Linnæus University
Sweden

Master of Science Thesis

Optic Fiber Communication in Commercial Vehicles

Testing of mechanical rigidity

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Abstract

The backbone of this dissertation is a discussion of the adaptability of optical fiber modes of transmission. The technological boom in commercial vehicles tends to include more electronic components and more data flow. The traditional copper transmission is reliable but has drawbacks. At present the optical fiber technology is in huge demand in fields like avionics, medicine, and communication across continents. The drastic shift to fiber was due to the enormous increase in capacity. Simultaneously the commercial vehicle sector is advancing in the direction of sensors that require a non-disruptive data flow. Furthermore, autonomous driving technology pushes the transition from copper to optic fiber. One expects optical fiber to supplant the traditional copper cables in the future. The dispersion and scattering losses need to be studied as well as the difference in cost.

Keywords

- EMI – Electro-Magnetic Induction
- LASER – Light Amplification by Stimulated Emission of Radiation
- LED – Light Emitting Diode
- MOST – Media Oriented System Transport
- EMC – Electro Magnetic Compatibility
- CDMA – Code Division Multiple Access
- ECU – Electronic Control Unit
- CAB – Cabin
- POF – Polymer Optical fiber
- LISN – Line Impedance Stabilization Network
- SDK – Software Development Kit
- EEPROM – Electrically Erasable Programmable Read-Only Memory
- USB – Universal Serial Bus

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Acknowledgments

"As we express our gratitude, we must never forget that the highest appreciation is not to utter words, but to live by them."- John F. Kennedy.

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Chapter 1

INTRODUCTION

Data transmission plays a vital role in various fields like telecommunication, aviation, and medicine. Reliability and cost reduction were goals that the technology was intended to achieve. The capacity to carry much information with low losses was essential [1]. When the laser was first discovered in 1960, its usefulness for optical communication was instantly recognized, and work in that arena could begin in earnest [1]. The last decade has seen fiber technology in telecommunications, aviation, and automation [2]. The reliability of optical fiber communication is due to a collection of qualities. The optic fiber is better than copper transmission cables due to the factors,

- Electro-mobility
- Shielding efficiency
- EMI robustness

These factors are vital [1], especially the elimination of the shielding problem. The data rates considered here are of the order of 150 Mbit/s [1]. The light source that was used in the early 1960s was LASER. In the late 1960s, diode lasers provided a higher data transmission rate and lower attenuation. After the invention of the Light Emitting Diodes (LED) and Polymer-optical fibers (POF), they became widely used for their speed and few intrinsic manufacturing defects [3]. Today the intricacy of components is high and increasing. At present, the typical optical data bus is MOST, but alternatives are underway [4]. For example, the current generation of aircraft is made of carbon fiber to reduce weight. This makes them vulnerable to lightning strikes if copper cables are used[1].

Modern avionic fiber networks offer higher bandwidth and less weight and attenuation [5]. The cable's mechanical durability is of the utmost importance. They must also withstand temperatures ranging from -55℃ to +125℃ along with swift temperature changes, vibration, abrasion, and toxic smoke [2]. The fly-by-wire technology is used in commercial and military aircraft, space applications, and Unmanned Aerial Vehicles. The optic fiber reduces weight in unmanned vehicles by reducing the copper cable sheathing that takes up a lot of space and is costly [6]. They can also be used in the parts of an aircraft that are inaccessible. Presently the aviation industry depends on optical fiber technology as a substitute for copper cables [2].

The present scenario in the automobile industry is an indulgence in multimedia and telematics applications. The proper functioning of this equipment requires a considerable transmission bandwidth which led to the development of Media Oriented Systems Transmissions and topologies that facilitated a smoother transmission [1]. This calls for a high-caliber mode of communication, where optical fiber plays a significant role [7]. Their data flow rates are of the order of 10 Gigabits per second. Also, they are cost-efficient since they depend only on the intensity and quality of the Light Emitting Diode (LED) [8].

In the long run of copper cable systems, their maintenance becomes a little pricey, and sometimes the sheathing of the copper cable becomes expensive. This type of equipment has EMC issues similar to those occurring in automobiles or in domestic or industrial environments [9]. The use of copper cables requires a lot of space, and the weight may have structural consequences [4].

At present, optical fiber communication is the most reliable alternative. The fiber infrastructure is utilized in broadband networks worldwide [7]. Therefore, there is a need for large bandwidths and short delays. The optical fiber cables provide massive and incomparable transmission bandwidth with insignificant loss, and it is at present the only dependable means of massive transmission [13].

Research and development in this field led to innovation in transmission [11]. Code Division Multiple Access (CDMA) uses multiple channels, and the modes of wavelength transmission squeeze data together, allowing better flow. The future of telecommunications is dependent on optical fiber cables and their evolution [11]. The future trends of optical transmission are

- all-optical communication
- multi terabit optical networks
- intelligent optical transmission
- ultra-long-haul optical transmission

The internet is based on fiber technology and has tremendous flexibility and speed [14]. Glass fibers are preferred for long-distance transmission, while polymer cables are better for short distances [15]. Criteria are the output optical power and the input electrical power. The spectral width of the light-emitting source, as well as the beam divergence and the geometrical size, should be small for a satisfactory coupling efficiency [13]. Primary light sources, that the present producers depend on, are the Light Emitting Diodes or Lasers. The direct application of optic fiber in the field of communication are sea links such as the Atlantic optical fiber sea-link and the Transatlantic connection sea-link [13].

1.1 This thesis

This thesis mainly focuses on the transition from copper to fiber. The copper transmission cables serve as the spine of the commercial vehicle, comparable to the nervous system in the human body. They play a significant role in combining different ECU components like multimedia systems, audio/video inputs, and lights in warning systems [9]. These varieties of ECU systems contribute to the proper functioning of the whole system [9].

This EMC issue poses difficulties in the functioning of system as a whole and threatens to cause malfunctioning of sensors [4]. Furthermore, there is an essential issue: the insulation of the copper cables from the heat generated by the motors that are in their proximity. The cables occupy a considerable space and add to the weight [16]. There is also the price since copper is expensive compared to the polymer cable.

