

Direct Attach Cable with Micro Coaxial Wire for Data Center

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In data centers, direct attach cables with twinax wire have been used to date in order to avoid defects such as skew. However these cables have drawbacks of being thick and hard. In the background of a recent trend of the rack highly dense with switches and servers, which is common in many data centers, there is a growing need for thin and flexible cable that provides better wiring operation and heat dissipation for intra-rack wiring of up to 3 m. Sumitomo Electric Industries, Ltd. developed novel thin and flexible direct attach cables (SFP+ and QSFP+) by using the advanced micro coaxial wire technology cultivated through information appliance products.

Keywords: direct attach cable, micro coaxial wire, SFP+/QSFP+, data center

1. Introduction

With the rapid increase in the use of mobile information devices such as smart phones and tablets in recent years, data traffic on the Internet is exploding, and data centers to support data traffic are increasingly important. With this background, the data transfer rate and the server density per rack in data centers are increasing. Currently, a data transfer rate of 10 Gb/s between a switch and a server in the rack is becoming predominant, and devices to support a data transfer rate of 40 Gb/s are becoming available. Direct attach cables, such as Small Form Factor Pluggable Plus (SFP+) and Quad Small Form Factor Pluggable Plus (QSFP+), are mainly used as media to support high transfer rates between these devices in the rack.

Conventionally, twinax wire*¹ with a high skew performance has been mainly used for direct attach cables. However, since conventional direct attach cables are thick and hard, there is an increasing need for thin and flexible cables for high-density rack wiring of up to 3 m that offer ease of installation and operation and high heat dissipation performance. To meet this need, we have successfully developed direct attach cables (SFP+, QSFP+) that are thinner and more flexible than conventional ones, using our advanced micro-coaxial wire*² technology, which we have developed for information appliance products.



This report presents the outline of the design of the cables and their characteristics, as well as the evaluation results of the characteristics of SFP+ and QSFP+ using the developed cables.

2. Brief Description of the Direct Attach Cables

Table 1 briefly describes the developed direct attach cables. SFP+ and QSFP+, which are the form factor for transfer rates of 10 Gb/s and 40 Gb/s (4×10 Gb/s), respectively, are connected to a cable terminal. Generally, the diameter of conventional 1 m SFP+ and

QSFP+ twinax cables is more than 4 mm and 6 mm, respectively. The diameter of the 1-m micro-coaxial cables is small, with 3.2 mm for SFP+ and 5.0 mm for QSFP+.

Table 1. Outline of the direct attach cables

Form factor	SFP+	QSFP+
Transmission rate	10 Gb/s	40 Gb/s
Compatible standards	10GSFP+Cu (SFF-8431)	40GBASE-CR4 (IEEE802.3 QDR (Infiniband))
Number of cores in cable	4 cores (2 pairs)	16 cores (8 pairs)
Cable diameter	3.2 mm (1m) 3.6 mm (3m)	5.0 mm (1m) 6.4 mm (3m)
Wire gauge	AWG34 (1m) AWG32 (3m)	AWG34 (1m) AWG30 (3m)
External view		

3. Brief Description of the Cable Design

3-1 Cable design and construction

Figure 1 shows the cross sections of the developed cables. SFP+ and QSFP+ are for 1-lane bidirectional signal transmission and for 4-lane bidirectional signal transmission, respectively, and have 4 cores (2 pairs of wires) and 16 cores (8 pairs of wires) in the cable.

3-2 Transmission characteristics of the cables

The skew is one of the most important parameters that affects the signal transmission characteristics of cables. SFP+ and QSFP+ use the differential signal transmission method. The skew is the time difference after signal transmission between positive and negative signals in the transmission of differential signals. A differential signal is defined as the voltage difference

