Development of SFP+ (the smallest 10Gbit/s pluggable optical transceiver)

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SFP+ is the latest pluggable 10Gbit/s optical transceiver. Its form factor is compatible with SFP, which is a major lower-speed (below 4Gbit/s) optical transceiver on conventional optical networks. Sumitomo Electric had developed the 300pin, X2 and XFP as 10Gbit/s optical transceivers. This paper describes the fundamental structure of SFP+ and the design of Sumitomo Electric's "SPP5101-SR" 850nm SFP+ for 10Gbit/s multimode-fiber application (10GBASE-SR). The advantages of SFP+ are not only compatibility with SFP, but also the smallest size and the lowest power consumption as 10Gbit/s optical transceiver. SFP+ could be the most versatile device for expanding high-speed optical data communication networks.

1. Introduction

The significance of data communications in today's world is becoming greater and greater, due to the recent progress in information communication technologies.

This paper describes the development of a 10Gbit/s SFP+ which is the smallest in size and the lowest in power consumption among 10Gbit/s optical transceivers. The name "SFP+" means value-added SFP. SFP stands for small form-factor pluggable, and is a major optical transceiver used for data rates up to 4Gbit/s. SFP+ is expected to contribute to the realization of higher speed communication networks of the next generation.

2. Future communication network demand and optical module standardization

Optical fiber is the most suitable media to eliminate the bottleneck on communication networks in which higher-rate data transmission is required for equipment such as servers that provides data communication at more than Gbit/s for FTTB/FTTH applications which are included video providing and high-end computer operation.

For data communications up to 1Gbit/s, copper cables are a major medium for connection in data center over distances up to 100 m. However, even with the latest technologies, capability of copper cables are only <15m on 10Gbit/s.

Because of this fact, optical fiber networks are becoming a more major medium for 10Gbit/s than for lower data rate (<4Gbit/s).

The other requirement for next generation network is "flexibility" in application, transmission medium, distance and maintenance. According to this requirements, "hot pluggable transceiver" (pluggable transceiver) which does not require system reset or service suspension while increasing the number of data channels or during maintenance is the best solution.

Pluggable transceiver is an important component of data communication network and its design is usually defined under a Multi Source Agreement (MSA).

Sumitomo Electric has been the pioneer and the leading company of not only optical transceiver but also "pluggable" optical transceiver for data communication.[(1)]

SFP defined by the SFF committee's INF-8074i specification is a mainstream pluggable transceiver in Gbit/s data communication networks. SFP realizes the same port density as RJ-45 connector on a system board (blade).

Other types of 10Gbit/s optical transceiver are XENPAK, XFP, X2 and XPAK, and their properties and functionalities are defined by the respective MSA.

2-1 SFP+ MSA

An SFP+ MSA was established to realize larger capacity that would be needed for future communication systems. SFP+ (**Fig. 1**) is specified by the SFF committee as "SFF-8431"

The MSA specification had been defined based on reality-based feedbacks from the participating companies who were developing their own SFP+ designs during the MSA discussion. Through this process the MSA specification had been practical.

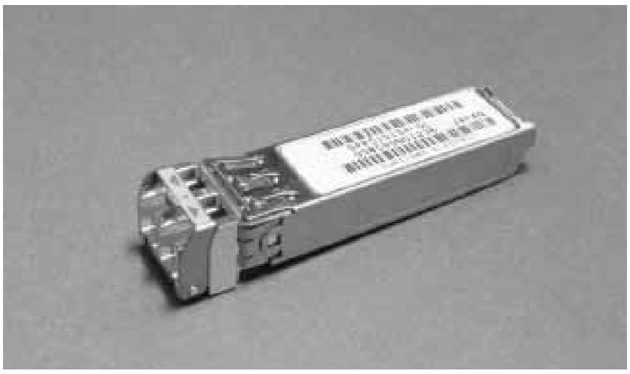


Fig. 1. SFP+

The MSA had discussed the specification and defined the size and electrical interface of SFP+ according to systems in which actual operation. Optical interfaces strongly depend on the transmission distance of medium, so they must be defined in accordance with actual installation on systems, in terms of such characteristics as wavelength, optical output power and receiving sensitivity.

