribbon bonding by Au
- 5) Flip chip bonding
After Au-bumps are fixed on the IC pads, conductive epoxy is put on the bumps , then IC chip with bumps is flipped onto substrate and cured, and then non-conductive epoxy is underfilled around the bumps.

Section 5 Design

In design, we normally perform simulations described below.

- 1) Circuit simulation
DC analysis, AC analysis, transient analysis, S-parameter calculation, harmonic balance analysis, etc. using circuit models of lumped parameter circuit model, semi-lumped parameter circuit model or distributed parameter model
- 2) 3 dimensional electromagnetic field simulation
Multi-port calculation of single-end or differential S-parameter, electromagnetic radiation distribution, and temperature distribution
- 3) Circuit parameter conversion by software
Single-end-to differential conversion, TDR conversion from S-parameter, eye pattern conversion from S-parameter, S-parameter de-embedding /embedding

Section 6 Measurement

We use following measurement tools for performance evaluation and intermediate / final inspection of fabricated product.

- 2-port vector network analyzer VNA (1mm coaxial connector interface, up to 120 GHz)
- 4-port VNA (1.85mm coaxial connector interface, up to 67 GHz)
- Pulse pattern generator, Error detector, oscilloscope, etc.

Chapter 2 RF module fabrication

Section 1 Procedure of RF module fabrication

We do design and fabricate various types of custom RF modules used in optical transmission systems and wireless communication systems or high frequency measurement tools. We perform high-level macro design of module according to customer requirements at first, then makes initial proposed specification and provide it to the customer. And then, by repeating question, answer, and discussion with customer, we refine the initial proposed specification. Finally, we make "target specification sheet" before starting fabrication, which includes module block diagram, module structure, recommended operating conditions, maximum absolute ratings, RF performance, sample implementation, etc. Then start fabrication. When developing modules having both electrical and optical function as shown below, our company takes responsibility of design and fabrication of electrical portion and customer takes responsibility of design and fabrication of optical portion.

Section 2 RF module configuration

Block diagram of n-channel RF module with electrical/optical interface and n-channel RF module with electrical/electrical interface is shown in Fig.2-1(a) and Fig.2-1(b), respectively.

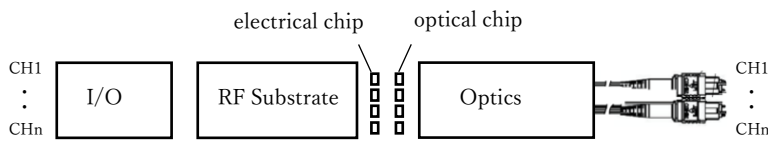


Fig. 2-1 (a) Block diagram of electrical/optical (E/O) interface RF module

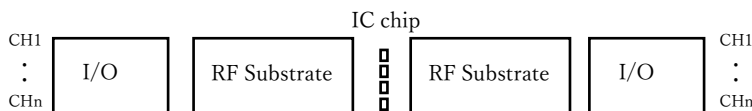


Fig. 2-1 (b) Block diagram of electrical/electrical (E/E) interface RF module

We use Fig.2-1(a) configuration having E/O interface for making all types of E/O interface modules of optical transmitter, optical receiver, and optical transceiver. In case of transmitter, electrical chip becomes laser driver, modulator driver and optical chip becomes VCSEL, DML or EML laser. There is a case that electrical chips are not integrated in the module. In case of receiver, electrical chip becomes TIA and optical chip becomes receiver chip such as PinPD or APD. There is a case that TIAs are not integrated in the module. In case of optical transceiver, devices for both transmitter and receiver are implemented in one module.

We use Fig.2-1(b) configuration having E/E interface for making driver module, for example, which is externally connected to non-driver integrated optical transmitter. We also use Fig.2-1(b) configuration for making TIA module, for example, which is externally connected to non-TIA integrated optical receiver.

Section 3 RF performance of module

“Maximum operating data speed, MDS (b/s) “ is convenient to show total performance of RF module capability. MDS is defined as

$$\text{MDS (bit/s)} = (\text{MS (baud)} \times \text{SB (bit/symbol)}) / \text{ch} \times \text{N(ch)}$$

Where MS is modulation speed (baud, symbol/s) and SB is symbol bit number (bit/symbol). In case of PAM4 modulation, for example, that is widely used for data center transceiver application, SB is 2.

N is channel count (ch).

To have large MDS, we have been making effort of two directions. One direction is baud rate increase. The other direction is channel count increase.

Subsect.1 Baud rate increase activity

Connector development :

To make module with data speed as high as possible, we have to make module that has high band width of RF characteristics. We have newly developed 1mm end-launch connector that can be mounted on RF substrate end. Band width of the connector is over 110 GHz implying over 150 Gbaud. See Fig. 1-3 in detail.

G3PO(SMPS) is also suitable for high baud rate modules. It can be operated over 80 Gbaud.

RF substrate high frequency design:

We have established GCPW design of thin film transmission line using substrate of alumina and quartz. Maximum confirmed operating frequency of alumina thin film circuit is over 67 GHz and that of quartz thin film circuit is over 110 GHz. See Table 1-2 in detail.

Assembly process

We have established assembly process of “Flip chip bonding “ on quartz substrate to decrease wiring inductance between IC pad and thin-film transmission line. This enhances operation frequency drastically. See 5) at section 4 in Chapter 1.

RF performance of module

1) Performance of 1ch E/E module using 1mm screw type connector and Quartz substrate

Measured S-parameter of thru line evaluation module shown in Fig. 2-2(a) which consists of 1mm-end launch connectors and Quartz GCPW transmission thru line is shown in Fig. 2-2(b). -3dB band width is much higher than 110 GHz. So, this technology can be applied for making over 150 Gbaud module.

By using this technology and flip-chip assembly process, amplifier module with Over 130 GHz-Bandwidth were actually developed using InP-DHBT (Note 1).

Note 1: “An Over 130 GHz-Bandwidth InP-DHBT Base band Amplifier Module”, NTT DTL, BCICTS 2021

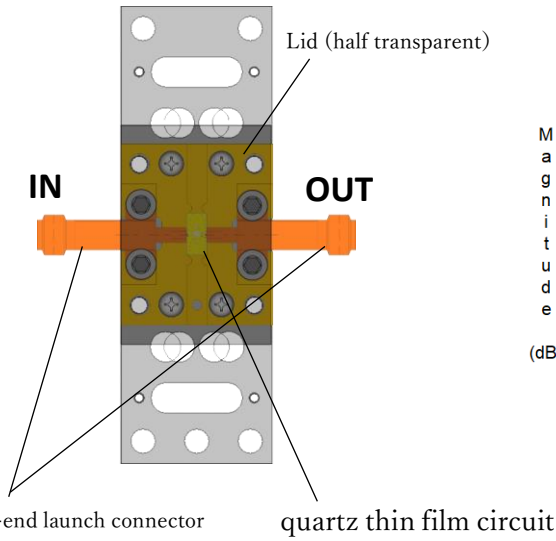


Fig. 2-2(a) Top view of thru line evaluation

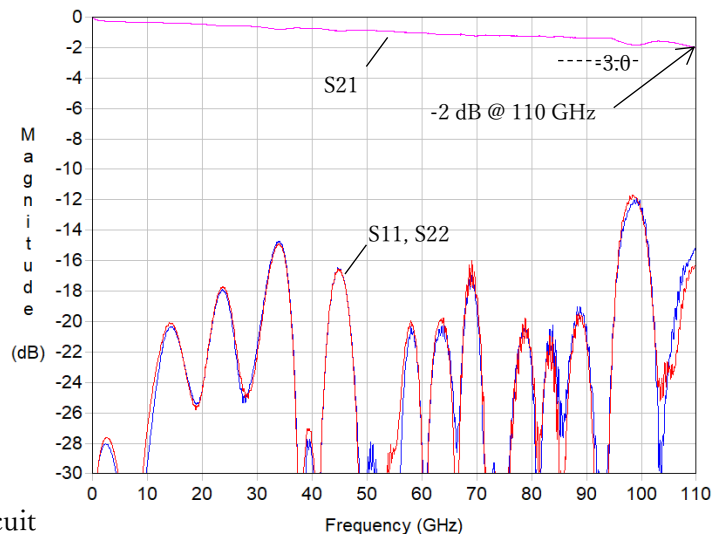


Fig.2-2(b) S-parameter of thru line evaluation module

2) Performance of 1ch E/O module using G3PO connector and Quartz substrate

Figure 2-3 (a) shows structure of butterfly package type E/O module . Hermetic type G3PO connector is embedded in 14-pin metal package wall and Quartz RF substrate is mounted in the package. Cover is put over transmission line of the substrate to prevent box resonance of package.

