High-Speed Transmission Sub-Harness for Automated Driving

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With the advancement of CASE technologies, particularly automated driving, the demand for high-volume information processing devices like LiDAR is increasing, necessitating faster in-vehicle data communication. Sumitomo (SEI) Electronic Wire, Inc. is actively engaged in developing and manufacturing information transmission sub-harnesses that comply with new global communication standards to enable high-capacity data communication. Additionally, the company has developed automated processing equipment for the efficient production of widely used connectors in sub-harness processing. This paper provides an overview of in-vehicle equipment trends, communication standards, and our wire and terminal processing technology, which are integral to high-speed communication sub-harnesses that connect these devices.

Keywords: automated driving, de-facto standard connector, STP, UTP

1. Introduction

Just ten years ago you could not have imagined that fully autonomous taxis would be in service on every street in town or you would be able to plan a karaoke competition in a vehicle using a large screen. Times have changed and these now are viable possibilities. These innovations in vehicle technology owe much to the improved performance of in-vehicle equipment, as shown in Fig. 1.

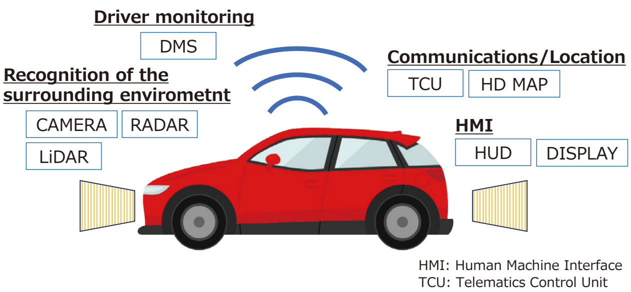


Fig. 1. Examples of in-vehicle equipment related to automated driving

In addition to cameras for image-based recognition of the surroundings, automated driving requires many sensors, including LiDAR,*[1] that are effective even in adverse surrounding environments such as at night and in bad weather. For enhanced in-vehicle entertainment, the use of more and larger displays is necessary. Additionally, emerging essential technologies include displaying navigation information by an HUD*[2] and monitoring the physical condition of the occupants by a DMS.*[3]

The cables (sub-harnesses) used to connect these devices are, as a natural course of action, on an upward trend along with their being increasingly mounted in vehicles to support increasing levels of automated driving, as illustrated in Fig. 2. Moreover, various transmission standards have been established with the aim of ensuring safe and efficient data communications, as presented in Fig. 3.

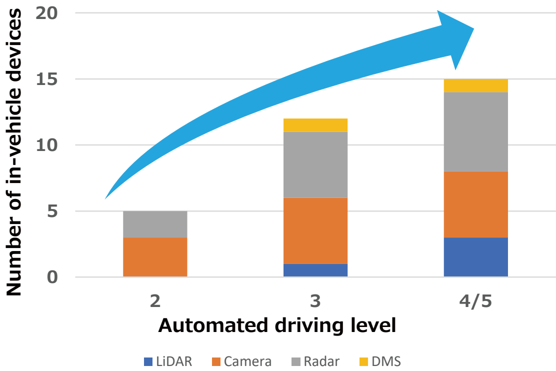


Fig. 2. Automated driving levels versus number of in-vehicle sensors (devices)

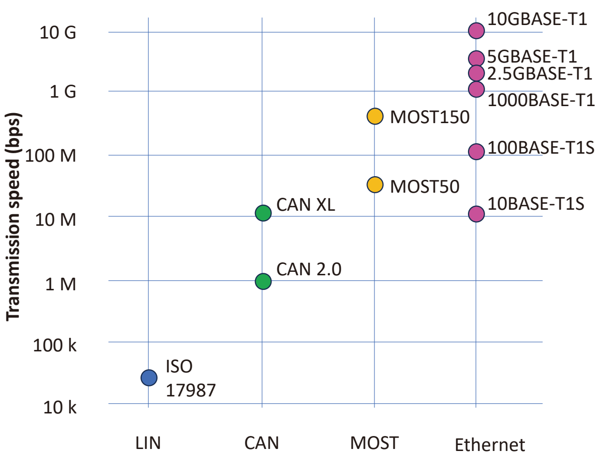


Fig. 3. Communication standards that sub-harnesses are required to meet

2.Trends in the Choice of Sub-Harnesses

A sub-harness, as described above, refers to cables connecting in-vehicle devices. Devices and sub-harnesses are schematically illustrated as electrical and electronic (E/E) architecture, whose configuration is currently evolving.

