DOES CABLE SHIELDING PREVENT ALL EMC CHALLENGES ?

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BMW GROUP

THE NEXT 100 YEARS

Rolls-Royce Motor Cars Limited

AGENDA

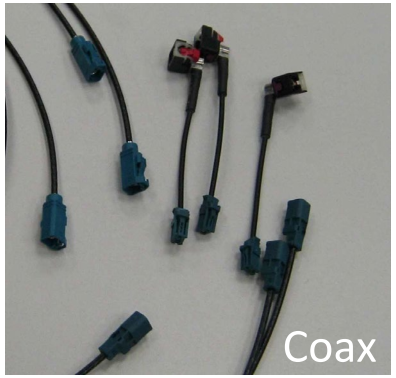
1. Background
2. Old versus new System Implementations
3. Cable Shielding Challenges
4. Means to prevent Shielding Interferences
5. Conclusion

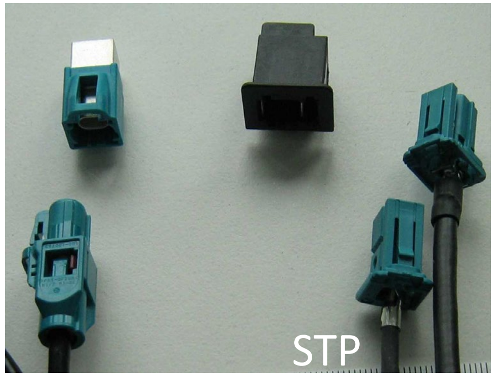
01

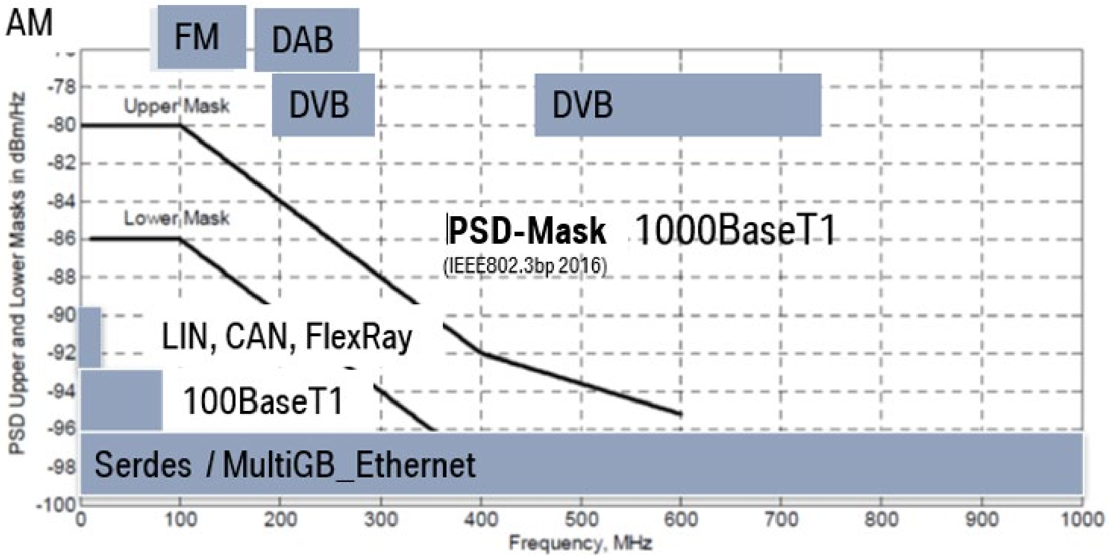
BACKGROUND

WHY DO WE NEED TO DISCUSS CABLE SHIELDING ?

- The legacy bus systems LIN, CAN, CAN-FD, FlexRay operate with unshielded cables
- Higher speed grades → smaller voltage amplitudes
  - More sensitive to noise
  - More crosstalk and noise coupling effects
- Ethernet & High Speed SerDes communications have a broad power spectrum coverage up to the GHz range→ potential impact to on-board radio system