Takada RF Labs performs design and fabrication of this RF portion.

Optical portion is designed and fabricated by customer.

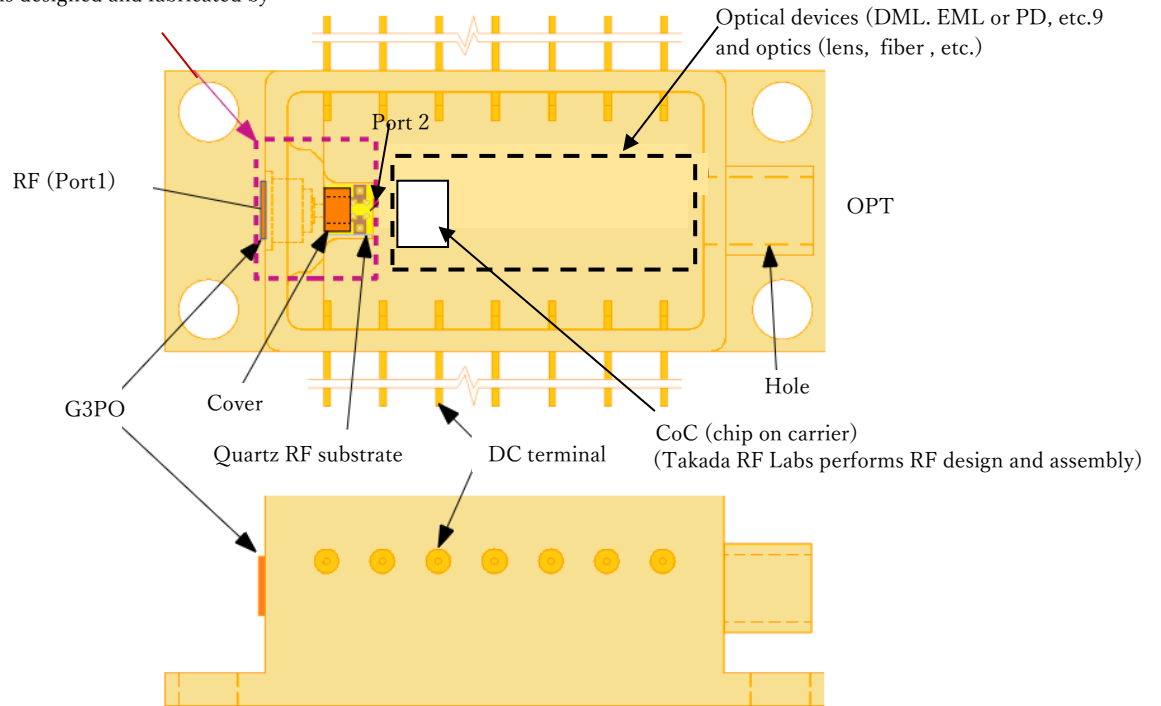


Fig.2-3(a) Structure of 14-pin butterfly package type E/O module

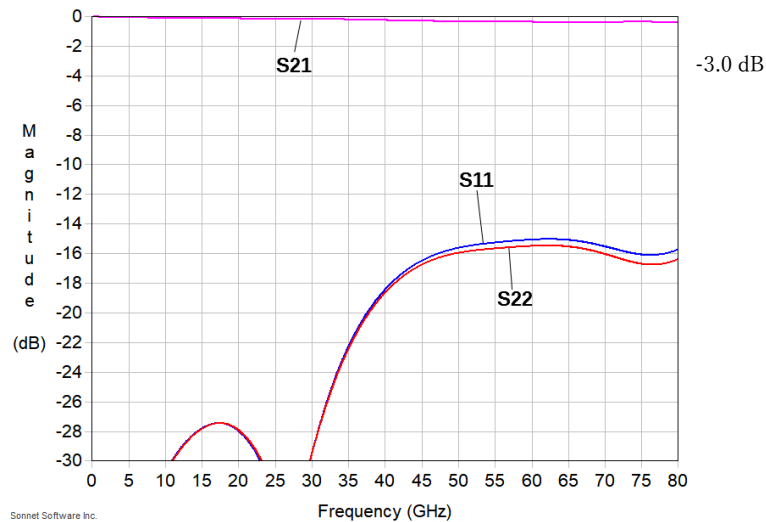


Fig.2-3(b) Estimated S-parameter of red broken line portion

Figure 2-3(b) shows an estimated S-parameter of the portion indicated with red broken line in Fig. 2-3(a). This is obtained from S11 measurement data (using Quartz substrate). -3dB bandwidth is much higher than 80 GHz. So, this technology can be applied for making over 100 Gbaud module

Subject.2 Channel count increase activity

When we make multi-channel RF module to make high data speed more, screw type connectors such as 1.85mm, 1.0 mm and 0.8 mm connectors are not adequate to be used because connector size is very big. They are originally made for the purpose of measurement interface and used for single channel evaluation module. For multi-channel module application, there are push-on type small size connectors such as SMP, SMPM and G3PO. 4 ch SMPS (compatible to G3PO) edge mount receptacle called 3811-60051 seems to be most advanced connector among push-on type connectors. It's signal pitch is 2.79 mm and maximum operating frequency of 65 GHz. However, if we consider to make 8 ch or 16 ch module that are recent requirement, 2.79 mm signal pitch is still very big to make reasonable size of module. Moreover, there is another big problem. Since IC pad signal pitch is small (normally around 0.15mm), signal line traces on RF substrate should be spread out to large connector signal pitch. This makes signal line length long because of requirement of equalizing multi-channel signal line length. Long length signal line has large insertion loss that reduces -3dB bandwidth of the module. In this point of view as well, connectors with large signal pitch reduce RF module performance significantly even if maximum operating frequency of connector itself is high.

We propose to use Cable Edge Connector(CEC series) to cope with above mentioned big problems, which is developed specially for multi-channel module RF signal interface.

8 ch CEC(CEC8) with 1.3 mm signal pitch (meaning less than half of 2.79 mm SMPS pitch) has been developed and performance has been confirmed (See Chapter1, Section1, page 3). Maximum operating frequency is much higher than 100 GHz implying over 150 Gbaud.

Farther more, we are now under development of 16 ch CEC(CEC16) of which signal pitch is as small as 0.9 mm.

We privately call the module using connector CEC series as “Cable Edge Connector Module, N Channel, CECMn” Structure example of 16 CH electrical/ electrical interface is shown in Fig.2-3. Module width is 40 mm which is same as width of pluggable module CPF8.

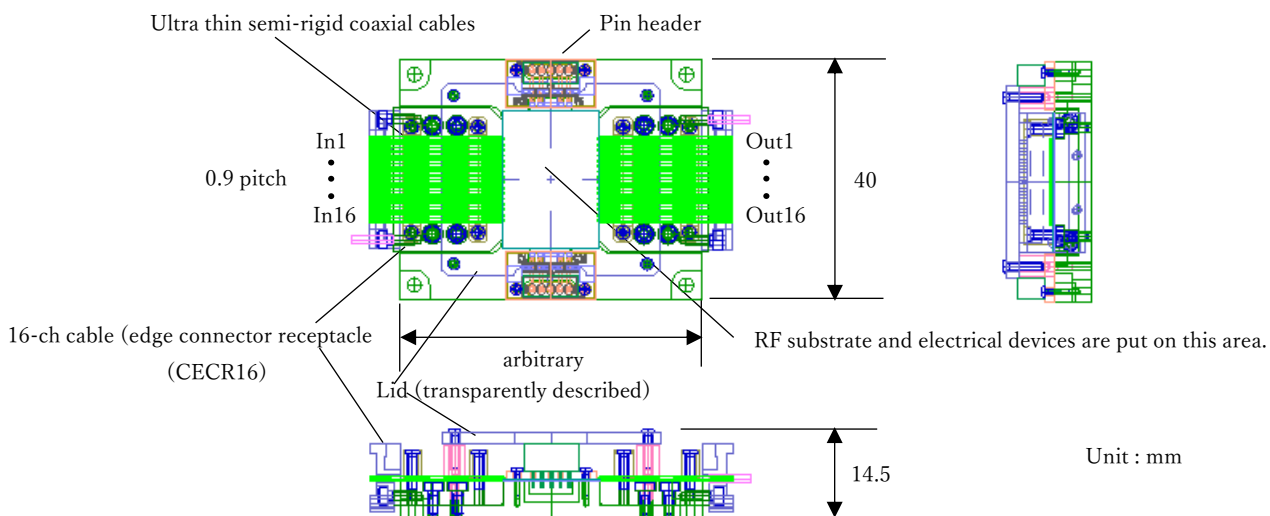


Fig. 2-3 Structure example of 16-ch electrical/electrical interface CECM16

If we make an optical transceiver using this technology with current available chips assuming 50 Gbaud rate , data speed becomes 800 Gb/s (8 ch x 2 bit x 50 Gbaud).