In the past, the distributed architecture directly connecting a device to other devices was the mainstream (Fig. 4 (a)). Regarding communication rate requirements, this system had no problems as long as it accommodated data volumes that one unit of a device could process.

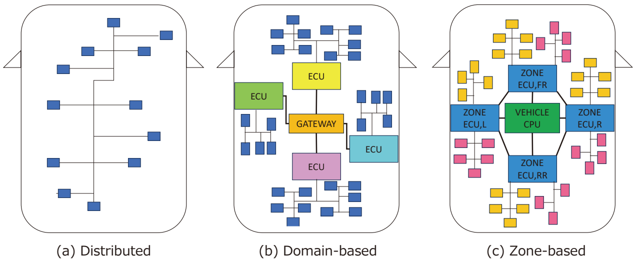


Fig. 4. Evolution of in-vehicle E/E architecture

In recent years, domain-based architecture in which similar devices are collectively controlled via an electronic control unit (ECU) has been increasingly adopted because the higher the level of automated driving, the larger the number of mounted devices and sensors mounted and the more complex the wiring. Because multiple devices are connected to each ECU, sub-harnesses connecting ECUs are required to be capable of transmitting amounts of information commensurate with several to tens of devices. Moreover, it is presumed that the zone-based architecture given in Fig. 4 (c) will come into use in the future. In this system, a Vehicle CPU is placed at the center of a vehicle and zone ECUs are placed in four locations—front, rear, right, and left—with zone ECUs collectively controlling devices in their own area (= zone) regardless of function. Presumably, this system requires many sub-harnesses to be densely laid in a narrow zone and sub-harnesses connecting ECUs to send and receive (via Ethernet connection) amounts of information commensurate with tens to a hundred devices. Thus, the number of in-vehicle communication sub-harnesses has been steadily increasing although efforts have been made in the industry to concentrate and streamline information. Consequently, sub-harnesses are required to offer high-speed (multigigabit/s) communication performance and be highly flexible for ease of routing.

3. Sub-Harness Configuration and Development of Cables

Photo 1 shows the exterior of typical sub-harnesses used for in-vehicle high-speed communications. At both ends, these sub-harnesses have high-speed data (HSD) connectors, which are representative of de-facto standard connectors.*4 For cables, either shielded twisted pair (STP)*5 or unshielded twisted pair (UTP)*6 cables are used. Table 1 presents the respective cross sections and features of typical STP and UTP cables.

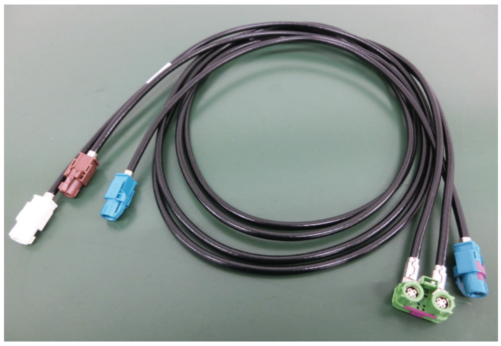
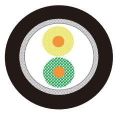


Photo 1. In-vehicle high-speed communication sub-harnesses

Table 1. In-Vehicle High-Speed Communication Wires

Type	STP	STP with foam insulation	UTP
Conductor	0.14SQ (TA)	Same as left	Same as left
Insulation	PP	Foam PP	PP
Shield	Double	Same as left	-
Jacket	PVC	Same as left	Same as left
Outside diameter	4.3 mm	3.8 mm	3.2 mm
Cross-sectional view			
Communication rate	100 M ~ 2.5 Gbps	100 M ~ 1 Gbps	100 Mbps
Other	-	Lightweight and thin	Lightweight and thin

