Electromagnetic Emission of an Optical-to-BroadR-Reach Converter

Dennis Degueldre, Thomas Waas and Markus Kucera

Computer Science and Mathematics, OTH-Regensburg, Prfeninger Strasse, Regensburg, Germany

Keywords: BroadR-Reach, EMC, Media Converter.

Abstract: The automotive solution for Ethernet is BroadR-Reach, which cannot be found as a common Ethernet-interface in the consumer industry. Hence a media converter from IEEE 802.3 Ethernet to BroadR-Reach is needed to debug and test the communication of automotive devices under test (DUT). If the functionality of a BroadR-Reach connection has to be tested for electromagnetic compatibility (EMC), a BroadR-Reach to optical media converter is needed, which has to comply to the same EMC test specifications as the DUT. This research explains the internal structure of a media converter and defines a test setup for copper bound emission test of BroadR-Reach. By using a standardized stripline measurement like it is common for electromagnetic emission test, it could be shown, that the tested Technica/Tinytron media converter can safely be used inside an EMC chamber.

1 INTRODUCTION

Current automotive bus systems are not able to fulfil bandwidth demands of future automotive applications. A promising alternative solution is the use of switched Ethernet in a vehicle. Ethernet provides high data rates and it is possible to create different topologies within a switched Ethernet network. One solution is the BroadR-Reach technology which enables a data rate of 100 Mbit/s over unshielded twisted pair cables. This adapted physical layer for automotive use makes Ethernet more cost-effective to reduced wiring effort, reduced shielding effort, and reduced connector cost (Bruckmeier, 2010).

The OPEN (One Pair Ethernet Network) Alliance (OPEN Alliance, 3 05) is enabling a wide scale adoption of Ethernet-based automotive connectivity. The main goal is to establish industry standards for Ethernet connectivity over an unshielded single twisted pair cable. This alliance was founded in November 2011 and is supported by the vehicle industry, suppliers and chip manufacturers. The OPEN Alliance is a central point where open questions with Ethernet for in-vehicle use are discussed and solutions are developed.

One of the open questions is how to qualify the DUTs inside of an electromagnetic test chamber. This is an electromagnetic shielded chamber where the emission and the immunity of Electronic Control Units (ECU) can be tested under realistic conditions. Therefore all the network and control lines are connected to a counterpart inside or outside of the chamber to communicate with an residual bus simulation or control real actors. Since an copper based connection in or out of the chamber would influence the EMC measurements, all connections to the outside of the chamber have to be optical. This avoids distortion of the measured data while having an eye on electromagnetic emission. This is the field of application for optical Ethernet-to-BroadR-Reach media converters.

2 GOAL OF THIS PAPER

This paper gives a look in the inside of an BroadR-Reach media converter and explains how a conversion between optical Ethernet and BroadR-Reach is done to understand which stages in the conversion can influence the quality of the signal. To guarantee that the media converter itself does not add any distortions to the whole system under test, it is measured separately under the same conditions and requirements to qualify its electromagnetic compatibility. The goal is to verify, that the EMC limits - in this paper the limits from BMW Group Standard 95002(BMW Group, 4 10) - are not exceeded.

Degueldre D., Waas T. and Kucera M..
Electromagnetic Emission of an Optical-to-BroadR-Reach Converter.
DOI: 10.5220/0004711401310135
In *Proceedings of the 4th International Conference on Pervasive and Embedded Computing and Communication Systems* (PECCS-2014), pages 131-135
ISBN: 978-989-758-000-0