The MSA specification must be defined as being feasible with conventional and proven technologies, like as other standardization. One of the main objectives that SFP+ must achieve is to realize higher package density and the same package size as SFP on the system, and for the purpose of reducing power consumption, the clock-data recovery (CDR) function is basically not included in SFP+.

Because of the deletion of CDR, the SFP+ MSA specification does not support Telecom applications (ex. SONET/SDH).

According to this definition, XFP and SFP+ are located on different positions by their applications.

XFP: Telecom and datacom applications, cannot be packed so densely

SFP+: Datacom application, can be packed densely

The MSA specification defines only the mechanical structure and electrical interface of the blade on which SFP+ is operated. The specification does not put restrictions on the use of SFP+ in other applications including telecom applications.

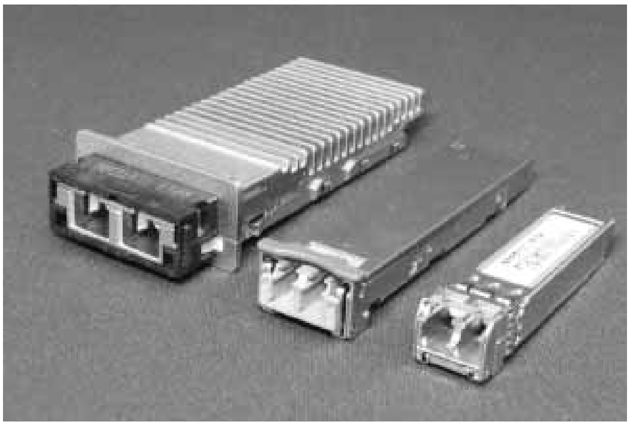


Fig. 2. 10Gbit/s pluggable transceivers (from left: X2, XFP, SFP+)

Table 1. 10Gbit/s pluggable transceivers

	X2	XFP	SFP+
Optical interface	Single-lane 10Gbit/s		
Electrical interface	4-lanes 3.125Gbit/s	Single-lane 10Gbit/s	Single-lane 10Gbit/s
Dimensions	91 × 36 × 13.4 mm (44 cc)	78 × 18 × 8.8 mm (12.5 cc)	55.7 × 13.4 × 8.8 mm (6.6 cc)
Power consumption	4.5 W	2.5 W	1.0 W
Applications	Datacom	Datacom Telecom	Datacom

2-2 SFP+ specification

Power consumption of 10Gbit/s optical transceivers is trade off with function which employ in them. Optical transceivers have become simpler, having less functions as they evolved from 300-pin, XENPAK and XFP to SFP+.

Figure 2 and **Table 1** show the comparison between X2, XFP and SFP+.

SFP+ is defined in the specification as having a mecha-nical structure compatible with SFP, and also as can be plugged into one blade up to 48 consecutive ports.

Power supply voltage defined in the specification is +3.3 V, but there are two maximum power consumption levels: Level-1 (<1 W) and Level-2 (<1.5 W).

Level-1 SFP+ does not require a heat sink, and can be built into smaller and higher-density systems.

On the other hand, Level-2 SFP+ requires a heat sink. On power-on sequence, Level-2 SFP+ has to be started operating at Level-1 (<1W) and then start at Level-2 after the system recognizes operation at Level-2.

In the MSA specification, electrical interface is also defined as the "SFP+ high-speed serial electrical interface" (SFI), which is a 10Gbit/s differential electrical interface. The SFP+ function is controlled and monitored by 2-wire diagnostic monitoring interface.