Although the shape of the mating parts of de-facto standard connectors is standardized, the parts connecting to cables differ in design concept depending on the manufacturer. In this regard, therefore, cables are required to ensure compatibility. For example, measures include the use of a compact-stranded wire as the central conductor, the use of foam insulation, and the preparation of several cable jacket materials. Using these measures, Sumitomo (SEI) Electronic Wire, Inc. is capable of manufacturing high-speed communication cables with varying diameters finely tailored to connectors from different manufacturers while maintaining the same transmission characteristics. In particular, for insulated wires, the selection of insulation materials, which have a considerable impact on transmission characteristics, is important. Sumitomo (SEI) Electronic Wire, Inc. has conventionally employed cross-linked polyethylene (XLPE) due to its low loss and high strength in high-temperature (85°C) environments and geometric stability. However, there is demand for further improvements in the resistance of sub-harnesses to high temperatures (100°C) due to the emergence of high-speed communication applications in the engine room. Therefore, Sumitomo (SEI) Electronic Wire, Inc. has newly developed and adopted a polypropylene (PP)-based material, which offers transmission characteristics at a comparable level to XLPE and improved resistance to high temperatures.

Figure 5 presents insertion loss measurements taken after conducting a hot environmental test at 150°C for 6 h as an example of reliability testing. After the testing, the XLPE material increased in insertion loss by a factor of approximately 1.3. In comparison, the newly developed PP material did not show any increase in loss after testing, proving that it maintained the same level of transmission characteristics as the initial value.

By allowing a PP material to become a foam resembling a sponge and with a low dielectric constant, the technology used for the STP cable with foam insulation enables insulated wires to be thinner while maintaining transmission characteristics (insertion loss) at a comparable level to ordinary solid PP insulation. Using this technology it is possible for the overall cable to decrease in outside diameter by approximately 10% and in weight by approximately 15% as compared to ordinary STP cables. Furthermore, although a shieldless construction enables UTP cables to decrease in outside diameter by approximately 25% and in weight by approximately 50%, their applications are limited due to high-loss characteristics as compared to STP cables and shieldless construction.

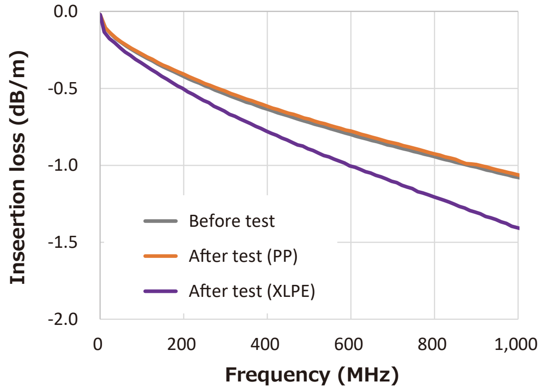
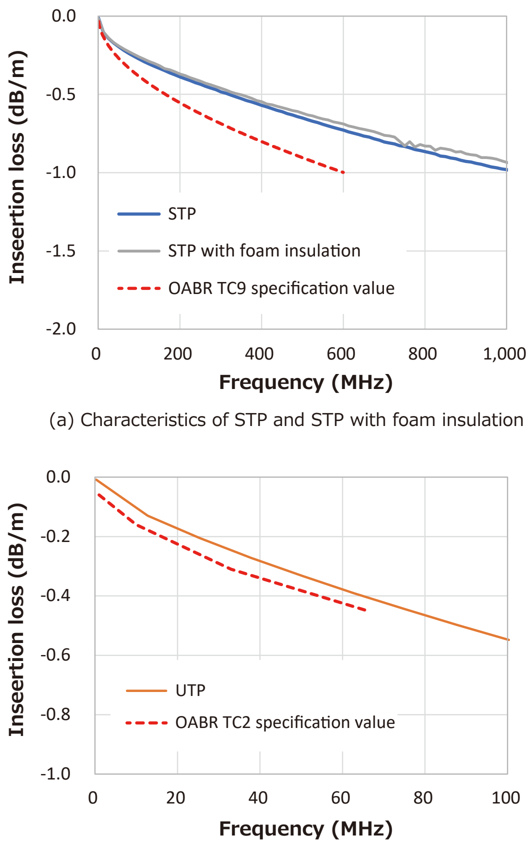


Fig. 5. Insertion loss measurements taken after high-temperature environmental testing



(a) Characteristics of STP and STP with foam insulation

(b) Characteristics of UTP

Fig. 6. Results of comparison of insertion loss for different cables

The transmission characteristics of different cables are shown in Fig. 6. STP and STP with foam insulation are consistently low-loss from low to high frequencies and meet the OABR*7 TC9 specifications. UTP meets the OABR TC2 (100 Mbps) specifications.

