Building signal integrity for PWM disturbed SPE links

Peter Fischer / BKS Kabel-Service AG

6/22/2022

Agenda

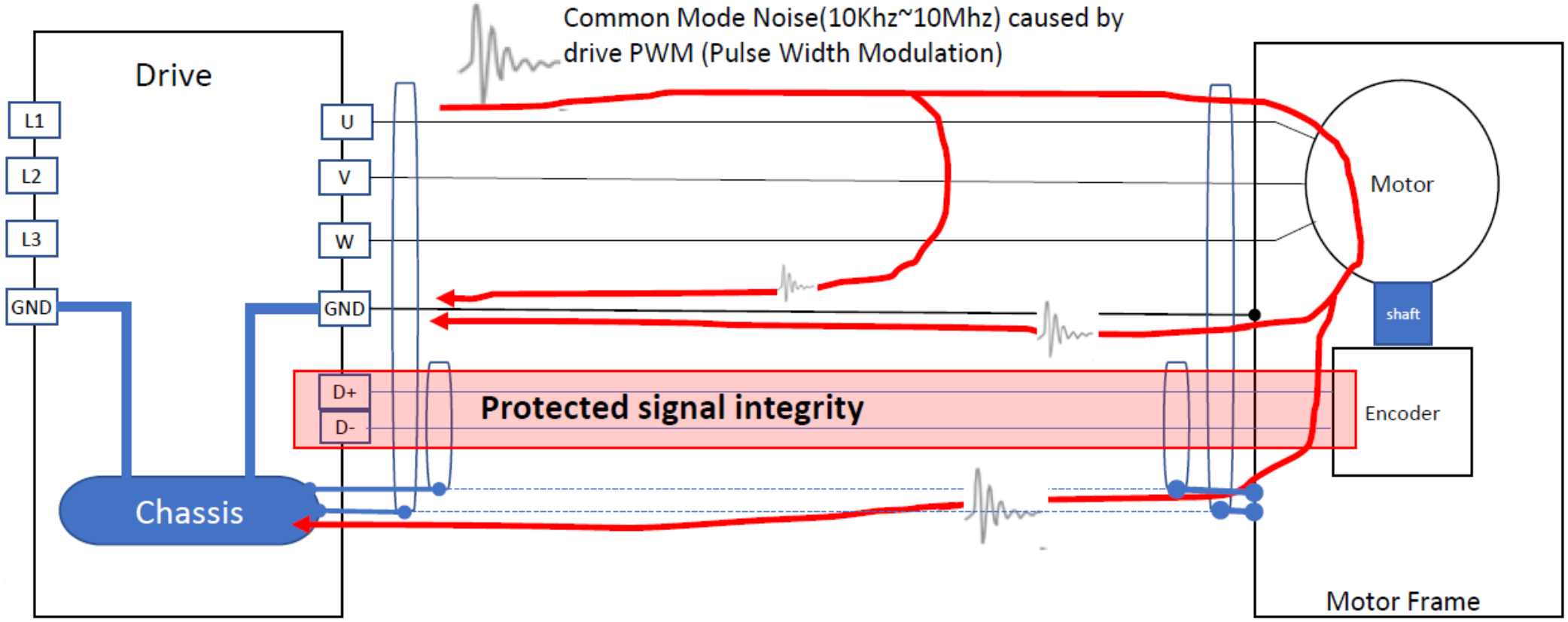
- Disclaimer
- Problem description
- Discussion with the EMC lab
- A way forward
- Discussion

Disclaimer

- The herein presented information is a result between an EMC lab in Switzerland and me.
- This work is still in progress, means not a final conclusion. More presentations are highly appreciated.
- There are EMC experts attending this meeting or IEEE ones with better knowledge about problem’s solution.