3. Development of SFP+

Based on the MSA specification for the new form factor SFP+, the authors developed SFP+, "SPP5101-SR" for 850nm multi-mode fiber (MMF) application.

3-1 10GBASE-SR

Figure 3 shows the block diagram and **Table 2** shows the specifications of the SFP+ "SPP5101-SR," which complies with the 10GBASE-SR standard specified by the Institute of Electrical and Electronics Engineers, Inc. (IEEE).

The optical output of 10GBASE-SR is specified by the spectrum width, optical modulation amplitude (OMA) and maximum safe optical power. Optical receiving sensitivity is specified by the IEEE standard, and electrical output interface to be connected to a blade is specified by the SFP+ MSA.

Figure 4 shows Optical output eye diagrams of SPP 5101-SR, and **Fig. 5** shows optical sensitivity on the receiv-

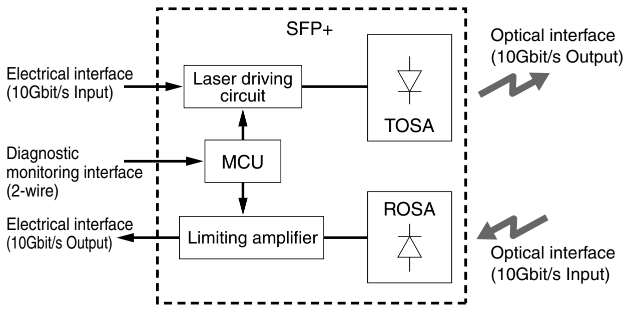


Fig. 3. Block diagram of SFP+

Table 2. Specification of SFP+ (SPP5101SR)

Items				Specification	Notes
Data rate (Speed)				10.3125Gbit/s 9.95Gbit/s	10GBASE-SR/SW IEEE802.3ae LAN PHY/WAN PHY
Media				MMF	
Distance				26 to 300 m	Depending on fiber grade
Optical interface	Tx	Wavelength		840 to 850 nm	
		Output power		> -4.3dBm	OMA (IEEE802.3ae)
	Rx	Wavelength		840 to 850 nm	
		Sen-sitivity	Back-to-back	-11.1dBm	OMA
			Stressed	-7.5dBm	OMA
Electrical interface				SFI	SFF-8431
Operation temperature				0˚C to 70˚C	Tcase
Supply voltage				3.3V	+/-5%
Power consumption				<1.0W (Level-1)	Typ.0.6W

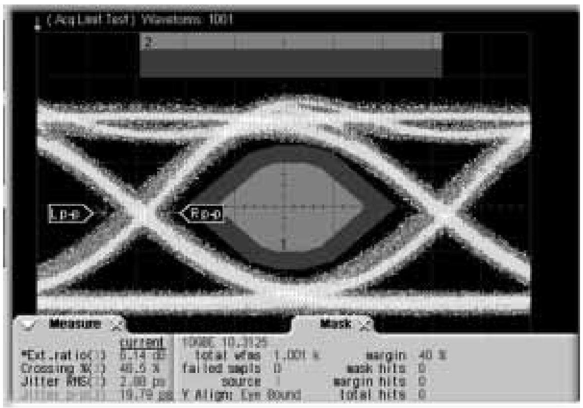


Fig. 4. Optical output (eye diagram)

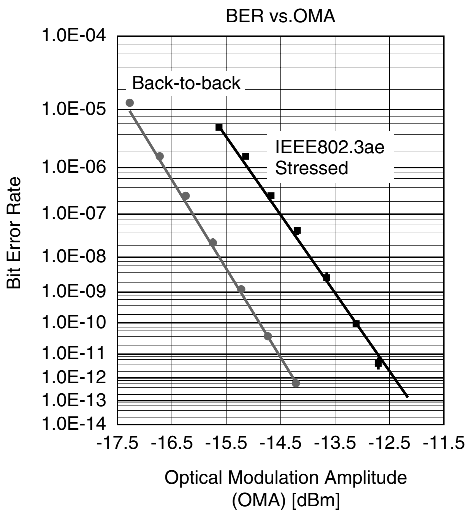


Fig. 5. Optical receiver sensitivity

er side. In the IEEE specification, two types of optical sensitivity are defined: One is "back-to-back" sensitivity, which is an intrinsic optical sensitivity, and another is "Stressed Eye" sensitivity, which simulates the worst condition in actual operation.