The optic fiber cables will displace copper transmission due to technical aspects such as bandwidth, transfer rate, attenuation of the signal, and immunity to EMC [11]. This thesis discusses various possible mechanical tests that can be conducted to check how the optical fiber cable performs in relation to pre-determined standards for commercial vehicles. The tests are the same as for copper cables. This idea is to be implemented only for specific parts of a commercial vehicle, the CAB, and the Chassis [9]. The tests are essentially applied to the fiber cable and the connectors [17]. One considers vibration in the vehicle, extreme temperatures, load-bearing capacity, drop tests, etc. [16].

Chapter 2

Optical Fiber Communication Systems

By understanding the basics of an optical fiber, we can appreciate its essential qualities and function. Optical fiber technology utilizes photon pulses to transfer information through an optical fiber cable from one point to another. The transmitted data is usually generated by telephone systems, computer systems, and multimedia transmission [15].

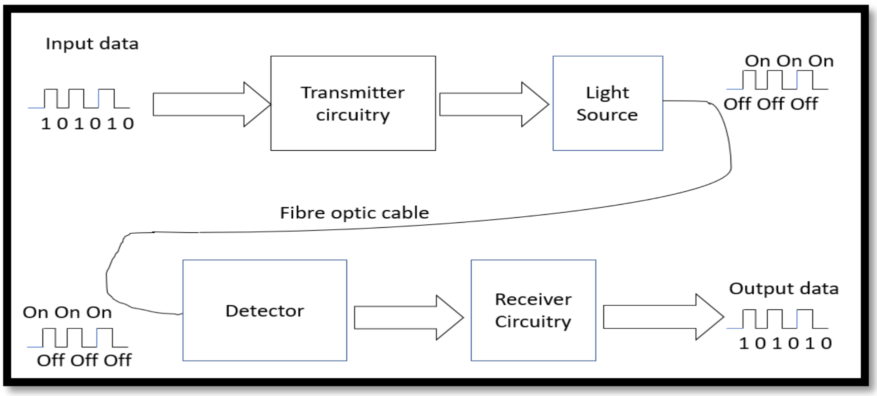

Figure. 2.1. Optical fiber communication system.

The figure 2.1 describes the optical fiber communication system. The system has two ends, and transmission occurs at one end. At the input, the signal is converted from an electric signal to a photon pulse in the transmitter.

A photon pulse is then detected at the receiver and decoded into digital form [11]. By this method, the transmission takes place in an enclosed dielectric medium [11]. Usually, to reduce the attenuation and increase the efficiency, the cable is graded by means of enhanced semiconductors. In another method, additional layers of silica material are provided with lower refractive indices [7].

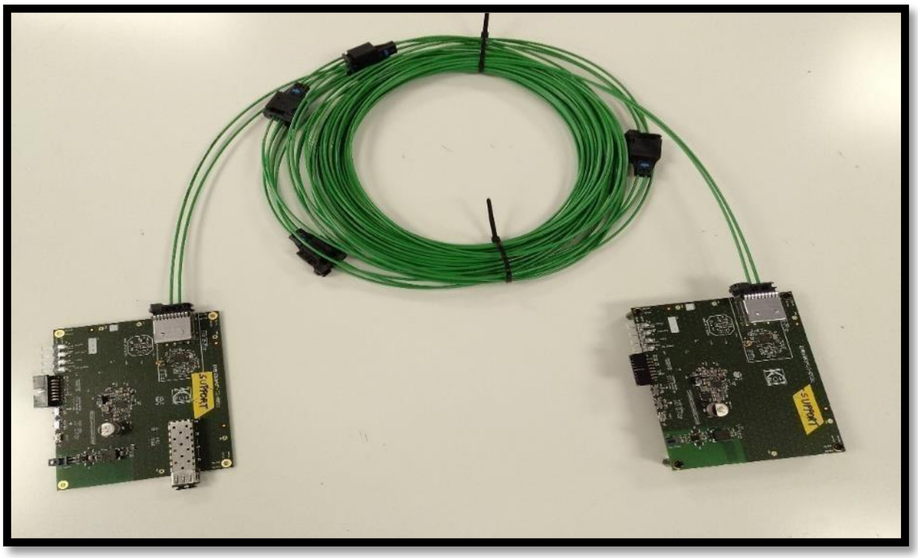

Figure.2.2 Pictorial representation of a basic optical fiber system (polymer cables).

The figure shows the transmitter and the receiver circuit connected by a polymer optical fiber cable [18]. In general, the optical fibers come in two categories: Step index optical fiber, with single or multi-mode optical fiber, and the graded-index optical fiber [3]. The single-mode step-index fiber has a radius of 5 micrometers and allows only one mode [3]. The multi-mode optical fiber has a core radius greater than or equal to 25 micrometers, allowing multiple modes to pass through the fiber [3].

2.1. Optical fiber types

The basic structure of an ideal optic fiber has three concentric components the core, the cladding, and the outer coating. The core is generally made of either glass or polymer. This part of the cable is the medium through which the light propagates [19]. The cladding is generally made of more purified silica with a slightly lesser refractive index (usually about 1% lower) [19]. The change in the refractive index causes total internal reflection at the interface to the cladding. As a result, the lightwave propagates through the core rather than leaking through the sidewalls [19]. The third and outermost layer typically comprises one or more coats of a plastic material to shield from the environment [19]. The coating is classified according to mode of transmission and material.