If we make an optical transceiver using this technology with near future available chips assuming 100 Gbaud rate, data speed becomes 1.6 T b/s (8 ch x 2 bit x 100 Gbaud).

Construction image of transmission system using eight CEC16s which use currently available chips is shown in Fig. 2-3. Data speed of this transmission system is 3.2 Tb/s . If we use near future available chips, it becomes as high as 6.4 Tb/s.

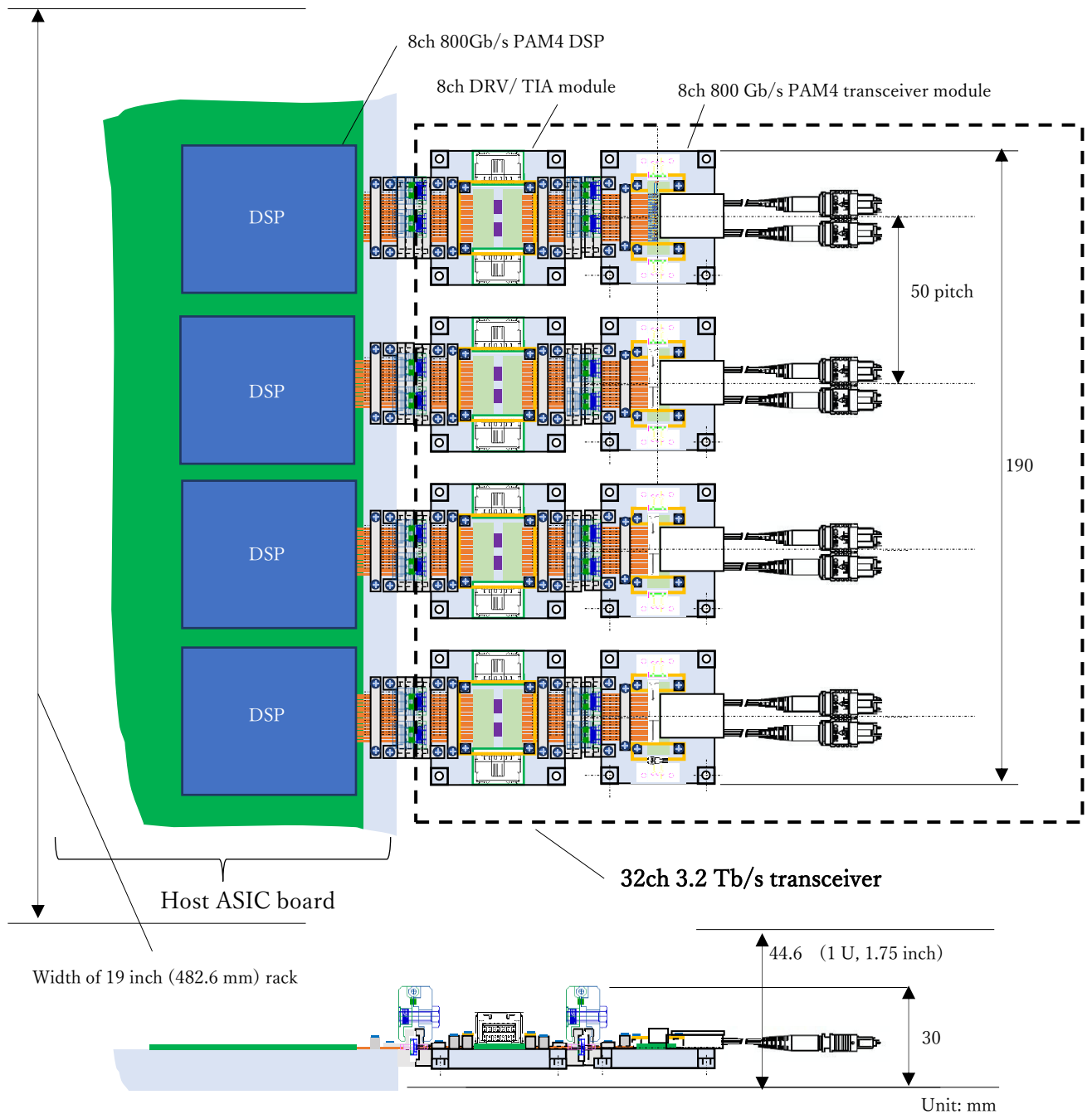


Fig.2-3 Construction image of 3.2Tbit/s (32ch 50Gbaud PAM4) transmission system using currently available chips

Section 4 Other Examples of RF module

Our company makes custom modules basically. So, we do not sell general purpose standard product except two products. We sell 56 Gbaud broad-band Linear amplifier module (BBLAMP_56A) and G3PO 60GHz DC Block (DB_60B) as standard product.

Followings are RF module examples that were actually fabricated. By seeing data sheet of various kind of RF modules , customers can estimate our company's capability of custom module fabrication.

Figure 2-4 shows photographs of representative RF modules.

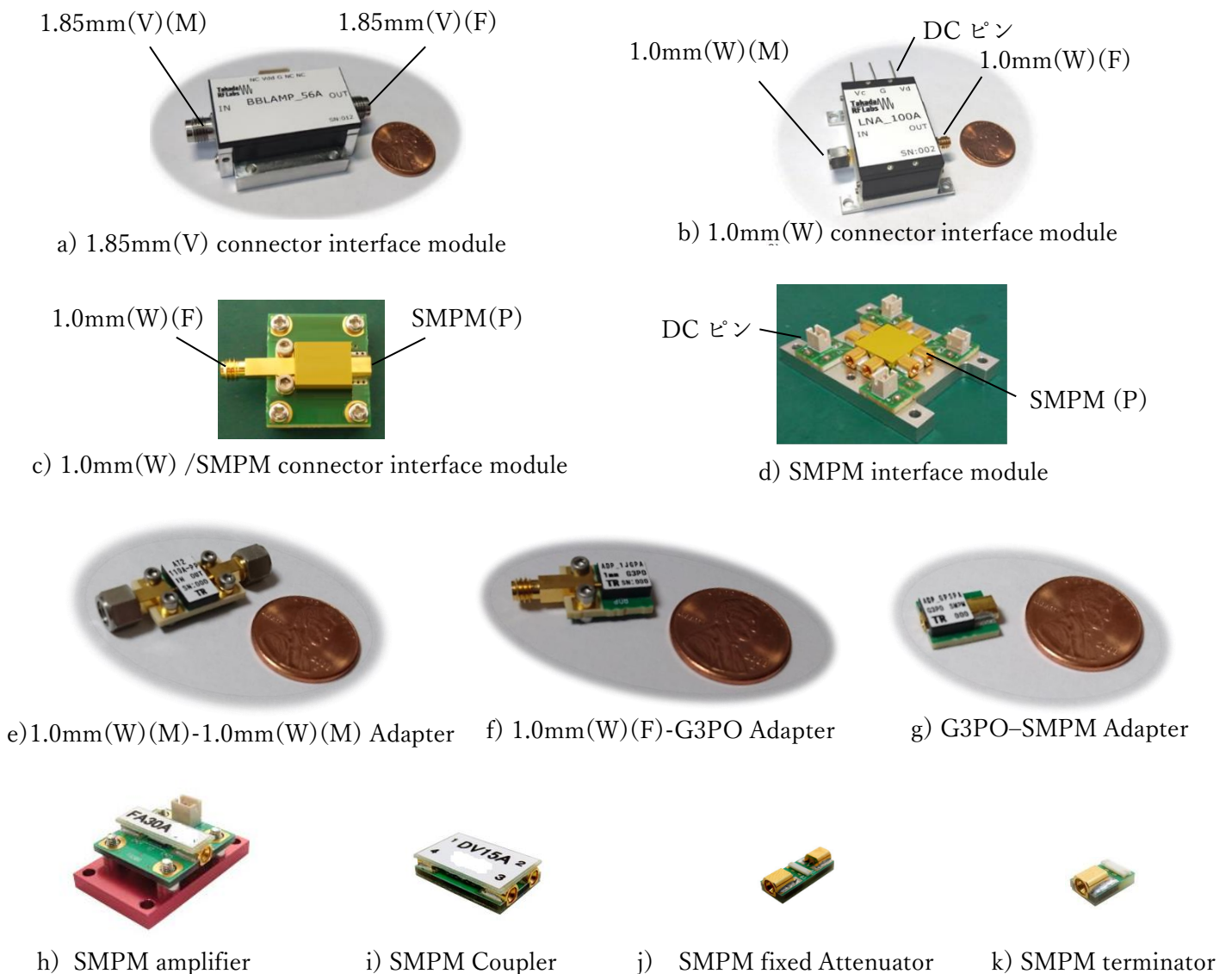


Fig. 2-4 Photograph of representative RF modules

Table 2-1 and Table 2-2 summarize main performance, connector used and application for active modules and passive modules respectively that were made and confirmed performance so far.