Usage of shielded cables is seen as a solution

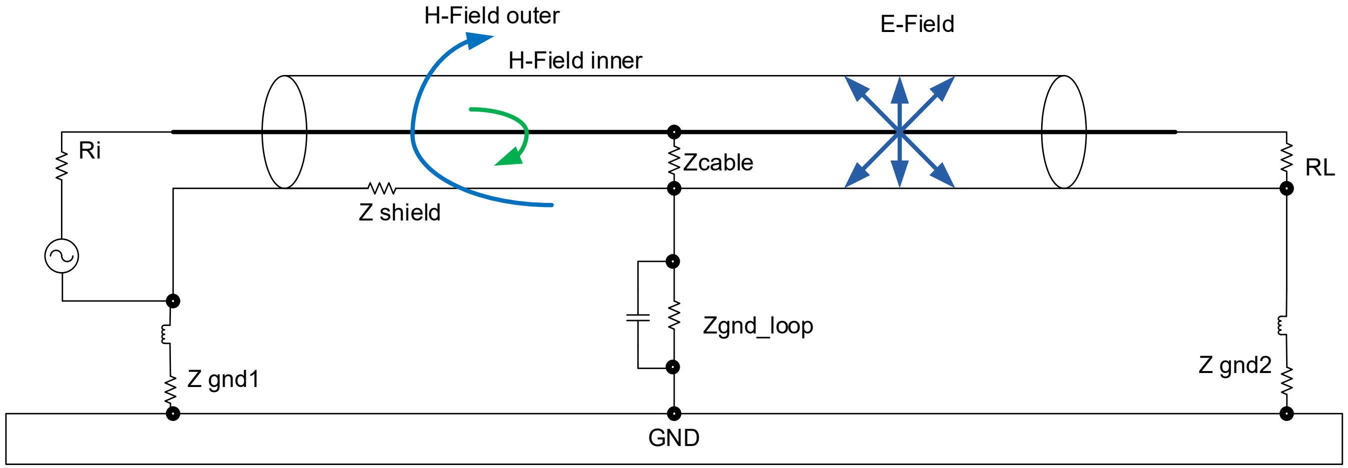
- Today, shielded cables are already used in cars for specific applications: e.g. radio antennas with focus on analog data applications
- Today, shielded cables are also used for data communication in close proximity to radio antennas

A/FM: Amplitude/Frequency Modulation; DAB: Digital Analog Broadcasting; DVB: Digital Video Broadcasting, PSD: Power Spectral Density

LIN: Local Interconnect Network; CAN: Controller Area Network; CAN-FD: CAN Flexible Data Rate

WHAT DO WE INTEND TO ACHIEVE BY USING SHIELDED CABLES ?

- Through the usage of shielded cables, aim is to prevent existing noise sources from entering sensitive sub-systems by targeting:
  1. Reduction of **capacitive coupled interferences** due to electric fields
  2. Elimination of **common mode interferences** through low impedance path
  3. Eliminating inductively coupled **magnetic field radiations** with the shield
     – With STP cables, this is attained through twisted signal conductor pairs
     – However, with single conductor cables these radiations can be cancelled if there is an equal & opposite current flowing on shield versus signal conductor
  4. Attaining **additional EMC margin→** adequate coupling attenuation (unbalance and screening attenuation)



- **Not directly connected to expectations of using shielded cables is:**
  – **Prevention and elimination of coupled magnetic field noise sources.** This is strongly linked to shield-ground loop area and how a shield-ground termination is implemented. Hence, cable shield effectiveness on magnetic field noise sources can be achieved through loop area reduction and proper shield termination