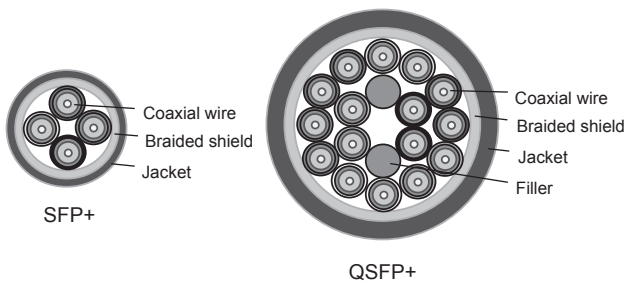


Fig. 1. Cross section of the cables

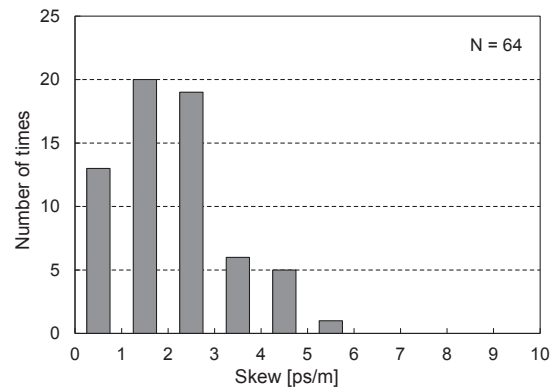


Fig. 2. Typical skew

between the positive and negative signals. Therefore, the magnitude of the skew affects the voltage difference (differential amplitude). That is, the magnitude of the skew affects the signal transmission characteristics of the cable in proportion to the frequency of the signal. It is important in controlling the skew to reduce the difference in characteristics between two coaxial wires to make them a pair as much as possible. More specifically, it is necessary to make the physical length and signal delay time of the two coaxial wires as equal as possible. For example, for a 1-m cable, a skew of 4.7 ps/m occurs if there is a difference in length by only 1 mm between the two coaxial wires (because the average signal delay time of the coaxial wire is 4.7 ns/m). We reduced the effect of flattened shape or non-perfect circular cable shape on the difference in the physical length as much as possible by arranging coaxial wires concentrically and making a pair of two adjacent coaxial wires to reduce the difference in the physical length when making a multi-core cable.

As the signal delay time (T_d) is given by $T_d = \sqrt{\epsilon} \cdot \text{dielectric constant} / \text{speed of light}$, the difference in the dielectric constant of the insulation material covering the center conductor of the coaxial wire directly affects the skew. Since the dielectric constant is specific to a material, selection of an insulation material is certainly important. To aim at a skew of less than 10 ps/m required for a transmission rate of 10 Gb/s, a variation in the small air layer between the center conductor and the insulation material cannot be ignored. We focused on the variation in the air layer and achieved a low skew in a coaxial construction by stably controlling the variation in the longitudinal direction.

Figure 2 shows a typical example of the skew of differential pair wires in an SFP+ (1 m) cable using the developed micro-coaxial wire. **Figure 3** shows a typical example of insertion loss. The skew is 5 to 6 ps/m at a maximum and low enough for a transmission rate of 10 Gb/s, or signal transmission at a signal interval of 100 ps per bit. The insertion loss of the coaxial wire is similar to that of the twinax wire. In addition, the coaxial wire shows no significant attenuation in a specific frequency range called suck-out, which appears in conventional twinax wires. Similar results to the SFP+ (1 m) cable shown in the figure were obtained for other cables shown in **Table 1**.

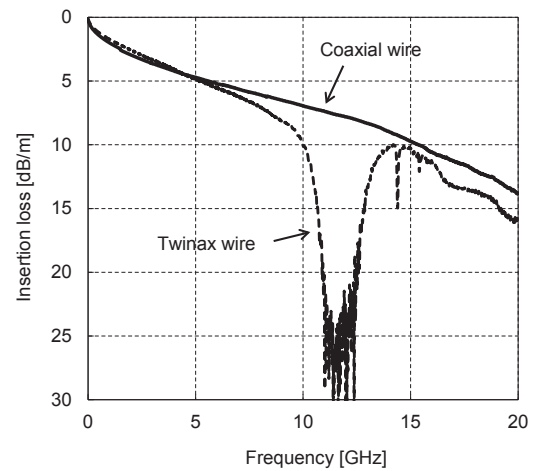


Fig. 3. Typical cable insertion loss

3-3 Mechanical properties of the cables

Table 2 shows the results of a flexibility test of coaxial and twinax SFP+ (1 m) cables. The load was measured when the cable was bent 15°. A cable with a lower value of load is more flexible. The coaxial wire multi-core construction provides much higher flexibility than the twinax construction. The load is more than 5 times lower for the former than for the latter. The level of flexibility directly affects the reliability of the cable. **Table 3** shows the insertion loss measured by bending the coaxial and twinax SFP+ (1 m) cables a specified number of times under the same conditions. While the twinax wire broke before being bent 1,000 times, the coaxial wire did not break until it had been bent 10,000 times and it maintained its signal transmission characteristics.