3 RELATED WORK

Broadcom is the inventor and the first chip manufacturer of BroadR-Reach with unshielded 2-wire cabling technology (Broadcom, 3 05). There are no public investigations available about the electromagnetic compatibility of their technology. Several EMI (Electromagnetic Interference) and EMC (Electromagnetic Compatibility) measurements were done by the automotive OEMs and first tier suppliers with the two wire Ethernet approach under automotive conditions (Verdon and Tazebay, 3 09) (Strobl, 0 25). The results have shown that the technology has proven its capabilities for data communication in vehicles. The BroadR-Reach standard is completed by the OPEN Alliance, where several compliance and test specifications are defined. The goal of those tests is the ratification of the standard but not of the built up products. The signal quality of the products is influenced by the layout, the used filter topologies, shielding and the connectors used. Therefore tests have to be made for each new product. Especially in case of a media converter for in EMC test chamber use the neutrality has to be ensured to avoid distortion while measuring. With focus on the two port converters there are three commercial media converters on the market. One is an 100BASE-TX to BroadR-Reach "Back-to-Back" media converter from Continental Automotive GmbH. This converter was the first on the market and was developed for internal laboratory- and demonstrator use. It is available at Continental Engineering Services (Continental Engineering Services, 3 07). An enhanced, electromagnetic compatible version is currently in development. The second and the third are media converters from Technica Engineering/tinytron. A 100BASE-TX and one optical Ethernet-to-BroadR-Reach converter (Technica Engineering, 3 07). Especially the optical version was designed to be used in an EMC test chamber and is evaluated within this research. This makes this device the only commercial media converter which was designed for in EMC chamber use.

4 FUNDAMENTALS

4.1 BroadR-Reach

BroadR-Reach is an IEEE 802.3 Ethernet based technology which allows to send data with a data rate of 100 Mbit/s over an unshielded twisted pair of cables. It was invented to provide a high data rate connection for existing old office buildings which are not equipped with Cat.5e cables, but rather two wire phone cables.

BroadR-Reach defines a physical layer which uses a different coding scheme than IEEE 802.3. So in difference to 100BASE-TX which uses two pairs of cables, BroadR-Reach uses only one. On top of that it was optimized to fulfil automotive EMC and EMI requirements. Therefore, it uses a three stage pulse amplitude modulation (PAM-3) with a fundamental frequency of 33.3 MHz. This technology is available as a single physical layer transceiver (PHY) or as bridging IC with several integrated standard and BroadR-Reach interfaces. As typical for an Ethernet PHY it supports the standard interfaces to the MAC (Media Access Control) Layer via Media Independent Interface (MII), Gigabit MII (GMII) or Serial GMII (SGMII) which can be directly connected to a small form-factor pluggable (SFP) interface.

4.2 Small Form-factor Pluggable Interface

The description SFP is used for a hot-pluggable and swappable device that contains a transceiver as well as the interface connector. A SFP module consists of a PHY with SGMII interface and the necessary supply voltage regulators for the PHYs sub-voltages. The SFP port was intended to be a modular transceiver for optical interfaces with different wavelength like 1000BASE-SX, 1000BASE-LX or for 1000BASE-T. But today there are also implementations with a reverse compatibility to 10/100BASE-TX.

4.3 Generalized Structure of a Media Converter

Simple media converters consist of two PHYs which are connected with each other over MII. So data can be converted from one PHY over MII to another PHY. This hardware configuration is called Back-to-Back-converter and can be used for every Ethernet-based communication where the data rate of the first and the second PHY is equal. Otherwise the slower PHY would not be able to transport the higher amount of data and discard data packets.

5 STRUCTURE OF THE TECHNICA / TINYTRON MEDIA CONVERTER

Figure 1 shows the block diagram of the Technica/tinytron BroadR-Reach-to-optical Ethernet media converter. These blocks are influencing the qual-

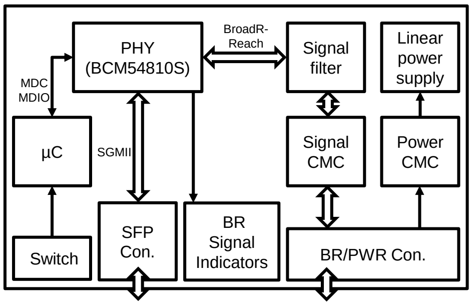

Figure 1: Block diagram of a Technica/tinytron optical Ethernet-to-BroadR-Reach media converter.