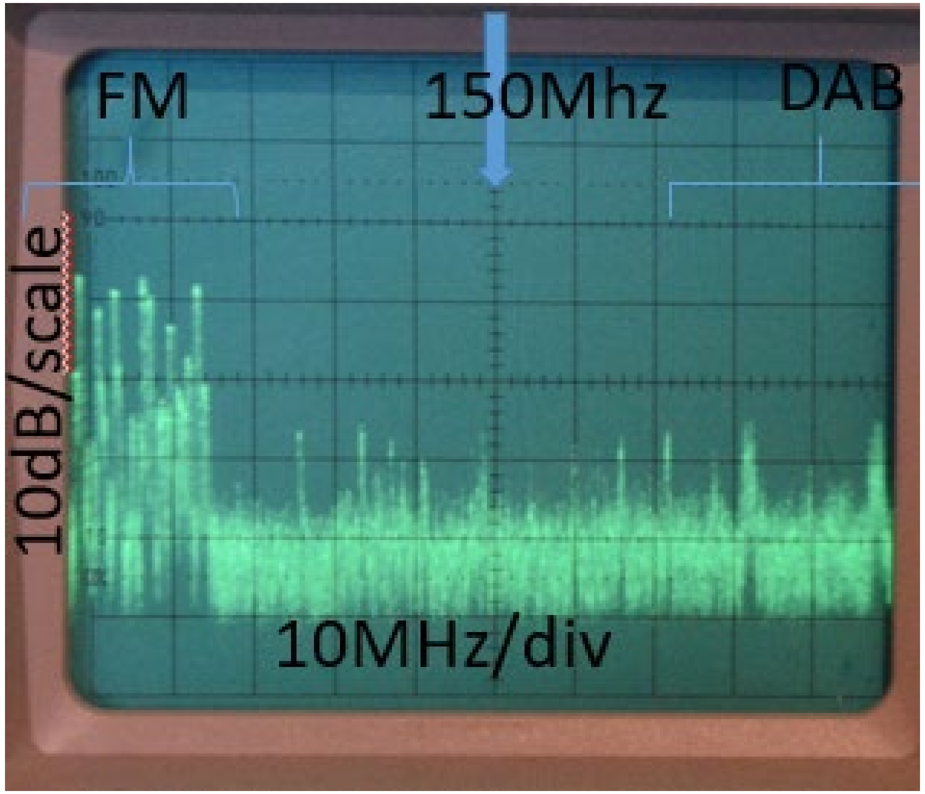
02

OLD VERSUS NEW SYSTEM IMPLEMENTATIONS

DIGITAL AUDIO BROADCASTING (DAB) FREQUENCIES IN THE PAST

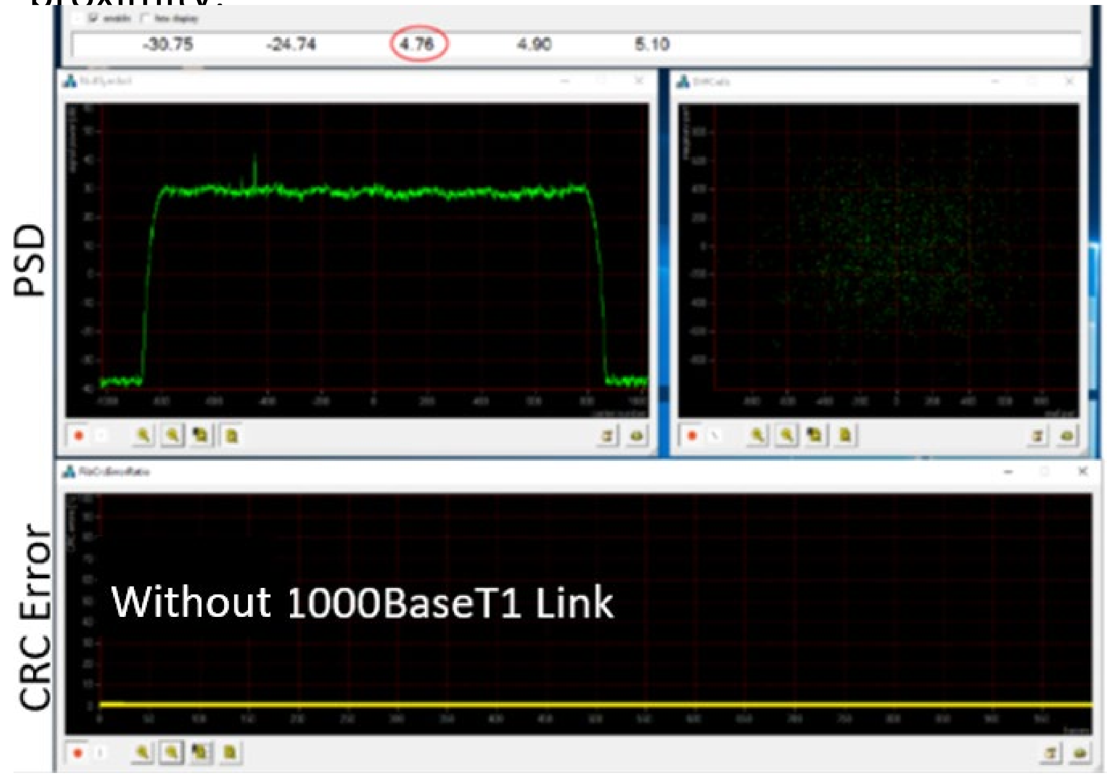
- Legacy bus systems e.g. LIN, CAN, CAN-FD, FlexRay only use frequencies below critical frequencies such as Frequency Modulation (FM) or DAB bands
  - In the past, the Amplitude Modulation (AM) band was more critical with respect to EMC challenges
- **Modern digital systems are accompanied by new challenges**
  - E.g. DAB, which requires high quality radio reception
  - For an effective usage of DAB, radio antenna designers have increased the sensitivity of the corresponding antennas

Power spectrum in a rural area in Bavaria, **DAB ~ 15dB lower than FM station →**



IN THE PAST- DAB FREQUENCIES WERE NOT AFFECTED

- The following figures display the impact of operating a DAB test receiver and a 1000BASE-T1 UTP data link in close proximity:

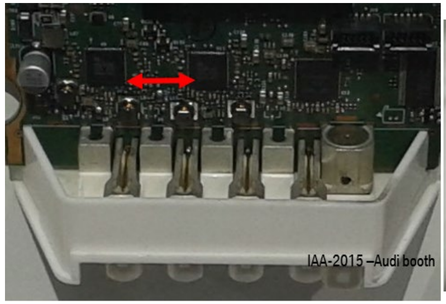


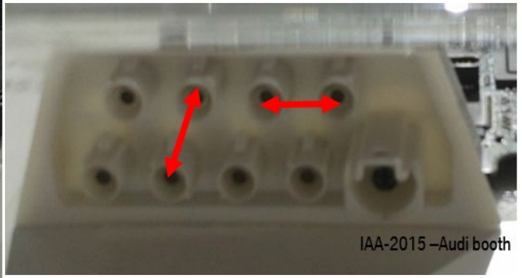
➔ DAB is prone to interferences from the 1000BASE-T1 data traffic