The detail specification of the products listed in Table 2-1 and Table 2-2 is described in the document “Data sheets of Takada RF lab’s RF products”.

Table 2-1 Active module specification outline

Category	Product name, Product No.	Main performance and connector used	Application	Data sheet name
Broad-band linear amplifier for fiber optic	56Gbaud broad-band Linear amplifier BBALMP_56A	FRQ: DC- 48 GHz, Gain: 12.7 dB P-3dBout : 16 dBm, PS: +6 V, Connector (CNT): 1.85 mm	56 Gbaud TIA, DML /EML driver for PAM4/NRZ signal Base band amp for wireless	BBLAMP_56A_DS_Rev 5.1
8-40 GHz general purpose amplifier	8-20 GHz Amplifier FA20C	FRQ: 8-20GHz, Gain: 20 dB, P-1dBout:19 dBm, PS: +5 V, CNT : SMPM	Gain block for variable subsystems, Clock signal amplifier	FA20C_DS Rev.1.0
	12-28 GHz Amplifier FA30A	FRQ: 12-28GHz, Gain:13 dB, P-1dBout: 15 dBm, PS : +5 V, CNT: SMPM		FA30A_DS Rev.1.0
	20-40 GHz Amplifier FA40A	FRQ : 20-40 GHz Gain: 15 dB, P-1dBout: 21 dBm, PS : +5 V, CNT: SMPM		FA40A_DS Rev.1.0
	6-18 GHz Variable Gain Amplifier VA15A	FRQ : 6-18 GHz, Gain: -12 ~+16dB, P-1dB in: 4 dBm, PS : +5 V, CNT: SMPM		VA15A_DS Rev.1.0
	8-32 GHz Variable Gain Amplifier VA30A	FRQ : 18-32 GHz, Gain: -18 ~+13dB, P-1dB in: 3 dBm, PS : +5 V, CNT: SMPM		VA30A_DS Rev.1.0
100GHz amplifier	65-110GHz Amplifier Module LNA_100A	FRQ : 65-110GHz, Gain : 13dB, P-3dBout: -6~+1 dBm, PS : +1.0 V, CNT: 1mm	Wireless E-band/W-band amplifier, Rader, imaging	LNA_100A_API_Rev1.1
VCO	10-20 GHz VCO SG20A	FRQ : 10-20 GHz, Pout : 0 dBm PS : +5V Cont. Voltage : 0 ~ +20V , CNT: SMPM	Signal generator for variable subsystems	SG20A_DS Rev.1.0
	20-28GHz VCO SG30A	FRQ : 20-28 GHz, Pout : 13 dBm, PS : +5V Cont. Voltage : 0 ~ +7V, CNT: SMPM		SG30A_DS Rev.1.0
Frequency multiplier	19-28 GHz out x2 Freq. Multiplier ML25B	FRQ : 19-28 GHz out Pin: +5 dBm Pout: +11 dBm (variable) PS: +5, -3.3 V, CNT: SMPM	Signal generation by frequency multiplier for variable subsystems	ML25B_DS Rev.1.0
	65-87 GHz Output Freq. Tripler X3A_80A	FRQ : 65-87 GHz out Pin: +9 dBm Pout: +10 dBm, PS +1.0 V, CNT: Input SMPM Output 1mm		X3A_80A_A PI_Rev.1.0
Variable Time delay	14GHz/12.5 Gb/s Time Delay with variable amplification, PS14B	FRQ : DC-14 GHz, 5bit switch control, Gain : 10 dB, 0.6Vpp out, PS: -3.3 V, CNT: SMPM	Phase control for Data / Clock signal	PS14B_DS Rev.1.0
Laser Driver	GHz /1 A -Class Laser driver	FRQ : 50 kHz-over 1GHz Driving current : over 1.0 App,	Measurement instruments for Optical devices	Custom
Short pulse generation	High speed short pulse repetition generator	Repetition freq: : 50kHz-over 20GHz Pulse half width : 18 ps, Pulse output: 0.4Vpp	Evaluation of Optical devices	Custom
MUX/ DEMUX	64Gb/s 2:1 MUX	Input: DC- 32 Gb/s, Output : DC- 64 Gb/s CNT: SMPM	Measurement tool for optical fiber system	Custom
Analog MUX	Analog 2-1 MUX	3 dB band width: over 50 GHz, CNT: Input SMPM, Output 1mm	Over 80 Gbaud Optical transmission system	Custom
DA converter	DAC Mod	Analog band width : over 40GHz CNT: Input 10 SMPMs, Output two 1mmCNTs	Over 70Gbaud Optical transmission system	Custom
	Multi-channel DAC Mod	Over 64 Gbaud, CNT: Input 20 G3PO, Output two 1mmCNTs	Measurement instruments for fiber optic	Custom
RF module for wireless	TX/RX Front-end module	40GHz band、TX Amp, 2-1 switch, RX amplifier multichip module CNT: there SMPMs	mm-wave wireless system	Custom

	Mixer module	40 GHz band, RF/LO/IF CNT: three SMPMs		
Optical TX/RF	4 CH differential TX module	25 Gbaud CNT: Input 4 CH G3PO Output 4 CH G3PO	25 Gbaud Optical transmission system	Custom
	Ultra high speed optical RX module	56 Gbaud 1CH differential out CNT: Output two 1.85mms	56 Gbaud Optical transmission system	Custom
Optical TX	Differential signal spread out RF substrate	60 GHz bandwidth 4 differential input CNT: eight 1.85mm	Ultra high speed optical transmission system	Custom

Table 2-2 Passive module specification outline

Category	Product name, Product No.	Main performance and connector used	Application	Detail document
Signal distribution	DC-32 GHz Power Divider, DV30A	FRQ: DC-32 GHz, Insertion loss : 8 dB, CNT: SMPM	Data signal distribution, combiner	DV30A_DS Rev.1.0
Coupler	10-18 GHz 3dB Directional Coupler DV15A	FRQ: 10-18GHz, Insertion loss : 3.5dB, 5 dB, CNT: SMPM	Sinusoidal signal distribution,	DV15A_DS Rev.1.0
	18-32 GHz 3dB Directional Coupler DV25A	18-32GHz, Insertion loss: 6 dB, 6dB , CNT: SMPM	Power monitor	DV25A_DS Rev.1.0
Fixed attenuator	DC-40 G Hz 3dB Fixed Attenuator AT03	FRQ: DC-40GHz, CNT: SMPM	Signal level/ gain control	AT03_DS Rev.1.0
	DC-40 GHz 6dB Fixed Attenuator AT06	FRQ: DC-40GHz, CNT: SMPM		AT06_DS Rev.1.0
	DC-35 GHz 10dB Fixed Attenuator AT10	FRQ: DC-35GHz, CNT: SMPM		AT10_DS Rev.1.0
	70- 110 GHz 2dB Fixed Attenuator AT2-110A	FRQ: 70-110GHz, CNT: 1mm		AT2_110A_API_Rev.1.0
	70- 110 GHz 3dB Fixed Attenuator AT3-110A	FRQ: 70-110GHz, CNT: 1mm		AT3_110A_API_Rev.1.0
	70- 110 GHz 5dB Fixed Attenuator AT5-110A	FRQ: 70-110GHz, CNT: 1mm		AT5_110A_API_Rev.1.0
	70- 110 GHz 8dB Fixed Attenuator AT8-110A	FRQ: 70-110GHz, CNT: 1mm		AT8_110A_API_Rev.1.0
	70- 110 GHz 9dB Fixed Attenuator AT9-110A	FRQ: 70-110GHz, CNT: 1mm		AT9_110A_API_Rev.1.0
Variable Attenuator	6-30 GHz variable Attenuator (for clock signal) VT 30A	6-30 dB, Attenuation range : 30 dB, P-1dB in: 25 dBm, PS : -3.3 V, CNT: SMPM	Clock/ Data signal level/ gain control	VT30A_DS Rev.1.0
	DC-28 GHz variable Attenuator (for 32Gb/s data signal)	FRQ : DC-28 GHz, Attenuation range : 24 dB, Max. input power : 24 dBm, CNT: K		Custom
	DC-40 GHz variable Attenuator (for up to 40 GHz clock signal, 56 Gb/s data signal)	FRQ : DC-40GHz , over 56Gb/s signal data, Attenuation range : 24 dB, Max. input power : 24 dBm, CNT: K		Custom
DC Block	40GHz DC Block , DB_40A	FRQ : 20kHz-40GHz, CNT: SMPM	Clock data signal AC coupling	DB40A_DS Rev.1.0
	60GHz DC Block, DB_60A	FRQ: 50kHz-60GHz, CNT: G3PO		DB_60A_API_Rev.1.0
Bias-T	64Gb/s Bias-T, BT_64A	FRQ : 50kHz-55GHz,	Bias-T	Module Data sheet (Rev.