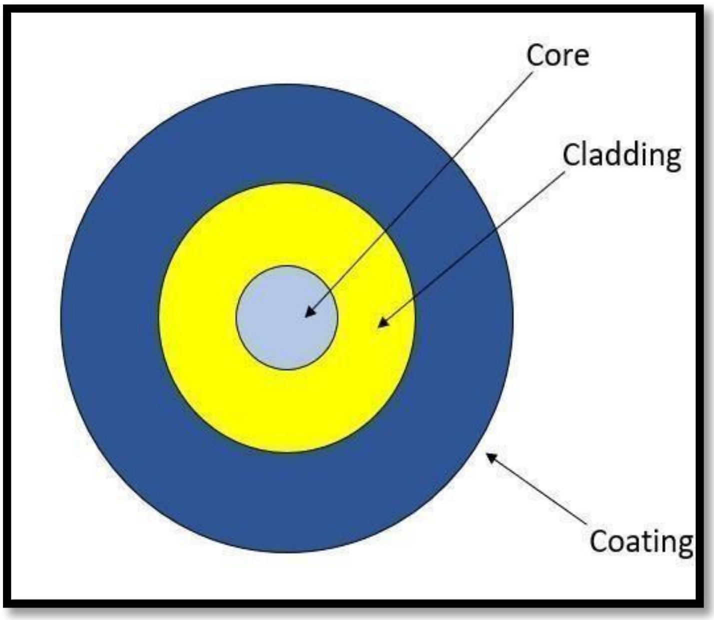

Figure 2.1.1 Basic structure of optic fiber cable.

2.2 The principle of total internal reflection

The refractive index characterizes optical materials and is defined as the ratio of the speed of light in vacuum to the speed of light in the material [19]. In other words, when a light beam passes from one material to another that has a different refractive index, the ray is bent according to Snell's law of refraction:

$$N_I \sin I = N_R \sin R$$

N_1 is the index in the core and N_R is the index in the cladding of the material by which the beam is refracted. The variables I and R are the angle of incidence and refraction respectively [19].

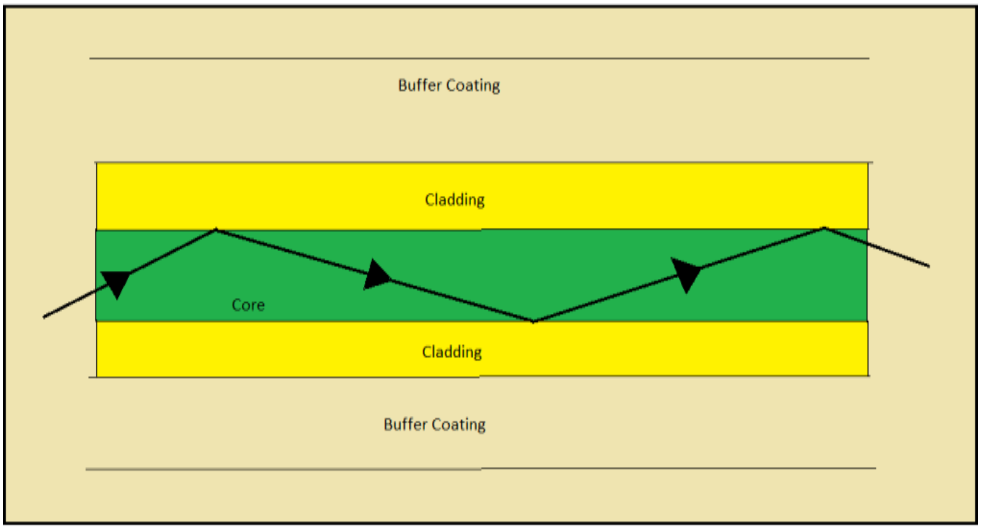

Figure 2.2.1 Representation of total internal reflection.

2.3 Glass optical fiber

These fibers are usually made of silica, which is smelted to form a thin optical fiber. Since they are made of glass they tend to break when subjected to bending, but they do not have the disadvantages of bending loss [8]. The glass fibers are also used in places such as space vehicles to view unreachable components by means of an arm and a camera [6].

These cables provide a data rate of the order of Gigabits/s. This exceeds, by far, even copper cables or wireless mode of transmission has ever been achieved. Glass optical fiber operates in wavelengths ranging from 800 nm to 1600 nm [14]. Due to the bending restrictions for glass fiber they tend to be used for lower frequencies [20]. For long distances there is attenuation and hence a need for repeaters [13].

2.4 Polymer optical fiber

These cables have benefits compared to glass and copper [7]. They are more robust and ductile to handle when provided with easy plug interconnections. Further developments include multiplexing multiple light sources in the given Polymer optical fiber (POF).

Figure 2.4.1 Polymer optical fiber.

The plastic optical fiber operates in wavelength from 550 nm to 1360 nm, which is the optimal bandwidth [19].

2.5 Attenuation in general

The signal power in an optical fiber decreases exponentially with distance,

$$P(z) = P(0)\, e^{-\alpha z}$$

The symbol α is called the attenuation coefficient of the optical fiber and gives the damping as a function of the fiber length [19]. The attenuation of a signal in an optical fiber depends on the diameter of the optical fiber core; as the core diameter decreases, the attenuation increases [19]. Since the optic fiber cables are used for moderate distances the attenuation can be handled [19]. The other factors contributing to attenuation are the spectral width of the light source implemented [19].

2.6 Losses in optical fiber communication

The mechanisms for attenuation are *intrinsic* and *extrinsic* [22]. Amid intrinsic losses, we have absorption and Rayleigh scattering. These factors are due to the molecular changes in the quantum fields [22].

Type	Mechanism	Origin
	Absorption	Vibration modes
		Electronic transitions
Intrinsic		
		Density fluctuations
	Rayleigh scattering	Orientation fluctuations
		Composition fluctuations
	Absorption	Transition metals
		Organic pollutants
		Dust
Extrinsic	Dispersion	Microfractures
		Bubbles
		Structural Imperfections
	Radiation	Micro bending
		Macro bending

Figure 2.6.1 Tabulation of types of losses.

Figure 2.6.1 can be clarified as follows.

- ***Intrinsic absorption*** is a phenomenon caused by interaction with one or more components of the fiber. There could be a photon interacting with an electron by exciting it from the valance band to a higher energy level near the Ultraviolet region [22].

- ***Absorption loss*** is related to the composition of the material and its fabrication method. It also results in the dissipation of optical power in the cable [22].

- ***Rayleigh scattering*** is a regular optical scattering phenomenon. Rayleigh scattering occurs when the size of the scatterer is less than one-tenth of the current operating wavelength [22].

- ***Extrinsic absorption*** is also caused by the impurities in the optic fiber material and relates to transition of electrons between states. Extrinsic absorption depends on the manufacturing of the fiber [22].

- ***Dispersion loss*** relates to the temporal spreading that occurs when a light pulse propagates through an optical fiber [22].