3-2 EMC design

Electric magnetic compatibility (EMC) is also an important parameter for designing optical transceivers, especially for designing SFP+ that will utilize more than 48 ports on a blade.

In actual operation, SFP+ is plugged into a "cage system" on the blade.

The cage system contacts with a front panel and suppresses the transmission of emission noise from the front panel to the cage system.

Figure 6 shows the noise path in actual operation. The source of noise is not only SFP+ but also signal processing circuitry on the blade.

In the case of SFP+ mounted on a blade, Path A is from SFP+ to optical connector (related noise source 1), Path B is the gap between SFP+ and cage system (related noise sources 1 and 2), and Path C is the gap between front panel and cage system (related noise source 2).

It is difficult to quantitatively design Path B because it depends on the positional relationships with SFP+, cage system and signal processing circuitry on the blade, but a design for suppressing noise from the gap between SFP+ and cage system is necessary.

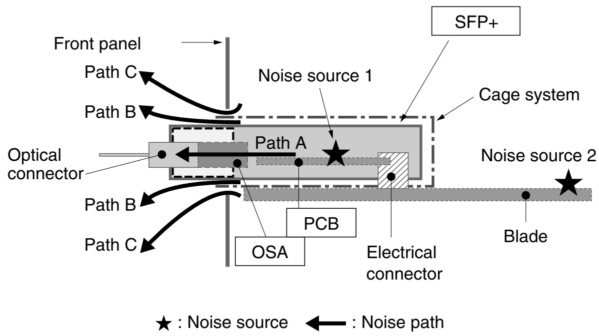


Fig. 6. Noise path

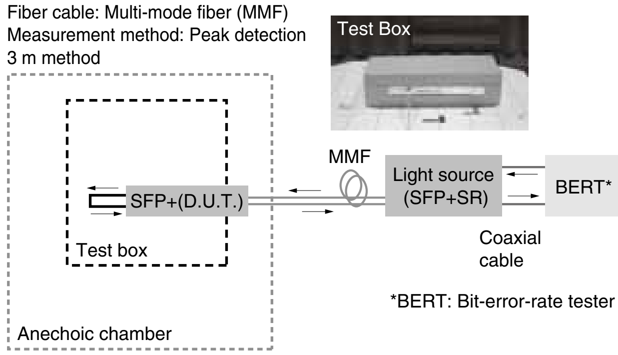


Fig. 7. EMI test set up (3 m method)

The emission noise level to comply with the Federal Comm-unication Commission (FCC) Class B limit is <54 dBuV/m at the 3m method.

For suppressing emission noise, SFP+ needs to be designed by taking into consideration its trace impedance matching, power line stability, and package shielding.

Figure 7 is test setup for evaluating EMC on the 3 m method. SFP+ was measured in a test box that simulates actual system.

The measurement results at a point of 10GHz are shown in **Fig. 6**.

Figure 8 shows that SFP+ fully complies with the FCC Class B EMC limit of 54 dBuV/m in both of horizontally and vertically polarized measurements. It complies by a wide margin.

3-3 Special requirement for SFP+ on system

Because SFP+ does not have the clock-data recovery function, 10Gbit/s electrical interface is degraded on the length of trace on the blade, as shown in **Fig. 9-1**.

Therefore, a blade on which SFP+ operates needs a pre-emphasis function (see **Fig. 9-2**) for compensating the degraded 10Gbit/s signal. The pre-emphasis function secures input signal quality at SFP+ input port. The blade must have this compensation function to optimize the performance of SFP+.