ity of the BroadR-Reach signal and are explained in the following. Arrows which are double headed show a bidirectional information flow. The thick arrows represent the flow of the information which is converted from one medium to another. The location of the blocks resembles to the layout of the circuit board. The converter has two main connectors. One for the digital SGMII connection to the SFP module and the other as a lockable Tyco connector for the analog BroadR-Reach and the power supply. To avoid distortion the power line is filtered with a common mode choke (CMC) and the supply voltage is divided to the necessary sub voltages 3.3 and 1.2 V by linear regulators. This spares filtering of switched power supplies. The analog and the digital parts are well separated from each other. Like the power line the BroadR-Reach signal is lead through a CMC and then filtered with a multi-stage LC-filter. Although the dimensioning of the filter components and the selection of the CMC is significant for the signal integrity, it is still under development and requires an Non Disclosure Agreement (NDA) from Broadcom, thus not part of this research. After the signal is processed by the PHY, in this case a BCM54810S with internal GMII to SGMII converter, the SGMII is connected to the SFP Plug to interconnect for example with the PHY in a SFP Module with LC Connector for optical data transmission. A simple microcontroller initializes the BroadR-Reach PHY and reads out two dual in line package (DIP) switches. The DIPs are used for configuration of common transmission parameters since autonegotiation is not used in the car. One is the selection which side is the clock source (master) or sink (slave). The other choses if the the output power is in half or full out mode. More about that can be read in the data sheet of the PHY (Broadcom, 3 05). Two LEDs show the link state and the activity of the BroadR-Reach connection. Link and activity of the SFP can be seen on some versions of the transceiver.

6 MEASUREMENT SETUP

6.1 Test Environment and Preset

All measurements were made in an automotive certified EMC test chamber which is calibrated weekly. Since the described media converter is used to test and qualify a DUT, the converter itself has to fulfil the same requirements to electromagnetic copper bound emission. Therefore, the emission has to be qualified with the same requirements as the tested DUT. This EMC requirements can vary between the projects and their client. One of these specifications is the BMW group standard for electromagnetic compatibility GS 95002 (BMW Group, 4 10) and was chosen because of its representativity. This standard describes several measurement setups, their fields of application, preferences and limit lines.
It was chosen to evaluate the emission with the stripline antenna and a measurement receiver. In this method the DUT, in this case only the data line, is placed under a stripline antenna which is connected to a measurement receiver. This receiver interprets the signal. This signal is then read out by a software which presets the receiver, triggers the measurement and logs the results. Table 1 shows the used receiver model and measurement settings defined from suggestions in GS 95002. All measurements were made with the Rhode & Schwarz ESC30 in Fast Fourier Transformation (FFT) mode. The detectors average and peak were set which built their result over the dwell time. The frequencies start at fstart and are stepped with fstep until fstop is reached. The IF-bandwidth of the used receiver internal input bandpass-filter is IF-BW.

6.2 Measurement Setup

The Hardware of the test setup consists of two BroadR-Reach nodes. A block diagram of the test environment can be seen in figure 2. Node A (left) and B (right) are realized with an Technica/tinytron media converter as explained in section 5. In this setup node A is set to master and node B to slave. Otherwise there would be no active link between the nodes. A and B are configured to full output power. Both nodes were connected with a "Dacar 609 FLR-CUAGY 2x0.18 AX" cable from Leoni.
The nodes were supplied from outside of the chamber. This power supply line is filtered over an EMC filter from the outside to the inside of the chamber to avoid distortions and connected to an artificial network inside of the chamber to simulate in-vehicle behavior. Since optical communication has no electromagnetic

Table 1: Measurement receiver settings from table 9 in GS 95002.