- ***Radiative loss*** occurs when the optic fiber is bent or curved. There are micro bending and macro bending [22].

Chapter 3

The necessity for Optical fiber

This thesis deals with the shortcomings of the traditional copper cable when used in commercial vehicles for in-vehicle communication [23]. In this chapter, we will discuss the drawbacks of copper in relation to standards for vehicles. This can be understood from knowledge of the system and the effects that cause impairment or abnormal functioning.

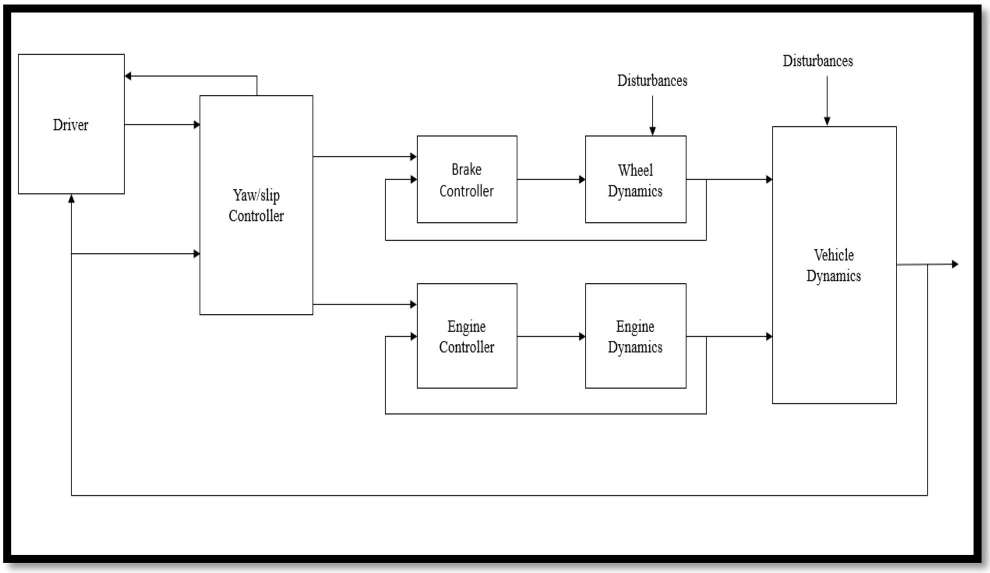

Figure 3.1 Basic representation of ECU in a commercial vehicle.

Various factors need to be considered. One aspect relates to the fields caused by the current through the copper cables. In early times, many radio components required suppression of electromagnetic disturbances [9]. Another problem is conducted interference, which is caused primarily by the transients from the ignition system that enter the radio via the 12 V power supply [4].

3.1 Automotive EMC contemplations

Since the introduction of semiconductors in commercial vehicles, automotive EMC has had a significant impact [9]. The use of electronic components for monitoring is essential. However, the sensory electronics tend to malfunction due to electromagnetic interference [9]. There are methods to avoid this such as insulation and increased area and space. Since the electronic components are susceptible to these weak interferences, they are important [4].

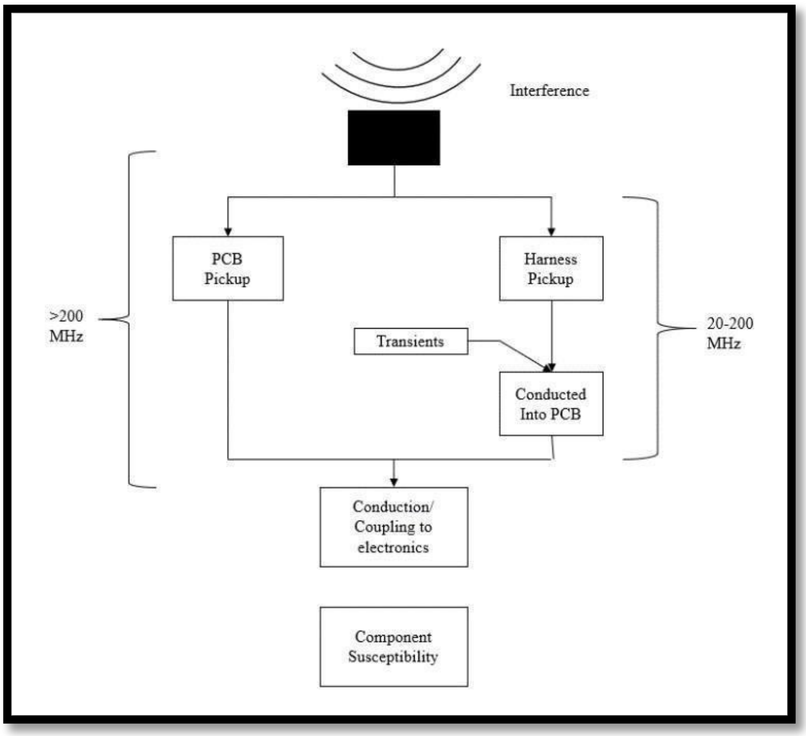

Figure 3.1.1 The effect of EMC in the automotive setting.

There are two ways that electromagnetic fields couple into vehicle electronics. Firstly (Fig 3.1.2), the electromagnetic fields are coupled with the circuit boards or the interior wiring [9]. Secondly, they can change the nature of the harness inside a vehicle into an antenna that induces interference [9]. The increasing number of electrical loads leads to more cables inside the vehicle [9]. These cables are tightly wound and placed in the chassis as a ground return path [9]. The vehicle industry is paying a lot of attention to interferences and their effect on size and cost. There are four main types of interferences:

- Conducted Emissions
- Conducted Susceptibility
- Radiated Emissions
- Radiated Susceptibility