➔Leading BMW to change the implementation concept of 1000BASE-T1 from UTP to STP

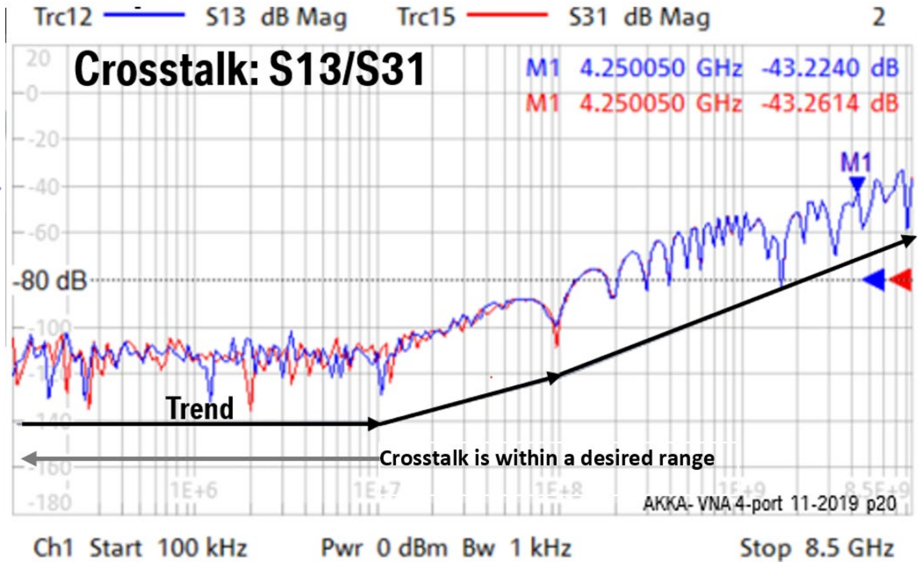
MULTIPORT CONNECTORS – PAST VERSUS PRESENT

- **Past generation of multiport connectors**





- **Present generation of multiport connectors**

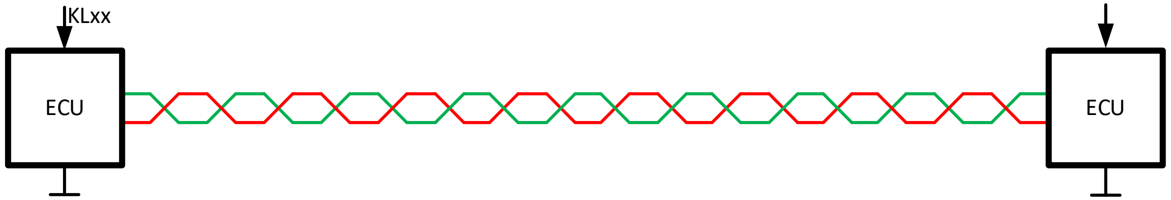


Crosstalk counter measures	Recent systems	Current systems	Findings
Distance	Ok	Smaller → **Shield**	Limited space at ECU
Shield	Ok, coax, **separate**	Ok, coax; **common**	**To be observed**
At PCB /distance	Ok, separate IC	Trend: more integration	Increased functionality

Almost no crosstalk effects below 10MHz; → no issue for classic bus system
Increase of 10dB/decade from 10 to 100MHz → only small impact for 100BASE-T1
Increase of 15 to 20dB/decade above 100MHz → impact for 1000BASE-T1 and SerDes

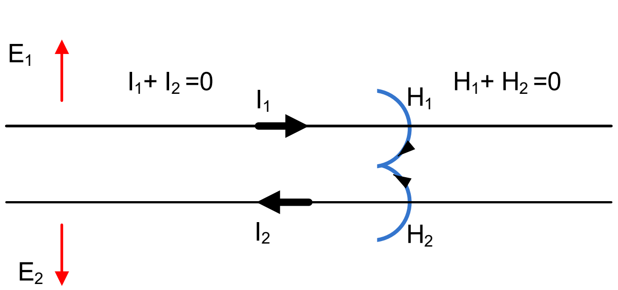
PREVIOUSLY: CONDUCTOR PAIR SYMMETRY WAS USED FOR EMI PREVENTION

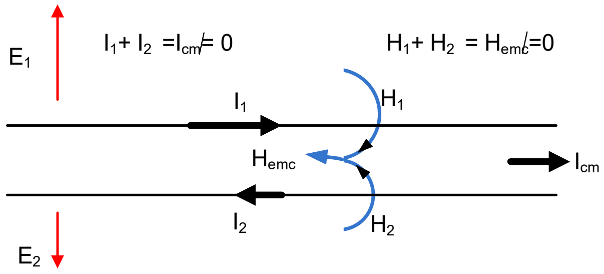
- Most of the EMC issues are tackled through usage of a twisted and differential pair cable
  - A defined cable topology was needed to partially address high speed signal transfer requirements



100BASE-T1:

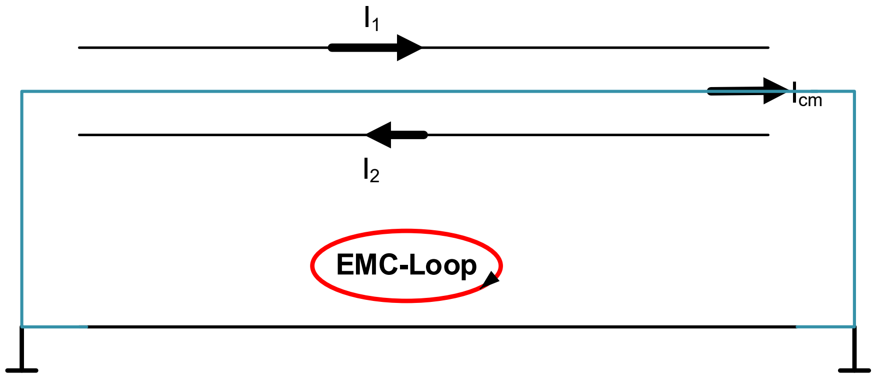
- This works fine since the Power Spectral Density (PSD) is above AM band and below FM Band.
- It also uses the impact of conductor pair symmetry as the main method of EMI prevention





➔ 1000BASE-T1 :

- Goes to the limits of the symmetry approach for cables, connectors & common mode chokes: crosstalk gets a new, major limiting parameter.
- Nyquist Frequency of 375MHz

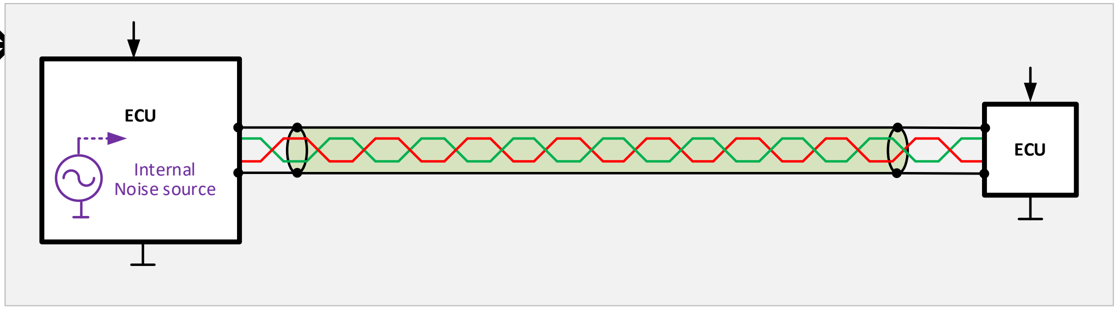


03

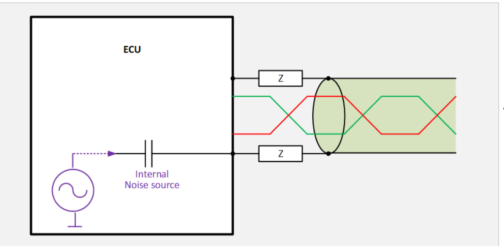
CABLE SHIELDING CHALLENGES

WHICH CABLE SHIELD-GROUND NOISE COUPLING MECHANISMS ARE TO BE EXPECTED?