		CNT: G3Po		1.1, Eng.) p.82
Bias-Feed	64Gb/s Bias-Feed DF_64A	FRQ : 50kHz-65GHz, CNT: G3PO	Bias Feed	Performance of G3PO 64 Gbaud DC Block, Bias- T, DC Feed
50Ω Terminator	40 GHz 50Ω Terminator TM_40L	FRQ : DC-40GHz, CNT: SMPM	Signal termination	TM40L_DS Rev.1.0
	110 GHz 50Ω Terminator TM_110A	FRQ : DC-110GHz, CNT: 1mm		TM_110A_API_Rev.1.1
Power detector	30kHz-110GHz broad-band Power Detector Module PD_110A	FRQ : 30kHz-110GHz, CNT: 1mm	Power detection	PD_110A_API_Rev.1.0
Filter	5 GHz Low Pass Filter	Fc : 5 GHz, Pass band insertion loss : < 3 dB, CNT: SMA	Low pass filter	Custom
	28 GHz Low Pass Filter	Fc : 28 GHz, Pass band insertion loss : < 2 dB, CNT, K(2.92mm)		Custom
	35 GHz High Pass Filter HPF_35A	Fc : 35 GHz, Pass band: 40- 60 GHz, Pass band insertion loss: 3 dB, CNT: SMPM	High pass filter	HPF_35A_API_Rev.1.0
	70-110 GHz Pass-Band High Pas Filter, HPF_63A-XY	Fc : 63GHz, Pass band : 70- 110GHz, Pass band insertion loss: : 5 dB, CNT: 1mm		HPF_63A_API_Rev.1.0
Equalizer	Less than 1.5 GHz band equalizer	S11: <-18 dB CNT: SMA	S21 flattening	Custom
Connector adapter	1mm Female / Male Adapter ADP_1X1YA	FRQ : DC-110GHz	Connection between different type connectors	ADP_1X1YA_API_Rev.1.0
	1mm-G3PO Adapter, ADP_1XGPA	FRQ : DC-92 GHz		ADP_1XGPA_API_Rev.1. 0
	1mm-SMPM Adapter, ADP_1XSPA	FRQ : DC-65 GHz		ADP_1XSPA_API_Rev.1.0
	G3PO-SMPM Adapter ADP_GPSPA	FRQ: DC-65 GHz		ADP_GPSPA_API_Rev.1. 0
	SMPM(P) SMPM(P) Adapter ADP_SPSA	FRQ: DC-62 GHz		ADP_SPSA_API_Rev.1.1

Chapter 3 Evaluation board and test fixture of high frequency (speed) devices

Section 1 Evaluation board

We design/fabricate and supply the evaluation board (EVB) to high frequency device suppliers by using our fundamental technologies shown in Chapter 1.

EVB is made mainly for the purpose that device users, who intends to use high frequency device in their system, confirm device performance before implementing them in their system board. The other purpose of EVB is that device supplier shows customers sample implementation of the device, that is, show example of circuit board design and assembly method of the device. Sometimes, EVB is used to make an experimental system board.

Our company's EVB technology is capable to apply to the devices that operate up to over 150 Gbaud, 110GHz range .

By considering functionality and maximum operating frequency, optimizations of substrate material, connector and transmission line are done using various kind of simulations.

When DUT device is packaged device, it is soldered on the EVB. When DUT device is die form, it is die bonded on the circuit board or board base and wire bonded.

Figure 3-1 shows a structure example of EVB for package device with 4 channel single-end inputs and 4 channel differential outputs. In most of cases for multi-channel device, small size of connectors such as SMPM and G3PO on the PCB are used to have low insertion loss of board. We often use ultra-thin semirigid cables and Alumina or Quartz substrate to have highest performance.

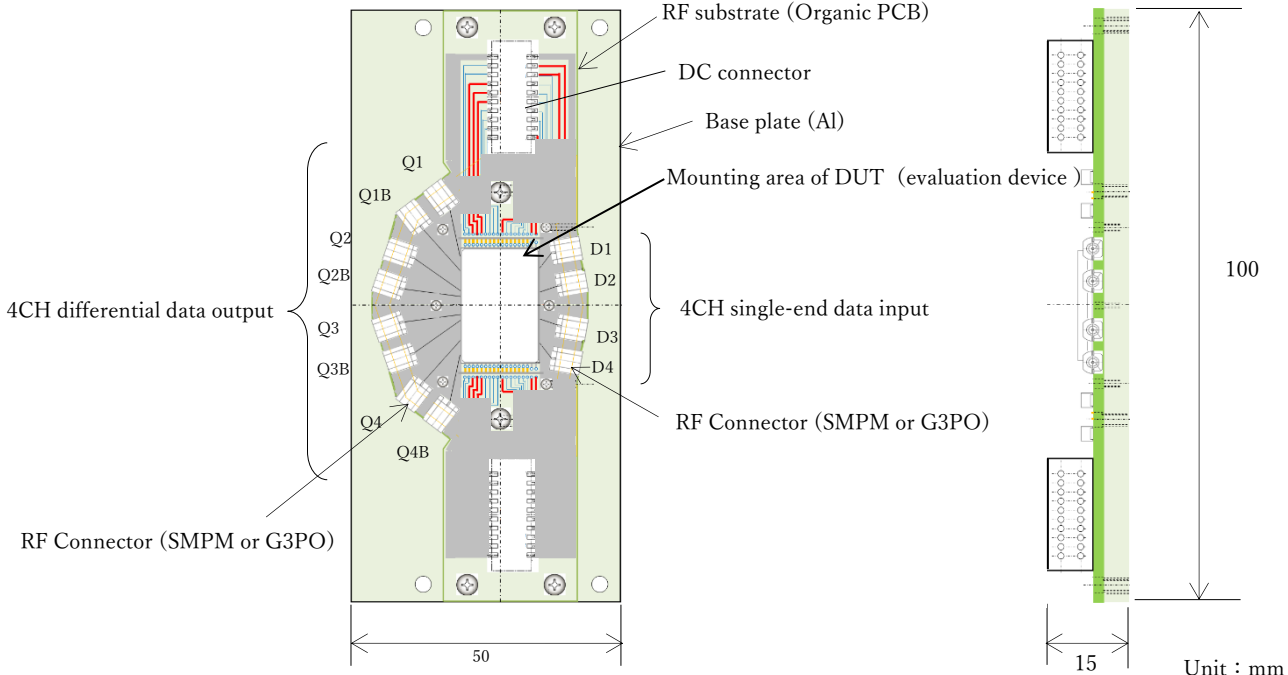


Fig. 3-1 EVB structure example

Section 2 Test fixture for high frequency devices

Subsect.1 Basic structure of test fixture

The purpose of test fixture for high frequency devices is different with EVB. While EVB is used to evaluate device performance, test fixture is used to measure RF performance in shipping inspection, acceptance inspection or failure analysis. Big deference in structure between EVB and test fixture is that DUT electrodes in the test fixture are not soldered but be mechanically contacted to the circuit board at RF measurement. Figure 3-2 shows basic structure of test fixture.

Although it is not so easy to have good RF performance in such mechanical contact condition, it should be designed so that characteristics degradation by test fixture portion is as small as possible. However, in many cases, it is difficult to make sufficient performance test fixture of which degradation is negligibly small. So, measurement data obtained in inspection measurement using test fixture can not be compared directly with pass fail criterion. We have to perform Pass/Fail decision as counting test fixture degradation accurately. One of the ways to remove test fixture characteristic from measurement data and to know DUT characteristic itself is performing calibration at DUT electrode instead of performing calibration at coaxial connector portion. For this calibration, we make 3 kind of calibration

standard (Open, Short, Load) and THRU standard for performance confirmation, of which bottom structure is same as DUT bottom structure. We can supply these calibration standard kit with test fixture if needed.