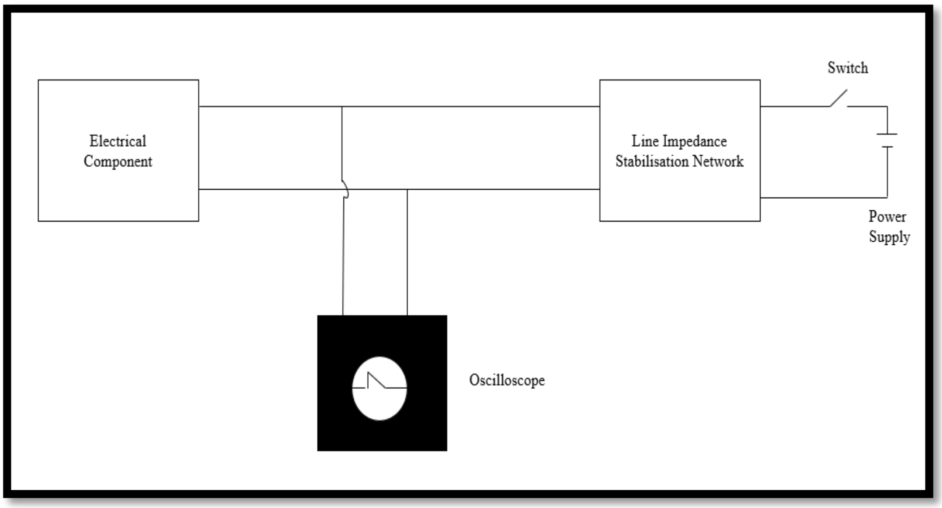

Figure 3.1.2 Conductive susceptibility measurement.

Conductive emissions are generated by the commutation in electric motors or the switching of solenoids, relays, and other inductive components [4], which produce transients. These transients are also conducted through the vehicle's wiring harness and into the power terminal points of the different electronic systems [4]. There is also a possibility that these transients can be coupled inductively or capacitively into the control or lead signal leads of the numerous systems of the vehicle. ***Conducted susceptibility*** or immunity is the system's capability to operate as required when exposed to radio frequency signals [4].

The conducted susceptibility can be assessed by injecting typical transients. Also, the transients that occur during the fault conditions are included [9]. ***Radiated emissions*** are caused by several sources. The conducted transients caused by the electrical components are emitted with the harness acting as antenna [9]. Electronic microprocessors with a fundamental frequency with very low narrowband harmonics are affected by the radiated harmonics from the arrangement [9]. ***Radiated susceptibility*** is the measure of the ability of a system to function adequately when subjected to an externally generated electromagnetic field [4].

These transients can affect the functioning of the electronic system on the vehicle, and cause conducted susceptibilities [9]. These transients are observed with the help of an oscilloscope and a LISN (Line Impedance Stabilization Network) is used to simulate the vehicle wiring harness [9]. To make the vehicle's electronic system less sensitive to the transients, a method uses a generator to insert typical transients [9]. The electromagnetic emissions are weak and in the order of µV/m or mV/m, and do not cause interference [9]. The radiated EMC emissions are measured by placing them on a ground plane in a screening room [4].

Chapter 4

Proposed Practical Analyses

The main idea behind the thesis is to find the critical factors in deciding whether optical fiber communication is more suitable than conventional copper cables. The data compiled in this thesis suggests that copper cable is the preferred and traditionally accepted method of communication in commercial vehicles. However, the optical fiber is more useful. For example, in case of disruption in the in-vehicle communication, the copper cable requires additional sheathing which helps in absorbing the transients whereas the optic fiber is inert to those transients. This measure was suggested by my esteemed organization SCANIA.

The several ideas behind this thesis can be explained in several ways. Firstly, the critical equipment in this thesis is the Software Development Kit provided by the KDpof organization [18]. This kit consists of a transmitter and a receiver, for communication between two nodes in a commercial vehicle. This kit has a polymer optical fiber cable that is provided with an industrial-grade connector [18]. The focus was primarily on the fiber's functionality and shortcomings in the experiments[24]. After the experimental observation, we can evaluate the alternatives and the conditions for a replacement. Is the transition to fiber viable economically and technically and do the connectors meet the environmental requirements [17]. The tests help us understand their mechanical capability and how they perform in relation to copper wires [15].

Finally, we staged an experiment with two different ECUs in a commercial test vehicle to investigate their micro-bending and macro- bending losses [25].

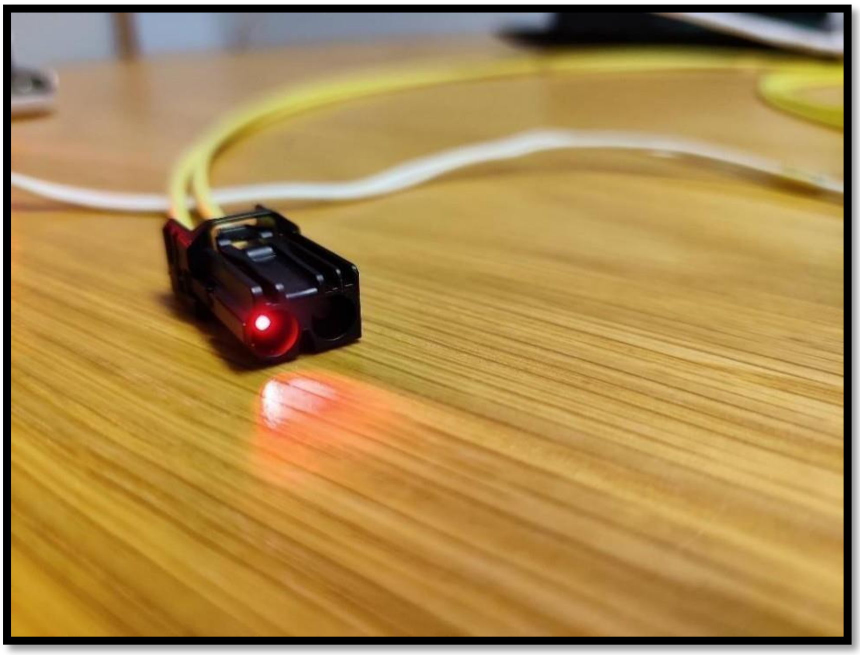

Figure 4.1 Connectors provided with the Software Development Kit.