As shown in **Photo 1**, the coaxial SFP+ (1 m) cable was folded at several points at a radius equal to its diameter, and the insertion loss was measured in the folded state. **Figure 4** shows the measured insertion loss. A conventional twinax wire degrades or breaks due to the contact that occurs when the cable is placed or inserted and removed or when the server rack is

opened and closed. When the coaxial wire multi-core cable was folded at a radius equal to its diameter, the signal transmission characteristics were not affected, indicating that the risk of degradation is very low.

Table 2. Flexibility test results (bending load)

Sample	Coaxial wire	Twinax wire	Unit
No.1	0.0055	0.0308	N·m
No.2	0.0049	0.0362	
No.3	0.0050	0.0420	

Table 3. Bending durability test

Number of bending cycles	Insertion loss at 5.0 GHz [dB/m]	
	Coaxial wire	Twinax wire
0	4.7	4.7
1,000	4.6	No electrical conduction
5,000	4.7	-
10,000	5.2	-
15,000	6.1	-
16,000	No electrical conduction	-

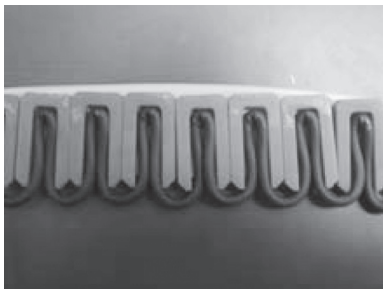


Photo 1. Cable folding test

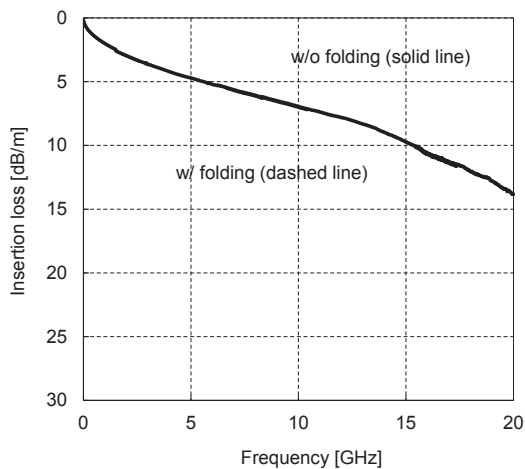


Fig. 4. Effect of folding on insertion loss

4. Evaluation Results of the SFP+ and QSFP+ Cables

4-1 Evaluation results of the SFP+ cable

SFP+ is a form factor specified by a multi-source agreement (MSA), an industry standard for communication modules. The electrical interface specifications, including transmission characteristics, are defined in SFF-8431⁽¹⁾. SFP+ (a passive cable) is specified as 10GSFP+Cu in SFF-8431⁽¹⁾. **Table 4** shows the main parameters related to the transmission characteristics. **Figures 5 to 8** show the evaluation results (3 m) of each parameter.

V_{cm} is the common mode voltage*³ output after cable transmission and a parameter most susceptible to the skew of the cable. The obtained value of V_{cm} proves that the developed low skew micro-coaxial wire has sufficient performance conforming to the specification. dWDP and VMA Loss are the parameters indi-

Table 4. Main parameters of 10GSFP+Cu

Parameter	Minimum	Maximum	Unit
Output AC Common Mode Voltage (V _{cm})		13.5	mV (RMS)
Difference Waveform Distortion Penalty (dWDP)		6.75	dBe
VMA Loss		4.4	dBe
VMA Loss to Crosstalk Ratio (VCR)	32.5		dB