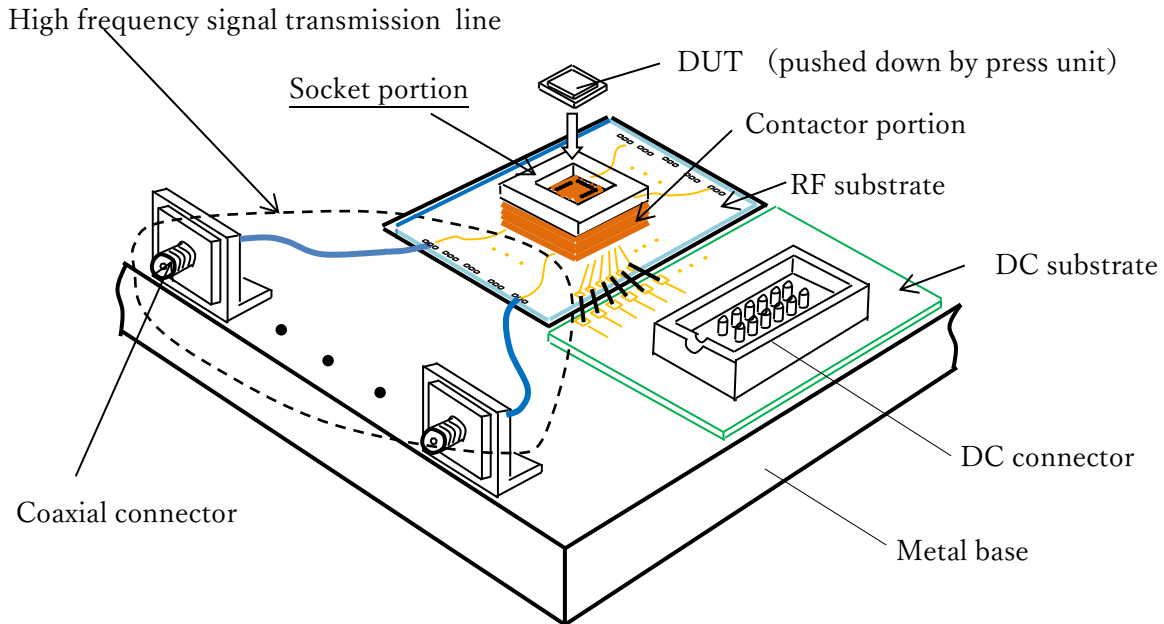


Fig. 3-2 Basic structure of test fixture for high frequency device

As shown in Fig.3-2, test fixture consists of 1) high frequency signal transmission line portion 2) socket portion for device position alignment and 3) device electrode contactor portion.

To have good performance of high frequency signal transmission line portion, technologies same as transmission line for RF module that are explained in Section 3 in Chapter1 are required.

For socket portion that is made with resin machined parts, high accuracy machining with small tolerance is the key to have good positioning of DUT electrodes. Detail is not described here.

Contactor portion RF characteristics mainly determines performance of test fixture assuming that good DUT positioning and good transmission line are realized. There are various types of contactors. Our company is using three types of contactors shown in Table 3-1. These are used properly depending on DUT structure (QFN, LGA, BGA, etc.) , operation frequency and application.

Table 3-1 Contactor type and feature

Contactactor type	Max. frequency	Application
Spring pin base vertical contact probe	About 30 GHz	Multi-pin count DUT
Anisotropic conductive sheet (ACS) (Shin-Etsu Polymer Co., Ltd)	110 GHz	Mainly used for ultra high frequency medium pin count DUT
Metal-rod vertical multi-contact-pin	About 80 GHz	For high frequency multi-pin count DUT

Subject.2 Contactor with spring pin base vertical contact probe

Typical structure of spring pin base vertical contact probe is that a small spring is inserted into metal pipe and pins are put on or under the spring inside the pipe.

The contact probes are inserted into pin-holder and these pins individually stroke under the DUT pads (electrodes) and electrical contact is performed. There are many kind of probes with different diameter, length, pin end structure and stroke distance, etc.

Spring pin base vertical contact probe generally provides stable contact performance because stroke distance is large. Frequency characteristic of this probe is worth than the other types of contactors, however, it can be applicable to be used for up to 30 GHz frequency devices, thus widely used for many applications. Figure 3-3 shows two port (GSG configuration) S-parameter measurement results for spring pin base vertical contact probe KHP3060 (4mm length, made in MORIMOTO)

Pink color line is S21 for entire measurement set-up. Blue color line is S21 of Ref-THRU that is circuit excluding DUT. The difference between pink color and blue color lines becomes S21 of KHP3060 with GSG configuration. 3dB down frequency F-3dB is 33 GHz

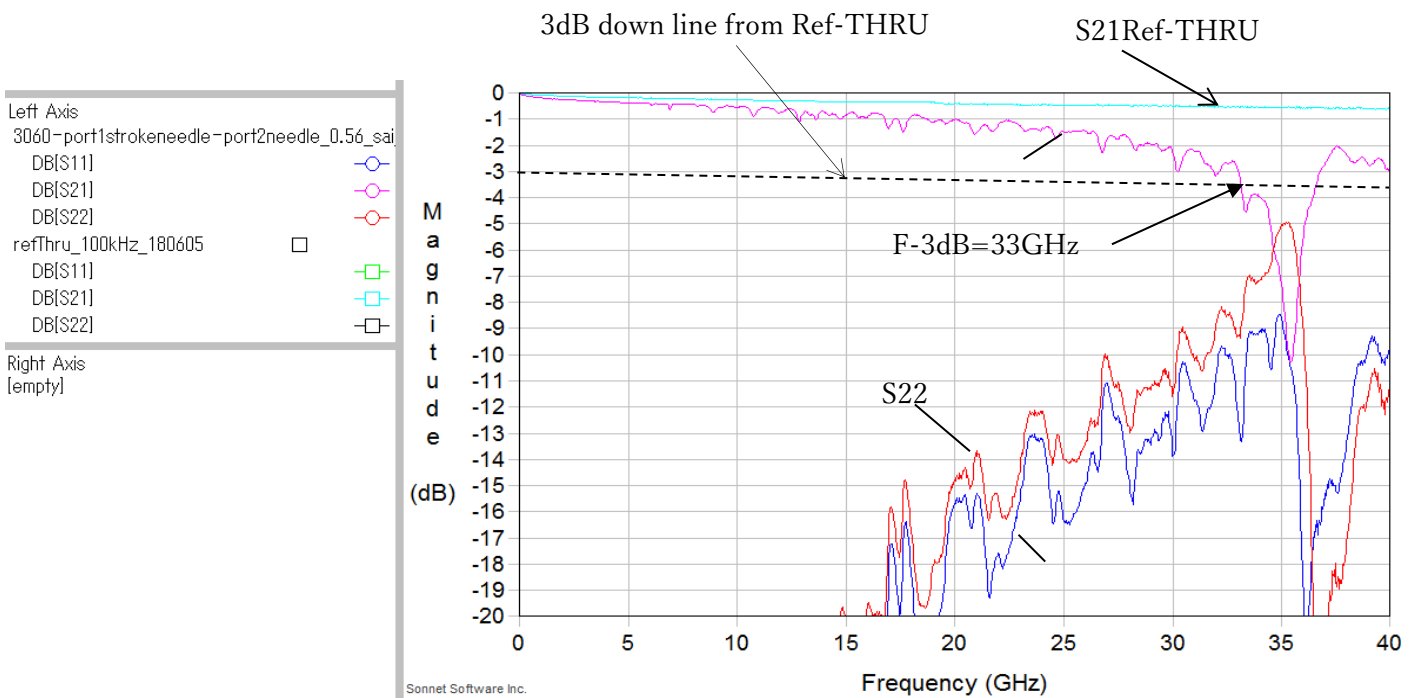


Fig. 3-3 S-parameter of spring pin base vertical contact probe

Figure 3-4 shows an output eye diagram of this probe obtained from the above S-parameter data using frequency/time domain conversion software (PLTS, Keysight Technologies) in the case of 32 Gb/s PRBS 2⁷-1 input data with 5 ps Tr/Tf. High quality output waveform with small jitter is obtained. Since characteristics shown in Fig.3-3 and Fig.3-4 are for contact probe only, characteristics of test

fixture including transmission line portion becomes a little bit degraded actually but not so big degradation.