4.1 Environmental tests

The optic fiber connectors provided by KDPOF were initially planned for these tests,

- Thermal withstanding capability test.
- Drop test (structural integrity)
- Dust test
- Chemical erosion test

The Thermal withstanding capability test involved exposure to a standardized high temperature for around eight hours, along with thermal aging and flammability tests [16]. That is a predetermined format for copper cable. There is a cold temperature test to check for their integrity and structure changes. After completing the thermal test, the cable and the connectors are replaced in the Software development kit to monitor the rate of attenuation. In a similar way the drop test checks the mechanical stress that could occur during their installation. The dust test checks if the cable and its connectors are affected or if attenuation is caused by dust particles obstructing the path of the light signal. Finally, the chemical tests are performed to check the rigidity of the connectors.

It is also checked on how they react to the chemical standard and the standards used by SCANIA for their traditional Copper transmission cables.

The cable shall withstand a pressure test at the temperatures stated in the following table

Temperature range according to ISO 6722	°C, test temperature
A	85 ± 2
B	100 ± 2
C	125 ± 3
D	150 ± 3
E	175 ± 3
F	200 ± 3
G	225 ± 4
H	250 ± 4

Apply the force, F, by the blade (0.7 mm) to the test sample as given by the formula

$$F = 0.8\sqrt{i(2D - i)}$$

Where
F = the total vertical force (N)
0.8 = coefficient (N/mm)
D = outside cable diameter maximum (mm)
i = nominal value of the insulation thickness (mm)

Figure 4.1.1 Standard temperature values for copper cable.

These values suggest the temperatures for each component indicated by the letters. Our considerations are A and B corresponding to the CAB and chassis respectively along with indicated tolerances. These tests are vital for fiber/copper cable comparison.

4.2 Proposed vibration tests

The idea behind this test was to determine the attenuation and calibrate the performance in terms of data flow in the polymer optical fiber.

They are employed between two different ECUs from the CAB to the chassis [26]. This helps us analyze the cable's performance under the influence of vibrations and bending in the layout [26]. The data for the vibrations are provided are according to the pre-defined standards for copper transmission [26].

2.3.9 Test with vibrations combined with temperature changing

Test conditions

If the connector is only used with one part permanently attached to a component the connector can be exposed to vibration test together with the component according to the requirements for the component.

Otherwise:

Vibration type: Random

Crest factor: 2,5

Roll off slope: 30 dB/octave at both ends of the spectra

		ASD-level	Freq range
Cab:	(3,3 g RMS)	0,2 g^2/Hz	8-12 Hz
		0,05 g^2/Hz	20-50 Hz
		0,015 g^2/Hz	100-500 Hz
		-6,5 dB/octave	12 Hz-20 Hz
		-5,2 dB/octave	50-100 Hz

Temperature changing: -25° C and +70° C (rate of temperature change1-5°/min, one hour at min/max temperature). The vibration exposure time shall be 72 h. One connector in each axis (x, y and z).

Chassis:	(5,1 g RMS)	0,2 g^2/Hz	8-20 Hz
		0,15g^2/Hz	30-100 Hz
		0,015 g^2/Hz	200-500 Hz
		-2,1 dB/octave	20 Hz-30 Hz
		-10 dB/octave	100-200 Hz

Temperature changing: -25° C and +70° C (rate of temperature change1-5°/min, one hour at min/max temperature). The vibration exposure time shall be 144 h. One connector in each axis (x, y and z).

Power train:	(24 g RMS)	0,40 g^2/Hz	20-1500 Hz

Temperature changing: -25° C and +85° C (rate of temperature change1-5°/min, one hour at min/max temperature). The vibration exposure time shall be 210 h. All three connectors in each axis (70 h in each axis x, y and z).

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Figure 4.2.1 Standard vibration values for copper transmission.

4.3 Bending loss

This part of the test includes connecting two different individual ECUs in CAB and Chassis and checking them for signal loss and signal speed and attenuation due to their layout. This involves the polymer optical fiber cable bending underneath the truck.

The two bending losses are Micro-bending losses and Macro-bending losses [21]. Micro-bending losses are mostly related to the material defects during its manufacturing, so we focus on the Macro-bending losses [25]. Macro-bending is a phenomenon that causes attenuation of the light wave due to the curvature of the optic fiber. The information can leak out of the fiber when it is bent [25]. In the fiber, there is an increase in attenuation with more information loss [22]. In each optical fiber, the increase in attenuation is contingent on three factors,

- The radius of the bend
- The number of bends
- The wavelength of the signal

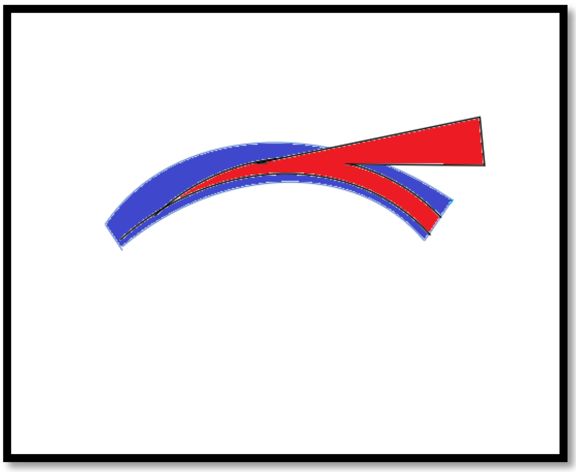


Figure 4.3.1 Macro-bending of light inside a fiber.

Figure 4.3.1 illustrates the losses that arise because of the macro bending. An industry standard exists for measuring optical fiber macro bending, IEC 60793-1-47, which conveys the *Measurement methods and test procedures for Macro bending loss* [22]. This entails measuring the insertion loss of an optical fiber sample when bent [25]. The macro bending loss can be related to the twisting and wrapping of the optical fiber cables. Light can propagate through the wire even though it is twisted or bent [25]. But when the bend is tighter, the information tends to leak out of the outer cladding layer [25]. For plastic optical fibers, the refraction index of the core is higher than that of the cladding, which results in the internal reflection of the light entering the core at the core-cladding interface [22].

Macro bending relates to the deviation in the refractive index profile due to the radius r of the bend according to the expression,

$$n_c(r, \theta) = n(r) + \frac{2n}{R} r\cos(\theta)$$

Hence n_c (r, θ) is the optical index as a function of radial coordinate where r denotes the radius inside the fiber, and the angle of refraction θ and due to the radius R of the bend. Other factors that contribute to macro bending loss is the number of bends and the wavelength of the signal [25].