No.	Receiver	Detectors	fstart [Hz]	fstop [Hz]	fstep [Hz]	If-BW [Hz]	dwell time [s]
1	FFT ESCS30, 9kHz	Pk, Av	500 k	2 M	3.1 k	9 k	200 m
2	FFT ESCS30	Pk, Av	2 M	30 M	3.1 k	9 k	200 m
3	FFT ESCS30	Pk, Av	30 M	1 G	49 k	12 k	100 m

emission, the SFP module is plugged in but not connected with optical fibers.
After the measurement setup was completely built up and wired inside of the chamber, the media converters were plugged out from power while the external power supply was still on and a baseline measurement was made. This ensures correct working of the power input filters and gives a feedback if the receivers are working correctly. Additionally it gives a statement about the noise floor which helps to interpret the following measurement. This baseline of the media converter noise floor was measured with the settings from table 1 and can be seen in figure 3. The blue line (starts at at 30 dbu V) is the limit line suggested by GS 95002. The black (starts at -10 dbu V) and the red line (Start at -19 dbu V) are the detector results for peak and average. It can be seen, that the graph is running parallel without any high spikes. The discontinuity can be explained with the different receiver settings and the resulting measurement range of the receiver.
After the noise floor measurement showed no external influence of the environment, the converters were supplied with power which makes them exchange idle packets. After a uptime of two minutes the measurement was started. Two follow-up measurements did not show a difference thus the first results are used. The result can be seen in figure 4 and is explained in section 6.4.

6.3 Test Setup

- The connection speed between node A an node B is 100 Mbit/s while using full duplex mode.
- While there is no data transmission between node A and node B the PHYs will send idle codes, which are a sequence of logical ones. Because there is no difference between sending data or idle codes, the signal on the physical layer would be similar.
- The power requirements of the DUT are 8 to 16 V DC with a power consumption of 2 W. Hence the internal 3.3 V and 1.2 V are generated by linear regulators, the supply voltage was set to 10 V to keep the heat dissipation low.

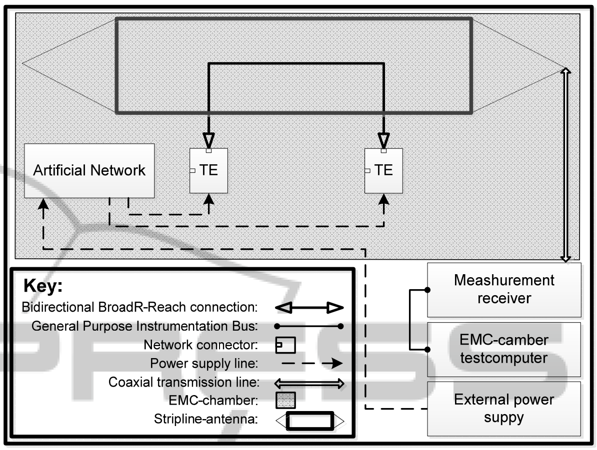

Figure 2: Blockdiagram of the test environment. Two Technica/tinytron media converter are connectet with each other to to interchange Idle-Codes.

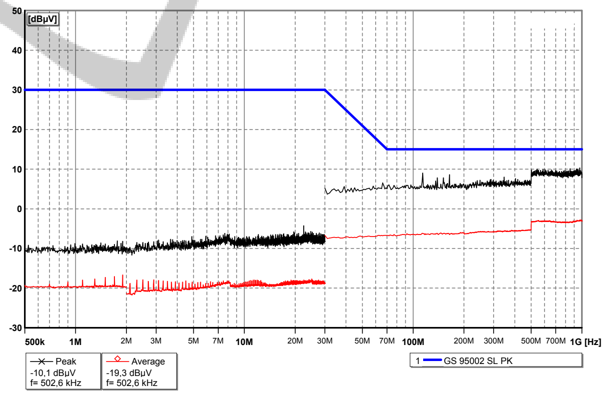

Figure 3: Baseline noise floor meashurement. Blue: Limit line from GS 95002; Black: Peak detector result; Red: Average detector result.