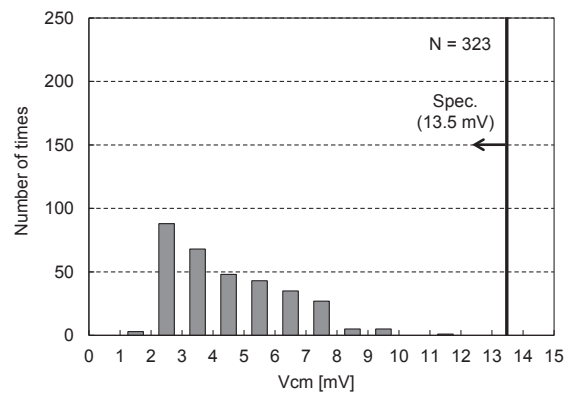


Fig. 5. Output AC Common Mode Voltage (V_{cm})

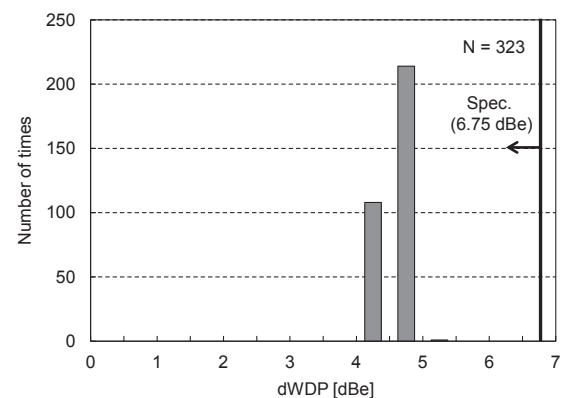


Fig. 6. Difference Waveform Distortion Penalty (dWDP)

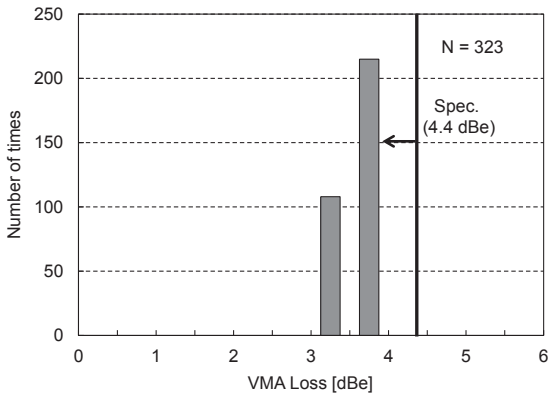


Fig. 7. VMA Loss

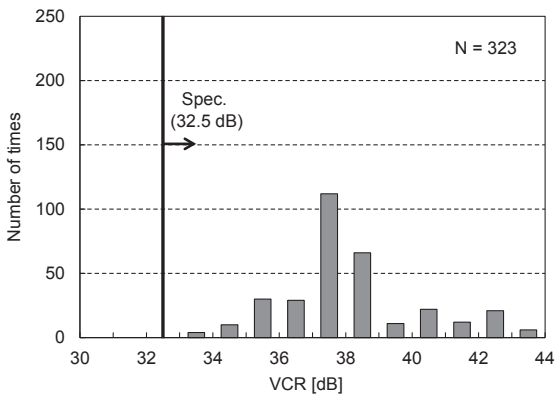


Fig. 8. VMA Loss to Crosstalk Ratio (VCR)

cating the level of degradation of a signal waveform after cable transmission. VCR is the tolerance to crosstalk*4 between opposing lanes. It has been confirmed that these parameters are satisfactory.

These results are for 3-m cables, for which the property requirements of the specifications are more severe. Satisfactory results were obtained similarly for 1-m cables.

4-2 Evaluation results of the QSFP+ cable

As with SFP+, QSFP+ is a form factor specified by MSA, but its electrical interface specifications are not defined in MSA. Communication standards, such as Ethernet*5 and InfiniBand*6, are referenced for QSFP+. This report presents the results of evaluation against 40GBASE-CR4(2), an Ethernet standard for passive cables for a transmission rate of 40 Gb/s (4×10 Gb/s).

Table 5 shows the typical transmission performance parameters of 40GBASE-CR4. **Figures 9 and 10** show the typical evaluation results.