Chapter 5

Conclusion

Copper transmission is traditionally used for in-vehicle communication in commercial vehicles. The installation cost of the copper cable is comparatively higher than that of a plastic optical fiber cable. The manufacturing plant of SCANIA develops their in-vehicle communication with the help of a CAN bus made of copper cables. A CAN bus connects various ECUs to the CAB for the driver interface. The primary issue was that the 12 V or the 24 V battery causes an induced current that runs in the electronic components and affects the radio devices and some electronic sensors.

The EMC issues related to the copper transmission are reduced by introducing proper sheathing of the copper cable along the entire body of the vehicle, with the ensuing increase in cable size. This brings another issue, the cost. The price per kilogram of copper compared with plastic is high but copper in its raw material form is cheaper than semiconductor optic fiber cables as their manufacturing cost is high. Another factor is the data rate, which for fiber is as high as 10 Gbps [27]. The copper transmission could achieve up to 2 Gbps. As the data rate increases, the radius of the cable increases as well.

The latest generation of trucks have an exponential rise in the number of electronic modules integrated inside the vehicle. The number of sensors has increased due to the size of the truck. The introduction of more electronic components creates more data flow. The rearview video, for example, requires a lot of data transmitted from the rear of the vehicle to the driver's user interface in the CAB. Furthermore, sensors like the fuel indicator, air gauge, axel load and differential load sensor require an uninterrupted data flow and are therefore affected by EMC issues. The optic fiber cable is immune to those EMC issues as the information is sent in the form of light.

The fiber technology is likely to be implemented with inspiration from car companies like Tesla, KIA, and VOLVO. They use plastic optical fiber for the inter-vehicular communication over short distances. Polymer optic cables are cheaper than copper cables to install and support. They are also reliable since industrial standards ensure that they can withstand the temperature changes.

This thesis was headed for the testing of some practical ideas but due to Corona the practical work and the implementation was affected. Still, we believe that the main factors have been investigated. This gives us the overview necessary for developing and introducing the product in the manufacturing environment. By assessing feasibility and adaptability, fiber can be compared to copper.

Appendix

Sample Testing of the Evaluation Kit

Contents of the Evaluation Kit

- The Software development kit contains a monitoring microcontroller USB2ALL module to monitor the optical fiber communication.
- Flat cable to install the registers to the optical fiber transceiver, which helps monitor the flow of information and the transfer rate.
- A USB cable integrates the USB2ALL module to a computer to have a user interface medium on a digital platform with software help.
- Fiber optic transceiver generates the signal to transmit as well as receive between two different mediums.
- A polymer optical fiber medium to felicitate the connection between two different modules has cables with different lengths.
- A power supply cord is required for the transceivers to produce a light signal transmitted and received.
- A USB adapter to connect two different systems to their transceivers.

Manual for Software Development Kit

The working for this SDK requires additional equipment that includes two different units capable of sending and receiving signals, in this case, two different personal computers and two voltage regulators for the constant supply for the working of the USB2ALL circuit for monitoring [18].

The Software development kit is a prototype of an optical fiber connection with a pair of equipment that acts as transmitters and receivers to demonstrate a relationship between two individual systems. For this thesis, they were supposedly be utilized for the purpose to connect two ECU's

In a commercial vehicle and understand it's working and theorizing its shortcoming. With the help of detailed calculations and by performing some environmental tests on this prototype, we could appreciate its performance under a conventional copper cable environment. Furthermore, it gives us a clear idea of how they could handle the system's stress during its deployment.

The following procedure gives us an idea about how to navigate ourselves with the basic functionality of the prototype, which could pave the way for better understanding and help with a walkthrough about how they function. The methods that are being followed are provided with a colored visual demonstration for better performance. The procedure is as follows,

- The USB2ALL module is the primary part of this connection, so we start by integrating the USB2ALL module to a primary computer along with the prescribed software pre-downloaded in the device with the help of a USB cable provided in the kit.

Figure 1. USB2ALL module connected to a system.

- The LED indicates the on and off stages of the connected modules, andthe link is established.
- Next, we would integrate the transceiver with the USB2ALL module with the help of a flat cable. This flat cable is also utilized to update the firmware and to access the registers.
- The transceivers relate to their systems to observe the signal flow using the help of a USB-Ethernet connector provided with the kit.
- The power supply to the transceivers is provided with the help of voltage regulators. In addition, we provide a controlled voltage supply of 12V to the transceiver using the power cord provided.
- Also, the optical fiber connection is made with one of the transceiver pairs where we use a double-headed transceiver which can be used at two different flow rates, 100Mbps and 1Gbps.
- At the beginning of the evaluation, we press the black reset button to reset their flow rate and other pre-entered values. The USB2ALL module has an inbuilt EEPROM that has a memory to store the previous input values.