- **Noise generated internally within the ECU→**

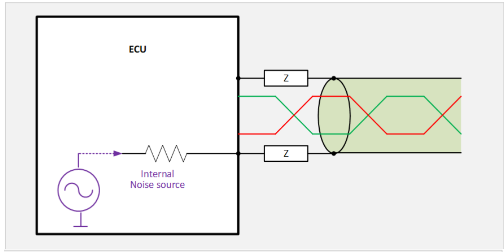


- **Direct noise source coupling to ground**

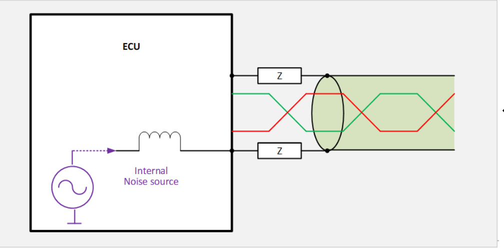


←Capacitive coupling: coupling ∝ frequency

- This is aside the capacitive coupling due to parasitic capacitances

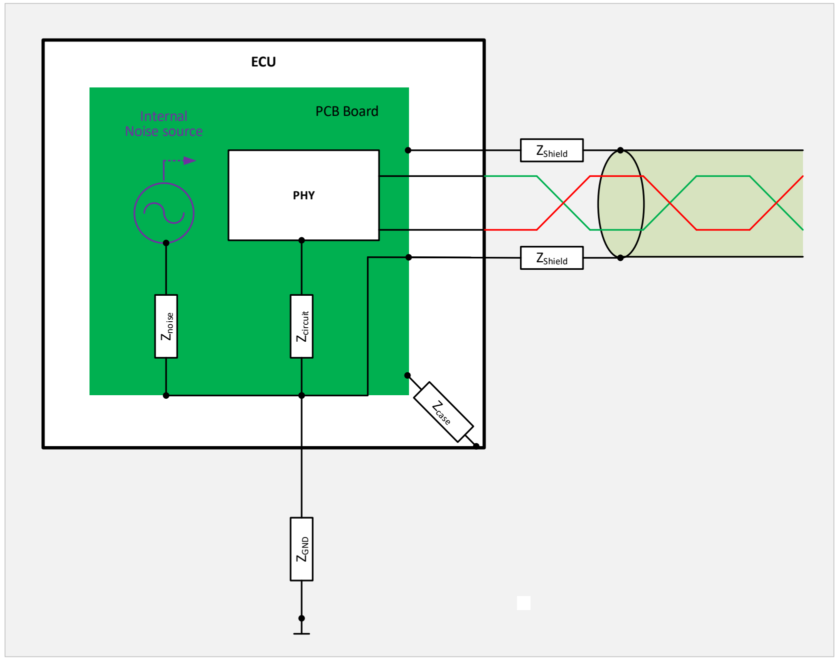


←Resistive coupling: independent of coupling frequency



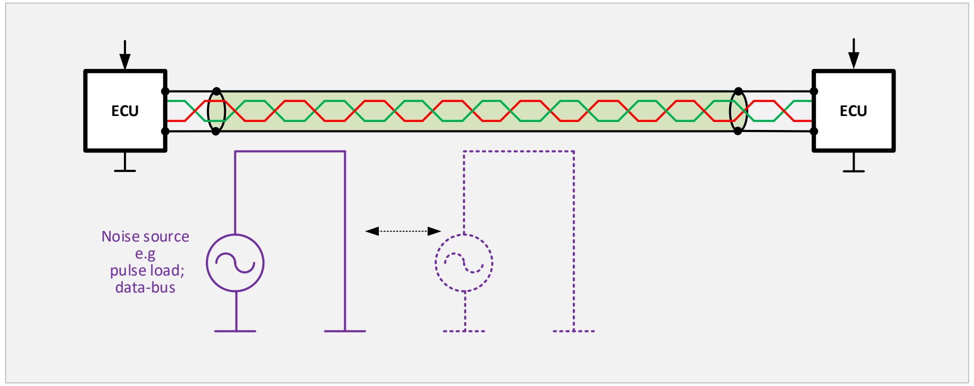
←Inductive coupling: coupling ∝ 1/frequency

Noise coupling via ground distribution

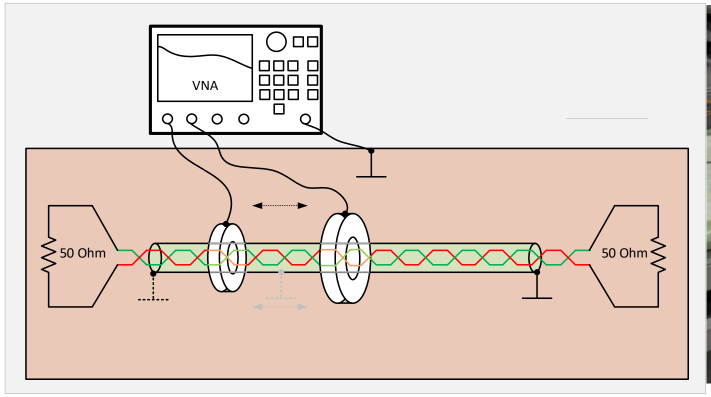


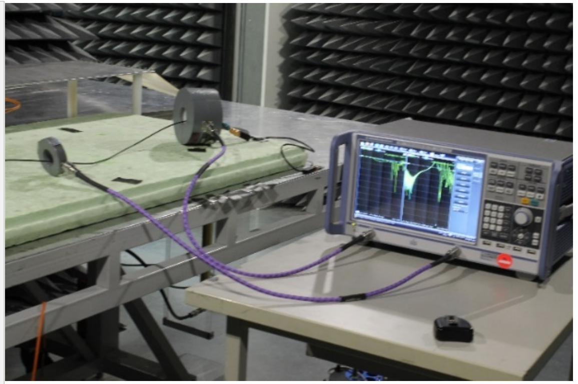
AN EXAMPLE OF INDUCTIVE NOISE COUPLING ON CABLE SHIELD

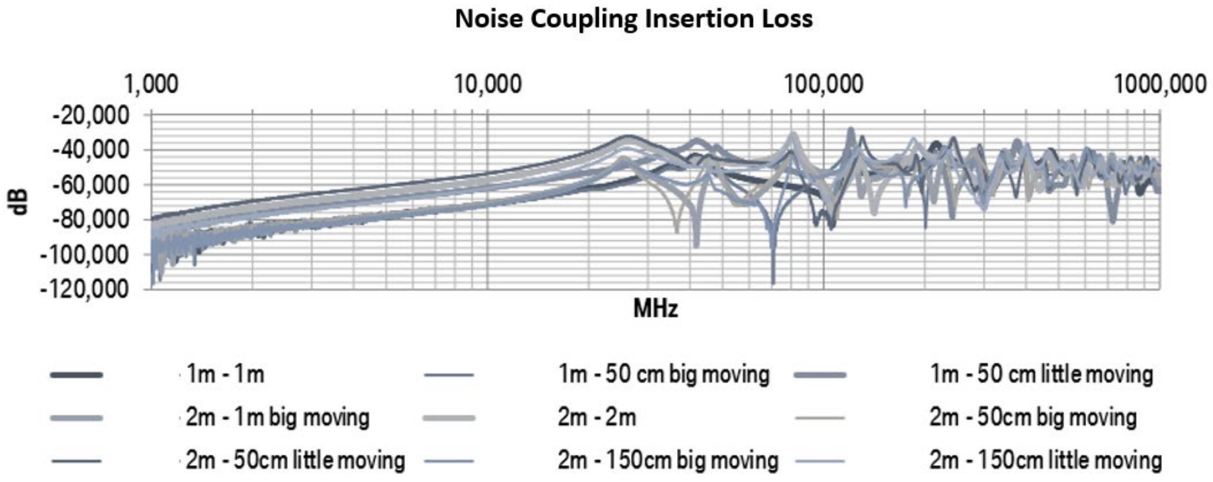
Noise coupled to shield from a source along the channel