4. Verification of Wiring Harnesses for In-Vehicle Applications

In addition to discrete cables and connectors meeting industrial standards and individual vehicle manufacturers' own specifications, cables and connectors require verification in their operating condition, taking into consideration workability and handling at original equipment manufacturing (OEM) tier 1 manufacturers and in-vehicle mounting layout, as well as specifications modeling in-vehicle mounting. Sumitomo (SEI) Electronic Wire, Inc. has conducted various verification checks for its wiring harnesses to be selected by auto manufacturers. By using the failure tree analysis (FTA) illustrated in Fig. 7 for thoroughly listing what to verify and considering situations not assumed in OEM specification testing, Sumitomo (SEI) Electronic Wire, Inc. has taken care to ensure the highest level of qualitative stability.

Based on the FTA results, characteristics to be evaluated and tested as discrete sub-harnesses were thoroughly listed. Representative examples are shown in Table 2. In

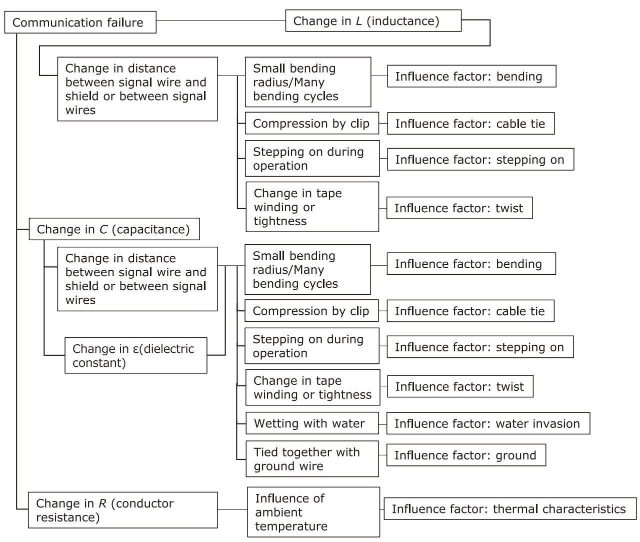
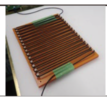
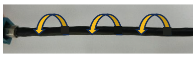
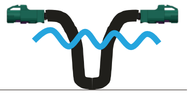
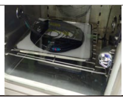


Fig. 7. FTA for considering what to verify

Table 2. What to Verify with Wiring Harnesses

Test	Description	
Bending	Checks on bending for wiring harness routing	
Cable tie	Impact of tightening during bundling together with main wiring harness	
Stepping on	Postulation of wiring harness being stepped on during assembly work	
Twist	Installation of twisted cable during assembly	
Submersion in water	Checks on the effects of routing outside the cabin	
Signal wire to ground distance	Effects of bundling together with ground wire	
Thermal characteristics	Effects of ambient temperature change	

particular, the electrical characteristics of UTP wiring harnesses are considerably affected by the three factors of “submersion in water,” “signal wire-to-ground distance,” and “thermal characteristics.” As a representative example, “submersion in water” is described below.

Figure 8 plots the evaluation results of characteristic impedance for sub-harnesses intentionally submerged in water in a pre-determined condition. The results revealed substantial fluctuation in characteristic impedance for locations submerged under water. According to these results, care should be taken for the engine room, which is subject to high temperatures and may be submerged in water, and the ground wire when bundled together with a sub-harness. The use of STP cables instead of UTP cables should be proposed depending on the requirements and specifications because STP cables are relatively immune to the aforementioned influences.

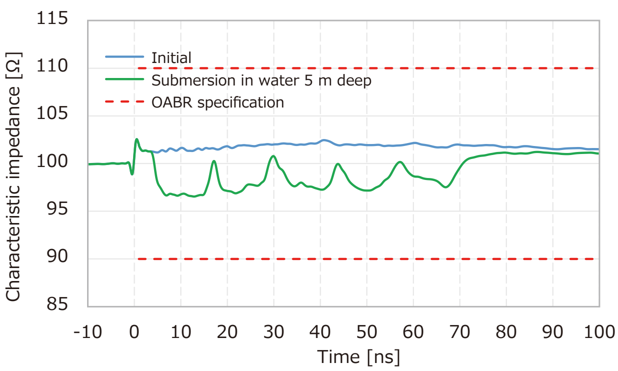
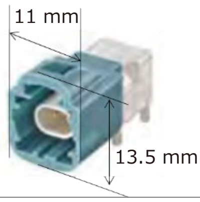