IL is a parameter indicating signal attenuation, which increases with an increase in the skew of the cable. It has been confirmed that with small variations among lanes, the obtained value of IL is sufficient to the specification. ICN is a parameter indicating the tolerance to crosstalk from the other seven lanes (3 lanes in

Table 5. Main parameters of 40GBASE-CR4

Parameter	Minimum	Maximum	Unit
Insertion Loss at 5.15625 GHz (IL)	3	17.04	dB
Integrated Crosstalk Noise (ICN)		See Fig.10	mV (RMS)

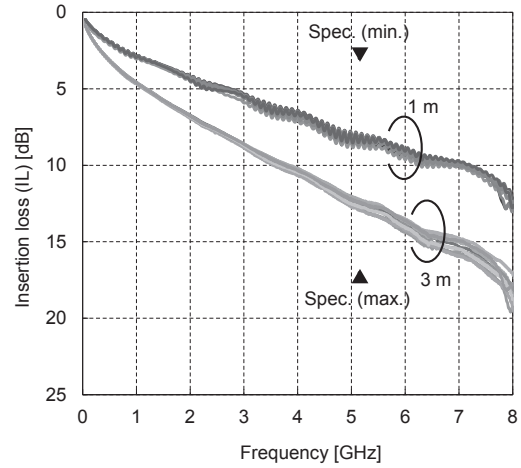


Fig. 9. Insertion Loss (IL)

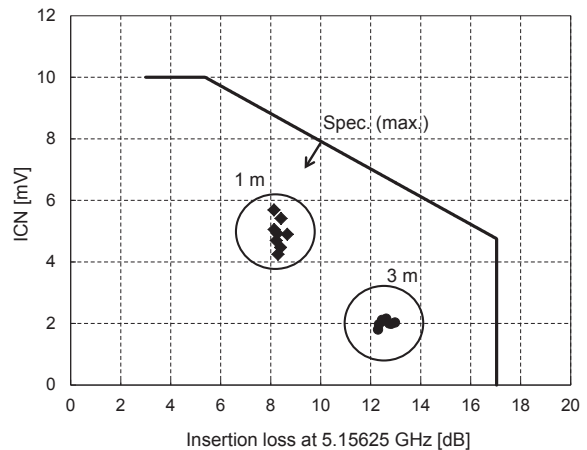


Fig. 10. Integrated Crosstalk Noise (ICN)

the same direction and 4 lanes in the opposite direction). The coaxial wires in the cable must have a high shield performance to meet this property.

It has been confirmed that with both high flexibility and shield performance, the developed coaxial wire has satisfactory properties for both 1-m and 3-m cables.

7. Conclusion

We have reduced the skew of a micro-coaxial wire and have successfully developed thin, flexible and robust direct attach cables (SFP+, QSFP+) for use in

data centers, which have transmission characteristics as good as conventional twinax direct attach cables. We believe that these products will make a significant contribution to improving the ease of installation and operation and in heat dissipation performance for high-density, high-speed signal wiring in the rack.

Technical Terms

- *1 Twinax wire: A twinax wire is made of two insulated signal wires and a drain wire placed in parallel and wrapped with conductive tape.
- *2 Coaxial wire: A coaxial wire is made of a single insulated signal wire surrounded by a braided external conductor. Two coaxial wires are required for differential signal transmission.
- *3 Common mode voltage: The common mode voltage is a voltage in the same phase generated between two signal wires. It is generated due to an amplitude difference or a phase difference (skew) between negative and positive signals.
- *4 Crosstalk: Crosstalk refers to the leakage of a transmission signal from one transmission channel to another. In this report, it refers to the leakage of a signal from one lane to a specific lane in a direct attach cable.
- *5 Ethernet: Ethernet is a communication network standard. It is widely used as a practical Local Area Network (LAN) standard.
- *6 InfiniBand: InfiniBand is a high-speed interface standard developed by the InfiniBand Trade Association (IBTA) for servers or external storage devices.

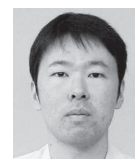
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- (2) IEEE 802.3ba™-2010 Media Access Control Parameters, Physical Layers, and Management Parameters for 40 Gb/s and 100 Gb/s Operation

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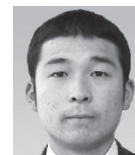
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