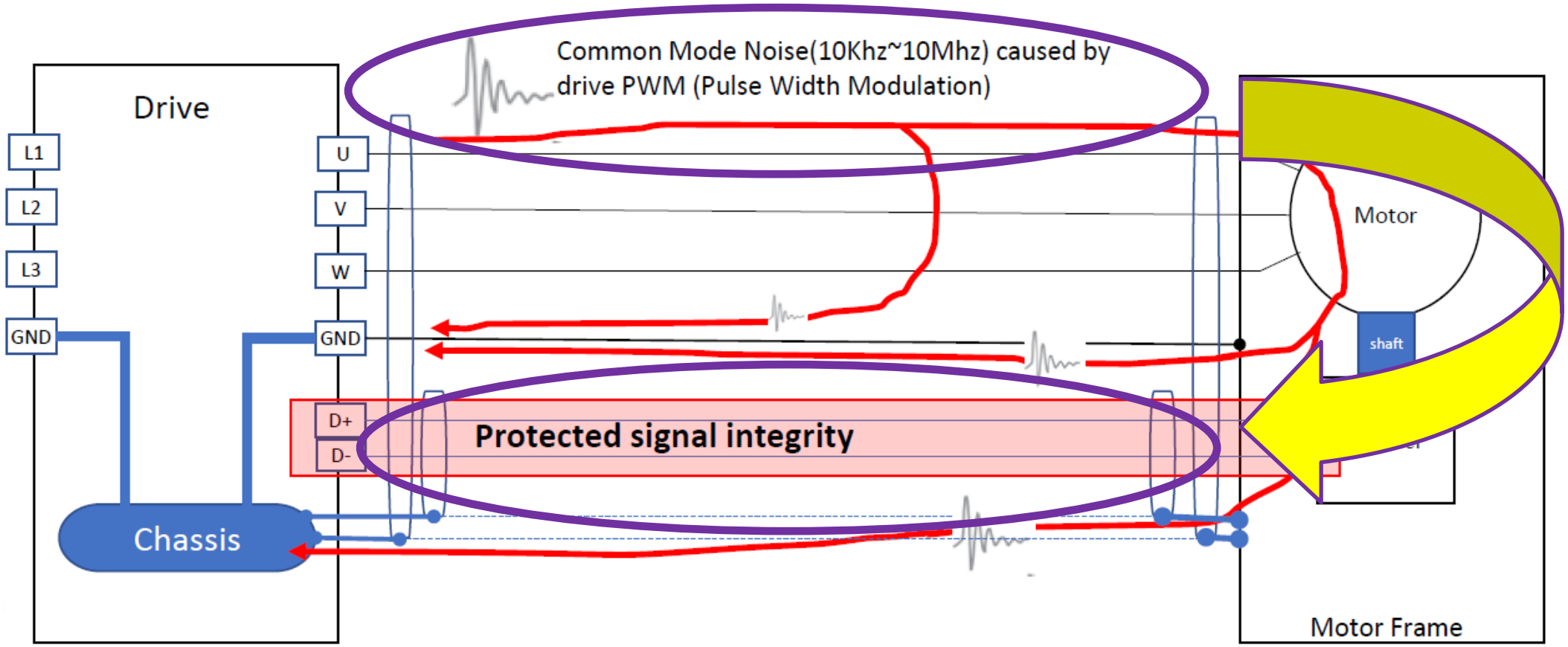
Problem description

- The problem was described in xu_3dg_01_05252022.pdf on slide 15:



Problem description

Disturber: Common Mode signal source



Victim: Differential Mode signal receiver

Coupling: Common Mode to Differential Mode

Problem description

- Disturber: PWM signal (Common Mode noise): What is the maximum allowed emitted signal?
- Victim: Screened differential mode transmission line for 100Base-T1L: What is the maximum received noise to still pass the bit error rate of 10^{-10}?
- Coupling: How good must be the coupling to reduce the maximum emitted signal down to the maximum allowed received signal?

Problem description

Sink: Maximum noise to still pass the bit error rate of 10^{-10}?

This is a question to the receiver and the modulation: What is the maximum allowed noise level at the receiver? What is acceptable to not fail the bit error rate?

This seems to be the last question we can answer.