6.4 Results

Figure 4 shows the final result of the measurements. Like in figure 3 the average and the peak emissions for the dedicated frequencies can be seen. This time with running media converters configured as explained in section 6.2. With regard to the noise level in figure 3, the emission is increasing steadily from 500 kHz to 30 MHz, where it begins to reach the fundamental frequency 33,3 MHz, mentioned in section 4. This is the range of frequencies where the BroadR-Reach signal filter has its lowest attenuation to let the signal

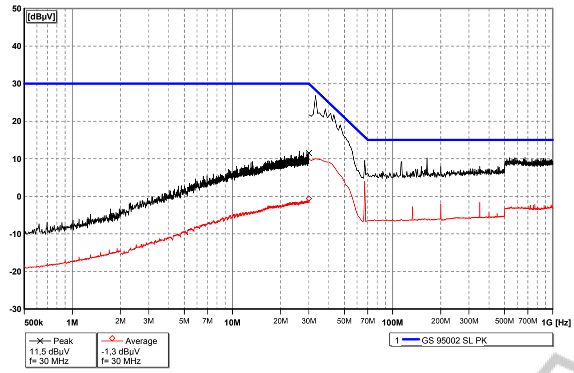

Figure 4: Result of the emission measurement. Blue: Limit line from GS 95002; Black: Peak detector result; Red: Average detector result.

pass. The frequencies over 70 MHz follow exactly the noise floor measurement what lets assume that the filter cuts of everything from here. Over the whole measurement there was no exceed of the limit line. Thus the signal of the Technica/tinytron media converter is GS 95002 conform with regard to copper bound emission.

7 SUMMARY AND CONCLUSIONS

In this paper a test setup was built up to measure the copper bound emission of the BroadR-Reach connection between two identical media converters from Technica/tinytron. The measurement receiver settings and the limit lines were taken from the BMW Group Standard 95002.

The results in figures 3 and 4 show that there was no limit line exceeded during the tests. That makes the Technica/tinytron media converters GS 95002 conformant in case of copper bound emissions. Additionally there is no difference between the noise level and measurements at frequencies higher than 70 MHz which is an indicator, that the signal filter does cut off the internal frequencies of the converter reliably.

That leads to the conclusion, that the Technica/tinytron media converters itself do not add any distortions to the test setup and can be used for inside EMC chamber use. But the measured emissions are relatively close to the limit line at about 40 MHz. A change in the cable, connector or in the filter topology, for example when node A and B are different, eg node B is a DUT, could cause a signal reflection. Thus an exceedance of the limit lines could be possible. Hence a further investigation has to be made when the filter values or topologies are changed in the setup. Optical-to-BroadR-reach media converters with matching filters to the DUT will be important for every future evaluation of ECUs.

The research leading to these results was supported by Regionale Wettbewerbsfaehigkeit und Beschaeftigung, Bayern, 2007-2013 (EFRE) as part of the SECBIT project (http://www.secbit.de)

REFERENCES

BMW Group (2004-10). BMW Group Standard 95002.

Broadcom (2013-05). BroadR-Reach Phyiscal Layer. http:// www.broadcom.com/products/Physical-Layer/ BroadR-Reach-PHYs.

Bruckmeier, R. (2010). Ethernet for Automotive Applications. Freescale Technology Forum, Orlando.

Continental Engineering Services (2013-07). Continental Engineering Services. http://www.conti-engineering.com/www/engineering_services_de_en/ themes/ electric_electronic_architecture_1_en.html.

OPEN Alliance (2013-05). One Pair Ethernet. http://www.opensig.org.

Strobl, M. (2012-10-25). Electromagnetic emissions measurements and powerline communication improvements.

Technica Engineering (2013-07). Technica Engineering media converters. http://www.technica-engineering.de/?page_id=1701.

Verdon, A. and Tazebay, M. (2013-09). Broadr-reach architecture.