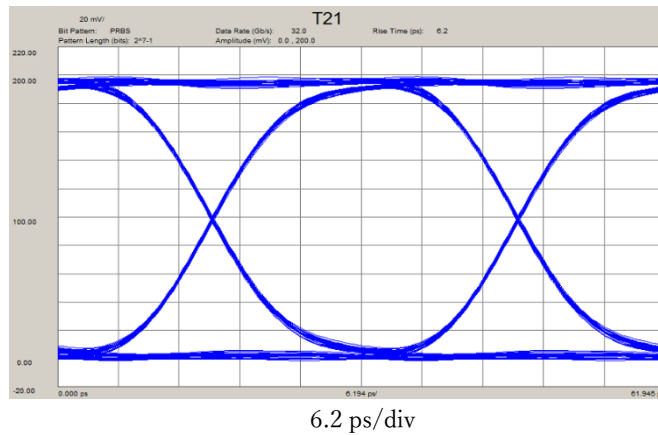


Fig. 3-4 32 Gb/s output eye diagram of spring pin base vertical contact probe

Subject.3 Contactor with anisotropic conductive sheet

When anisotropic conductive sheet (ACS) is compressed, vertical direction of sheet becomes conductive and horizontal direction becomes nonconductive. This anisotropic function is realized by making structure in which many thin metal wires are embedded vertically into insulating rubber, for example. Contactor with ACS has advantages described below .

- 1) DUT position alignment is easy because only one time position alignment between DUT pads and substrate pads is needed while other types of contactors need two times alignment among DUT pads, contactors, and substrate pads.
- 2) Maximum operation frequency is significantly high as comparing spring contact probe . This is because sheet thickness becomes transmission line length between DUT and substrate. Sheet thickness is around 0.15 mm to 0.25 mm that is much shorter than contact pin length around 3 mm to 10 mm.

Figure 3-5 shows S-parameter of contactor using ACS with 0.15 mm thickness.

Pink color line is S21 for entire measurement set-up. Blue color line is S21 of Ref-THRU that is circuit excluding DUT. The difference between pink color and blue color lines becomes S21 of ACS. 3dB down frequency F-3dB is over 110 GHz. By comparing with Fig. 3.3 , we know that frequency characteristics of ACS is significantly high.

Figure 3-6 shows an output eye diagram of this probe obtained from the above S-parameter data using frequency/time domain conversion software (PLTS, Keysight Technologies) in the case of 32, 64 and 100 Gb/s PRBS 2^7-1 input data with 2ps (20-80%) of Tr/Tf. By comparing 32 Gb/s waveform of spring contact probe shown in Fig-3-4 and waveform of ACS shown in Fig.3-6(a) , we know that Tr/Tf of output wave of ACS is much smaller than that of spring contact probe. Even at 100 Gb/s , ACS shows enough wide eye opening and very low jitter.

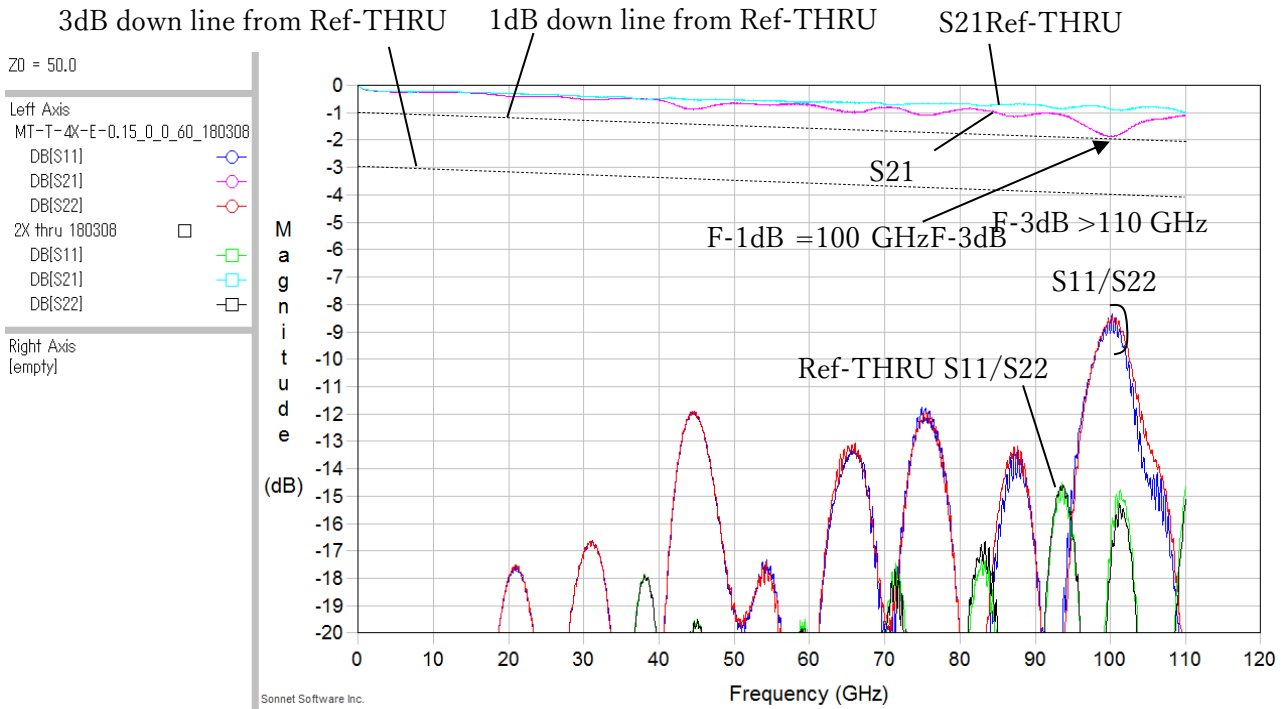


Fig. 3-5 S-parameter of ACS with 0.15mm thickness

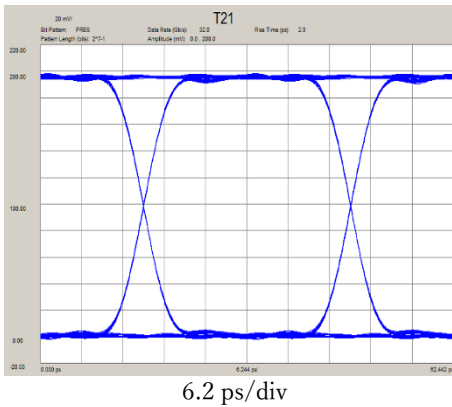


Fig. 3-6 (a) 32 Gb/s

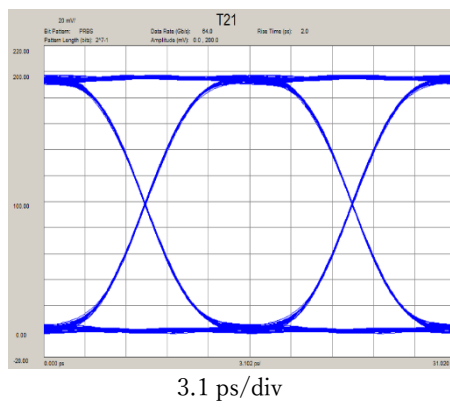


Fig. 3-6 (b) 64 Gb/s

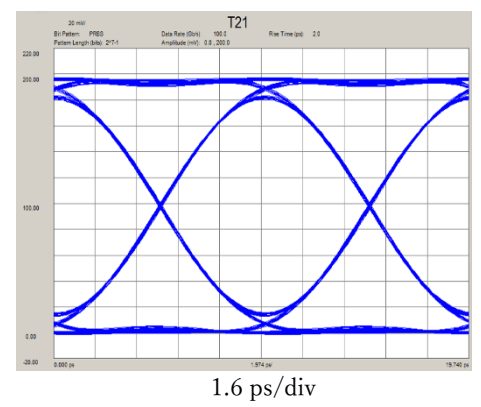


Fig. 3-6 (c) 100 Gb/s

Fig. 3-6 32, 64 and 100 Gb/s output eye diagram of ACS with 0.15mm thickness

Subject.4 Metal-rod vertical multi-contact pin probe (MRP) as contactor

Metal rod vertical multi-contact pin probe (MRP) is modified version of contactor with ACS. This was developed for the purpose that contactor does not make scars on DUT pads at measurement unlike contactor with ACS. Multiple metal rod pins, that are fixed on and under ACS in pin holder, make electrical contact individually between DUT pads and substrate pads like contactor with multiple spring pin base contact probe. Figure 3-7 shows S parameter measurement results of Quartz substrate short length thru line with GSG input and output pads (160 um pad pitch) by test fixture using MRP as contactor.