Problem description

Coupling: How good must be the coupling?

Coupling attenuation is describing the mode conversion from differential to common mode or vice versa. For a single screened pair it is defined as:

$$A_C = A_S + A_U$$

Coupling attenuation = Screening attenuation + Unbalance Attenuation

Problem description

All 3 parameters can be measured, 2 are needed to calculate the 3rd one. There is a limited room of freedom to improve one parameter on cost of another.

Behaviour:

AC: dB slope/ decade

AS: constant dB value

AU: dB slope/ decade

Discussion with the EMC lab

Disturber: PWM signal (Common Mode noise)

IEC 61800-3:2017: Adjustable speed electrical power drive systems - **Part 3**: EMC requirements and specific test methods; **Extension of Fail Safe**: IEC 61800-5-2:2017

IEC 61800-3 defines cable to cable as «N/A», see «Table E.1 – EM interaction between subsystems and environment», distinction between «Power Cable» and «Signal / Control Cable», a hybrid cable does not exist. The hybrid cable must be split according to EMC procedures.

Discussion with the EMC lab

Proposal:

Disturb the «Signal/Control Cable» with a CM-Signal according to **IEC 61000-4-6** or **IEC 61000-4-4**.

For **IEC 61000-4-6** a specific pulse modulation has to be defined, similar to EN 50130 for alarm systems.

For **IEC 61000-4-4** is «intended to demonstrate the immunity of electrical and electronic equipment when subjected to types of transient disturbances such as those originating from switching transients (interruption of inductive loads, relay contact bounce, etc.).”

Discussion with the EMC lab

As worst case an On/Off switching of a PWM can be seen as such transients.

IEC 61000-4-4 is quite tough and repetition is worse as for **IEC 61000-4-6**, but as fast test valuable to see if anything happens.

Problem:

We cannot test as the application does not exist yet.

Discussion with the EMC lab

New approach:

Analysis and suppression of conducted EMI emission in PWM inverter

https://ieeexplore.ieee.org/document/1210695

Abstract:

This paper presents a study of conducted EMI emission in PWM inverter complying with the EMC standard in 15 kHz to 50 MHz range. All major circuit components including switching IGBT, passive components and interconnects are modeled in high frequency domain.

Discussion with the EMC lab

Common mode and differential mode switching noise together with EMI's filter design and topology are the key aspects that have been considered. In addition, the paper reports the conducted EMI measurements results for PWM inverter that have turned to be decisive in the reduction of the conducted EMI.

Discussion with the EMC lab

Immunity of the sink:

The disturber signal can be modulated (for IEC 61000-4-6 it is pulse modulated 1 kHz, 50 % Duty Cycle from 150 kHz up to 80 MHz) and the CM-Impedance (distance to the ground plane, usually in EMC testing is 5 cm, the received signal has then to be extrapolated.

Discussion with the EMC lab

Closest to this issue comes automotive with requirements of ECE R10, see Clause 5.2 « Wired network port with PLC on power lines” in Addendum 9 – UN Regulation No. 10.

Here 2 Networks in parallel are described (one for power and one for data). Test method in this frequency range is **IEC 61000-4-6**.

Discussion with the EMC lab

The product standard ETSI EN 301 489-1 for Wireless equipment according to RED defines wired network ports, and also signal cables, which can transport power (DC or AC), but no test setup is defined in details and leaves it to **IEC 61000-4-6**.

In **IEC 61000-4-6** finally as test standard does not addresses this issue, also not in the upcoming Edition 5 (77B/856/CDV), here all ports exists separately (AC Power, DC Power, Signal and Control).

A way forward

1. Further investigate in maximum noise emission of PWM.
2. Approximate the needed coupling attenuation with existing application and their specific noise levels.
3. Define 2 coupling attenuation levels which might be close to keep the BER below 10^{-10}.
4. Use the resulting 2 noise levels in the final receiver calculations.
5. Decide for the coupling attenuation level which is leading to a BER better than 10^{-10}.

Discussion