Fig. 8. Results of characteristic impedance during submersion in water

5. Future Trend Forecasts for High-Speed Communication Sub-Harnesses

In these days of the downsizing of cars drawing attention, as exemplified by micro cars and driver-only vehicles, it is an important challenge to downsize the equipment mounted in the limited space of an automobile. Meanwhile, sub-harness connectors attached to each device will increase as a result of the use of more devices. Accordingly, the connectors are expected to evolve toward multiport connectors in order to reduce the area occupied by the connectors. Table 3 compares single-port and multiport connectors.

Table 3. Comparison of Connector

	Single-port	Multiport
Connector		
Connector area	148.5 mm^2	370.5 mm^2
Area for four connections	594 mm^2 (=148.5×4)	37% smaller than single-port connector

Multiport connectors, with which one connector accommodates multiple cables, enable unit downsizing through improved efficiency of sub-harness mounting. One multiport connector also enables STP and UTP sub-harnesses to coexist in it. However, the effects of this coexistence on high-speed communications in terms of characteristics are still in the verification phase. Therefore, checks similar to those described in the preceding chapter need to be conducted in cooperation with OEM tier 1 manufacturers.

It is also highly likely that cables will need to offer an additional level of high-speed compatibility. Sumitomo (SEI) Electronic Wire, Inc. is working on the development of new cables leveraging its techniques fostered in the field of consumer products, which require higher-speed capability than required in vehicles. One example is the shielded parallel pair (SPP). Unlike STP cables, its structure features non-stranded core wires. Consequently, SPP cables can be used at higher frequencies than is possible with STP because they are free of suck-out—noticeable attenuation at specific frequencies—a phenomenon that occurs with STP. It is, however, necessary to route SPP cables with resistance to noise in mind due to non-stranded core wires, which do not provide noise-cancelling effects.

In addition, shifting to SPP cables requires a non-conventional approach for processing equipment. Sumitomo (SEI) Electronic Wire, Inc. will similarly work on equipment development.

6. Conclusion

High-speed transmission sub-harnesses have been developed for automotive information communications. Sumitomo (SEI) Electronic Wire, Inc.'s characteristic cables have been developed by conforming to de-facto standard connectors and verified through various tests for use in wiring harnesses. It is highly likely that the trend towards higher-speed operation will accelerate. We intend to develop cables and the processing of innovative connectors in the future to keep up with this trend.

Technical Terms

∗1 LiDAR: Abbreviation for light detection and ranging. LiDAR is a technology used to measure distances towards and shapes of objects based on information conveyed by the reflected light of radiated laser beams. The number of in-vehicle LiDAR devices is expected to increase with higher levels of automated driving.

∗2 HUD: Abbreviation for head-up display. HUD refers to a technology used to project information on a vehicle's dashboard top or windshield. It reduces the driver's shifting of sightlines as compared to displaying information in the instrument panel and improves safety.

∗3 DMS: Abbreviation for driver monitor system. Using a camera, a DMS offers a safety driving support function by detecting inattentive driving by the driver or drowsiness and alerting the driver. In recent years, studies have been under way on devices that monitor occupants as well as the driver.

∗4 De-facto standard connector: A connector with a standardized, uniform shape at the connector-to-connector mating end so designed to allow for connection of a group of sub-harnesses. Several companies have entered the market. They design their connectors according to different concepts with the aim of offering performance advantages.

∗5 STP: Abbreviation for shielded twisted pair. STP refers to a stranded pair of wires shielded with metal braid or foil for protection from electromagnetic interference. It is used to transmit signals in a high-noise environment.

∗6 UTP: Abbreviation for unshielded twisted pair. UTP refers to a stranded pair of wires not shielded with metal braid or foil.

∗7 OABR: Abbreviation for OPEN Alliance BroadR-Reach. OABR is a standardization organization for automotive Ethernet. The 100 M Ethernet and 1 G specifications are known as "TC2" and "TC9," respectively.

Contributors

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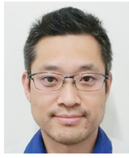

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