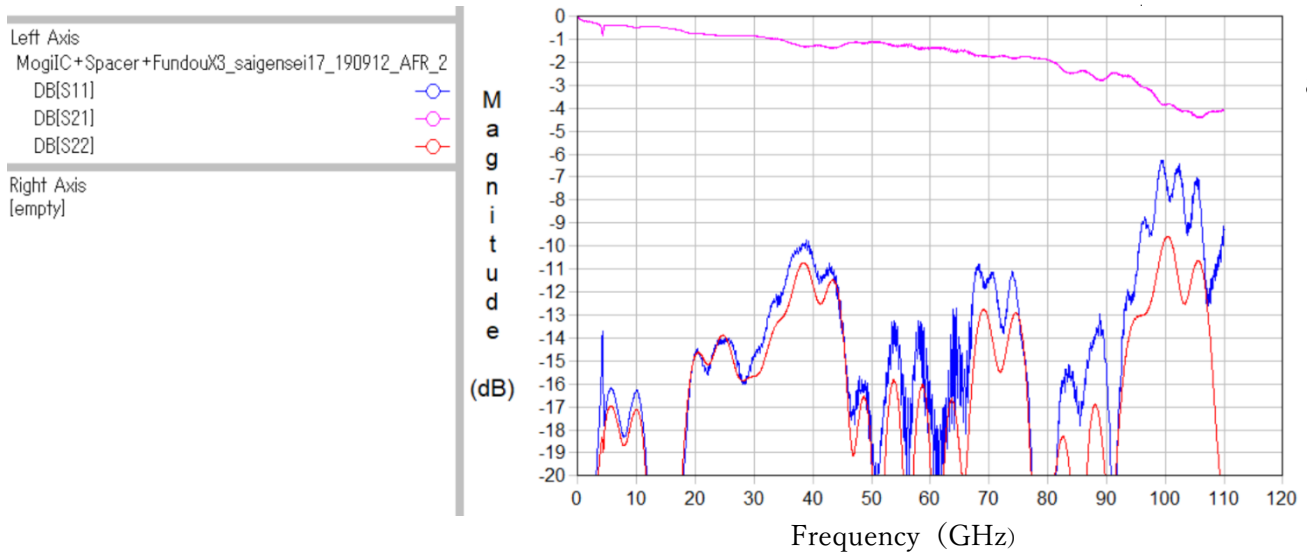


Fig. 3-7 Quartz substrate thru line S-parameter measured by test fixture using MRP as contactor

Although this measurement data shows entire performance of thru line (DUT) and test fixture transmission line, F-3db reaches 96 GHz that is lower than pure ACS F-3db of >110 GHz but is significantly better than characteristics of spring pin base vertical contact probe shown in Fig.3-3.

Figure 3-8 shows output eye diagrams of test fixture obtained from the above S-parameter data using frequency/time domain conversion software (PLTS, Keysight Technologies) in the case of 32, 64 and 100 Gb/s PRBS 2^7-1 input data with 2ps (20-80%) of T_r/T_f . By comparing 32 Gb/s waveform of spring contact probe shown in Fig-3-4 and waveform shown in Fig.3-8(a), we know that T_r/T_f of Fig.3-8(a) is much smaller than that of spring contact probe. Even at 100 Gb/s, waveform show enough wide eye opening and very low jitter.

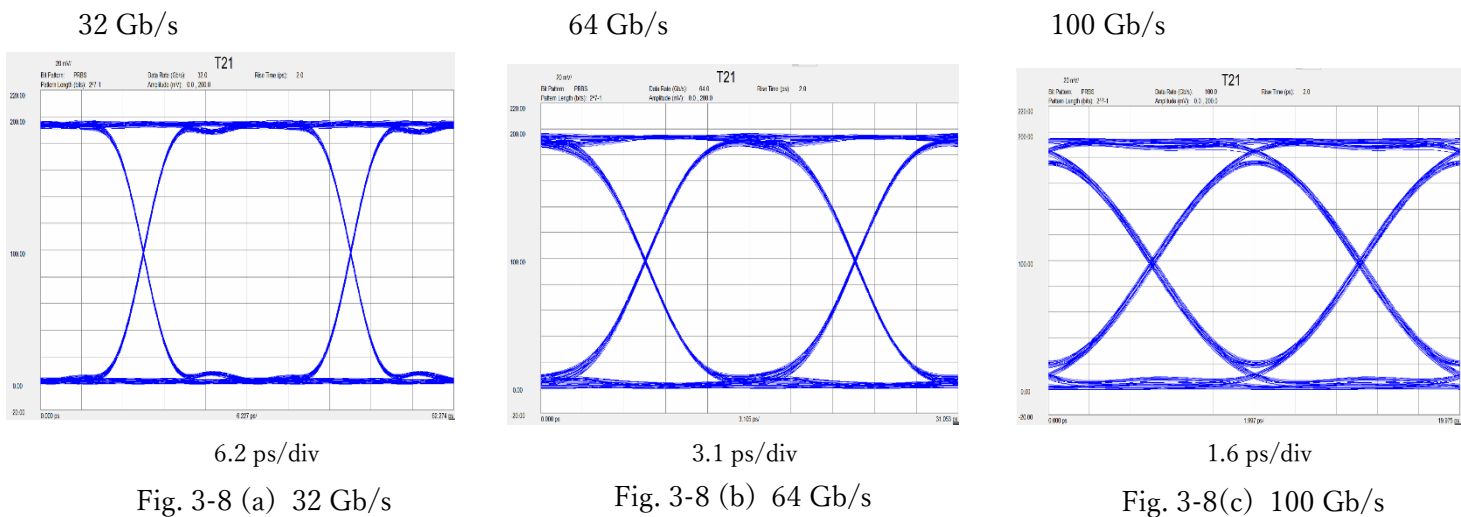


Fig. 3-8 (a) 32 Gb/s

Fig. 3-8 (b) 64 Gb/s

Fig. 3-8(c) 100 Gb/s

Fig. 3-8 32, 64 and 100 Gb/s output eye diagram of output eye diagrams of test fixture contactor using MRP as contactor

Chapter 4 High frequency probe-card using MRP

Test fixture described in chapter 3 is normally used to test packaged IC device in which IC die is mounted. The die performance is normally inspected using on-wafer probe card before being cut and mounted in the package. We call passed die in this test “known good die (KGD)”. To get KGD, sometimes only DC test is performed, however, it is better to perform high frequency AC test in addition to DC test. There are many devices having AC coupled interface. For these devices, AC test is mandatory.

So, on-wafer probe-card with high RF performance is needed.

On-wafer probe-card with three types of structure such as cantilever type, membrane type and spring pin base vertical contact probe type are mainly used.

Cantilever type structure can make high frequency performance probe card for ICs of which signal pads are placed on periphery, but it is very difficult to have good frequency performance to ICs of which pads are placed near the center such as BGA.

Membrane type probe card has excellent RF performance available to measure RF IC with operating frequency is up to around 80 GHz and also easily applied for large pin count ICs. However, since probe-card fabrication process is similar to semiconductor fabrication process, initial cost may not be small and delivery time may not be short, it may not be suitable for small scaled ICs and for R&D application.

Spring pin base vertical contact probe type probe card is suitable for the ICs of which pads are located at entire device surface area and has advantage that damage to DUT pads by probing is very small. However, it is difficult to apply high frequency devices because maximum operating frequency is limited at around 30 GHz as explained at section 2 in chapter 3.

We have newly we newly invented the MRP type probe card. In this probe card, MRP is fixed on the RF substrate and has following many advantages compared with other types of probe-cards.

- 1) Excellent high frequency performance having 90 GHz of F-3dB
- 2) Available to apply to relatively large co-planarity devices.
- 3) Available to apply to devices of which signal pads are located at entire device surface area
- 4) Available to apply to devices with large pad count of around several hundreds
- 5) No damage to DUT pads by probing
- 6) Low Initial cost

(Note) Our company will not supply this type of probe-card to the probe card users but will supply only contactor portion using MRP to probe card manufacturers.

Revision history

Rev.	Date	Modification place and modification contents
Initial version (Rev.1)	2020/7/21	Initial version is issued.
Rev. 1.1	2020/8/11	Modify wording partially
Rev. 1.2	2020/8/19	Modify wording partially
Rev. 1.2.1	2020/8/20	Modify revision history
Rev. 2.0	2021/3/22	Update Table 1-2 and Table 1-3 Modify wording partially
Rev. 3.0	2022/6/15	<ol style="list-style-type: none"> 1) Page2: 0.8mm connector and CECN connector are added in Fig. 1-1. 2) Page3: Description about CECN is added. 3) Page5: Tefron (CH2868D) is added in Table 1-1 and information about minimum L/S and minimum VIA diameter is added in Table 1-1 4) Page8, Page9: Contents of Table1-2 are updated. 5) Page9: Comments of 3) is modified. 6) Page13, Page 14: Description of broad band technology and multiport technology are added as recent topics.
Rev.4.0	2023/6/19	<ol style="list-style-type: none"> 1) Language is changed from Japanese to English 2) Page 16, Page 17: Detailed module fabrication technologies are described, which includes ultra-high frequency technology and multi-channel technology for optical transceiver application.