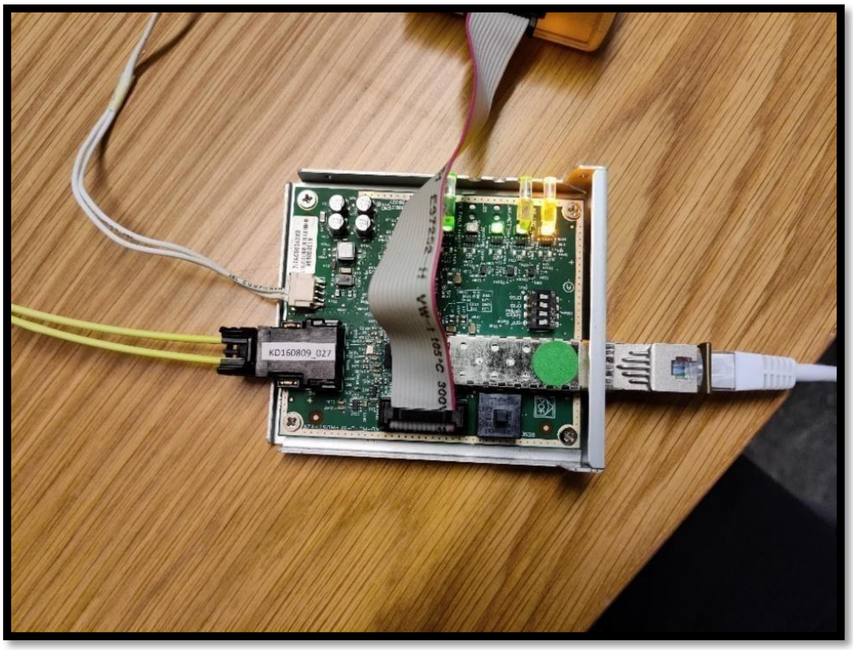
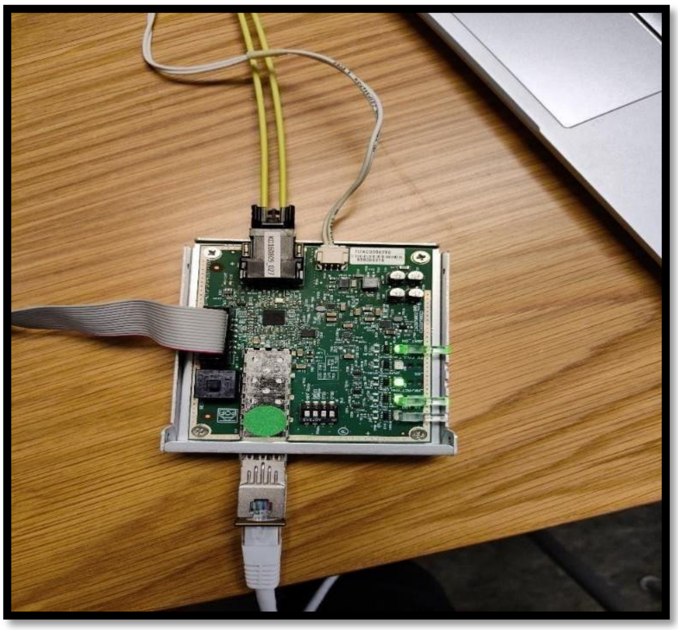


Figure 2. Transceiver optical fiber connection.

- The steps mentioned above are followed for the receiver pair, and they are connected to another computing system to test the data flow.

Figure 3. Similar connections on the receiver pair.



- The power supply is fed to both the transceivers to have a functioning data flow link with the help of a voltage generator.

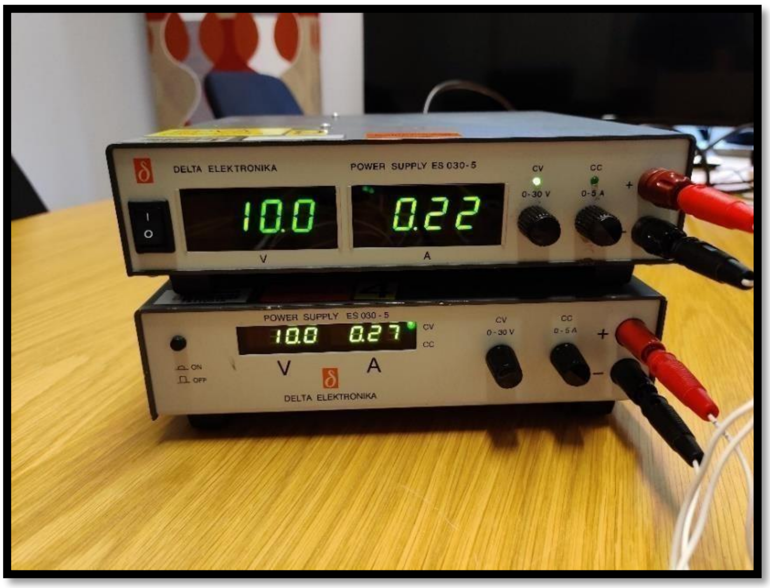


Figure 4. Power supply fed to the Transceivers.

- The test carried on had two different observations concerning their data flow rate, one with 100Mbps and another with 1Gbps, which helps understand the flexibility of the data flow modes that the system can operate.

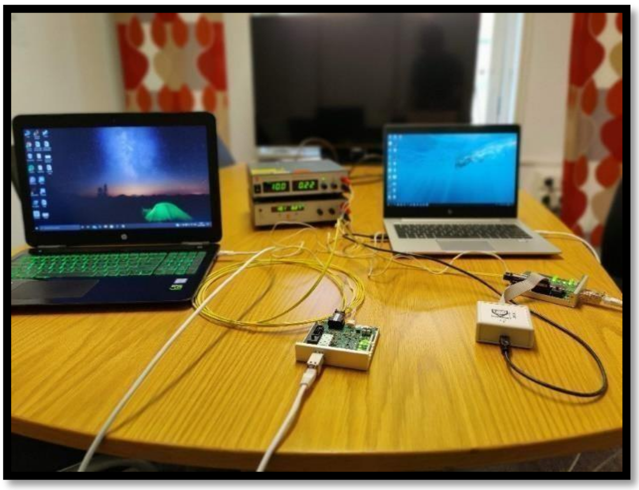


Figure 5. Complete setup of pair of transceivers.

- The complete setup of the optical fiber connection has been simulated with a standard format of two computers between which the data flow is observed.
- The output is obtained for data flow one with 1Gbps [18].

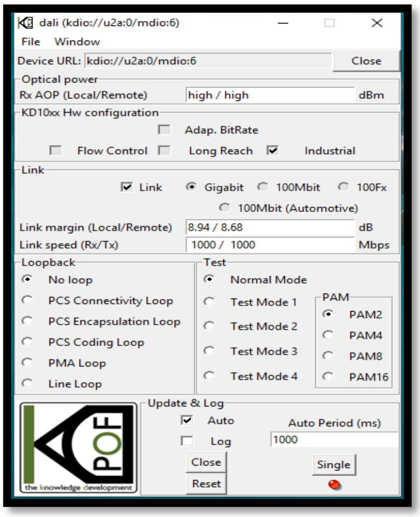


Figure 6. The obtained output for Link margin and link speed.

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