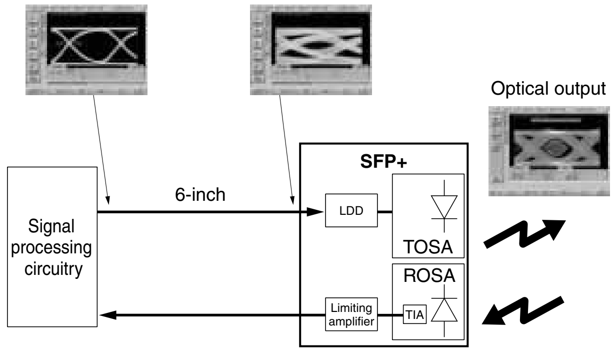


Fig. 9-1. SFP+ without pre-emphasis in actual operation

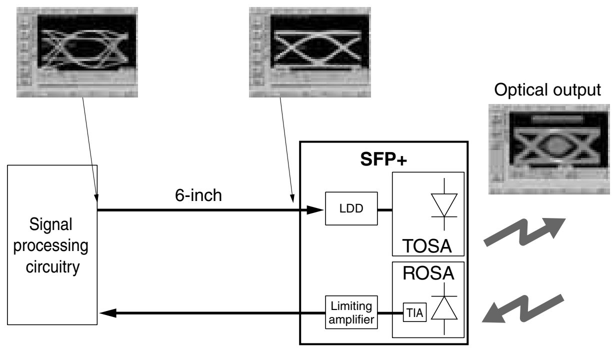
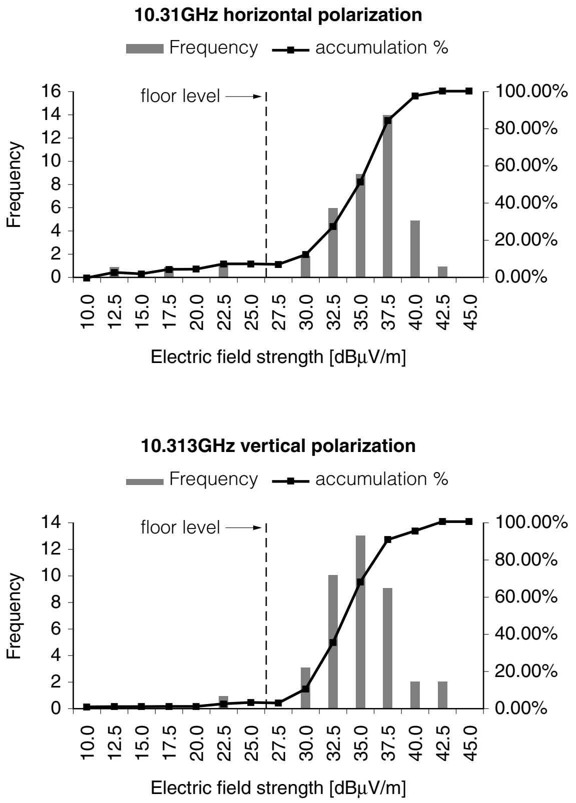


Fig. 9-2. SFP+ with pre-emphasis in actual operation



10.31 GHz	HOR	VER
Average $\overline{X}$ [dBμV/m]	35.1	33.9
Standard deviation σ[dB]	2.7	2.9
$\overline{X}$ + 3σ [dBμV/m]	43.2	42.6

Fig. 8. EMI test results

4. Conclusion

The authors have succeeded in developing a 10GBASE-SR SFP+ "SPP5101-SR." Compactness and lower power consumption are the advantages of SFP+, and these allow SFP+ to expand the range of its application. SFP+ could be the most versatile device for expanding high-speed optical data communication networks.

References

(1) M Nishie , Development of Optical Datalink (in Japanese) SEI technical review Vol .173. P-1-13 (July 2008)

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