Test setup



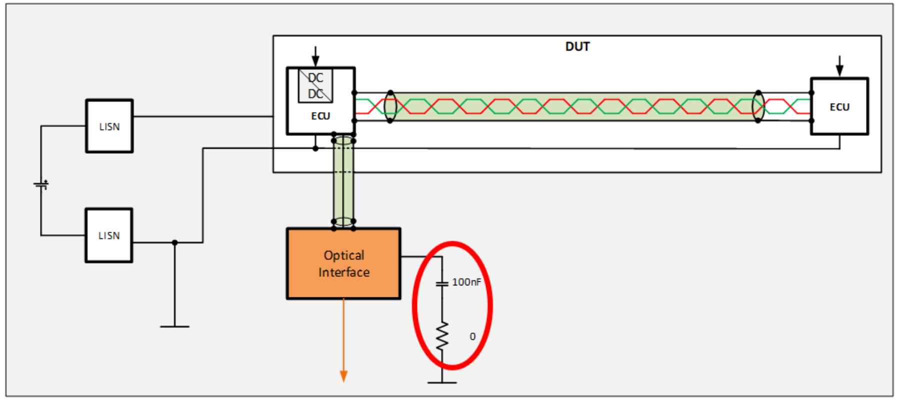




- ➔ Noise coupling increases up to a range of ~25MHz;
- It then remains at a certain base level, but with resonances
- The resonances vary with cable length as well as the length of its ground line connection; as second order of the noise source
- Additional ground clamps shift the resonances

DO SHIELDED CABLES PREVENT GROUND RESONANCE ?

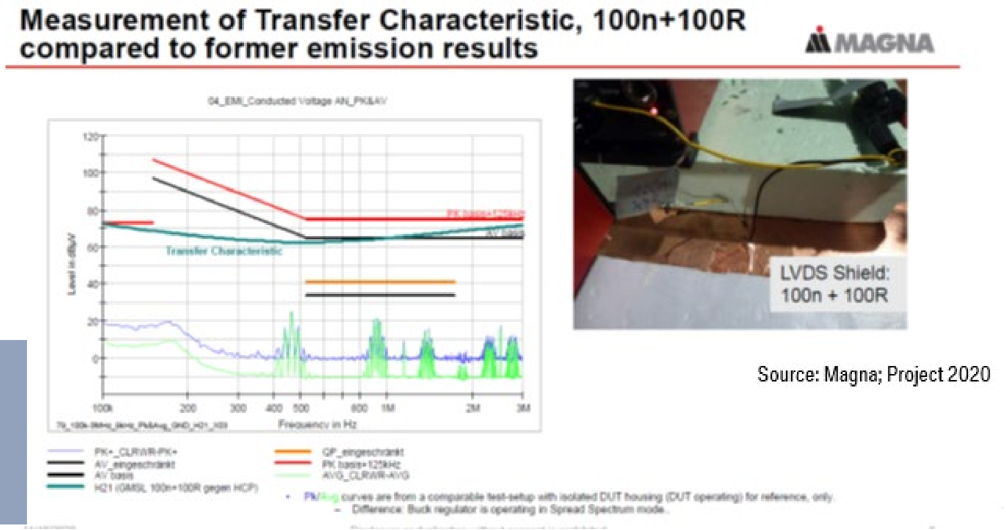
EMC Test Setup



- Initial assessment of the test results→ no abnormalities are observed
- Then, with an optical interface EMI noise above the limit within the kHz range is observed
- A weak resonance system with noise up to the MHz range is stimulated by a DC/DC converter within an ECU by adding a

➔ Internal ECU noise should be kept low

- Pre-check the resonance / impedance behavior of the ground system
- **Cable shielding does not prevent nor eliminate ground resonance**



04

MEANS TO PREVENT SHIELD INTERFERENCES

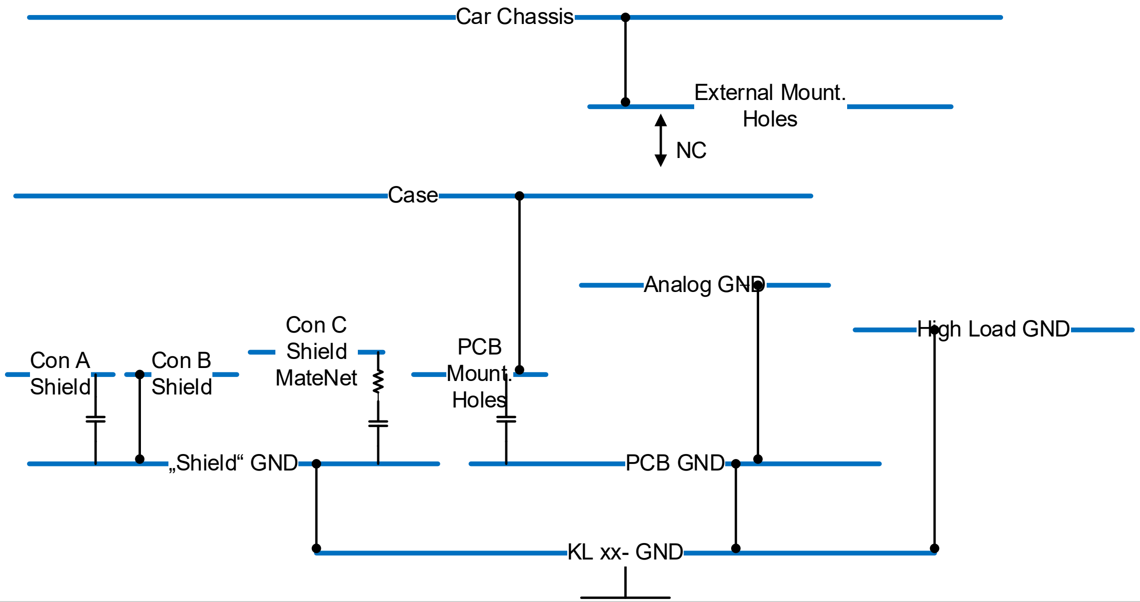
PRIORITIZING SYSTEM GROUND CONCEPT DEFINITION

- For an early prevention of cable shield interferences, It is essential to define a **specific system grounding configuration in the initial system design phase**

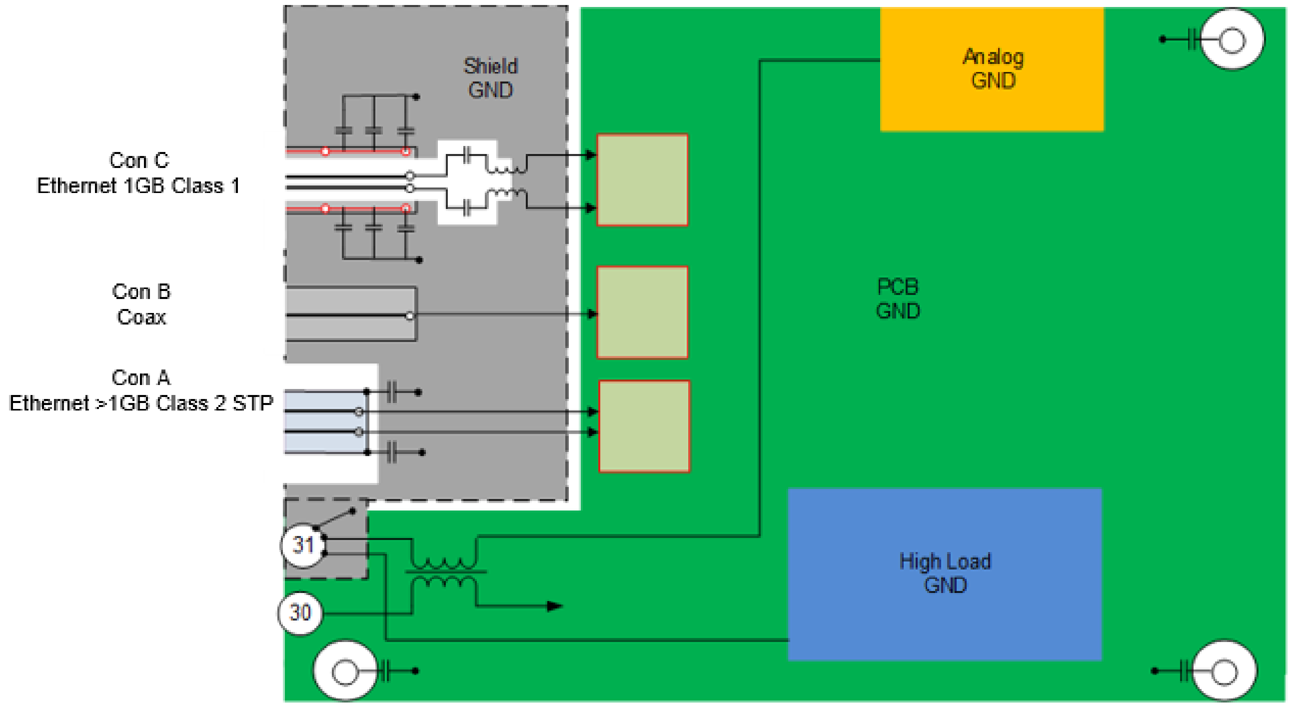
There has to be a correlation between system versus sub-system ground implementation

General complete system ground scheme

– Defining grounds based on signal type, frequency and voltage levels



Defining a grounding scheme within a sub-system

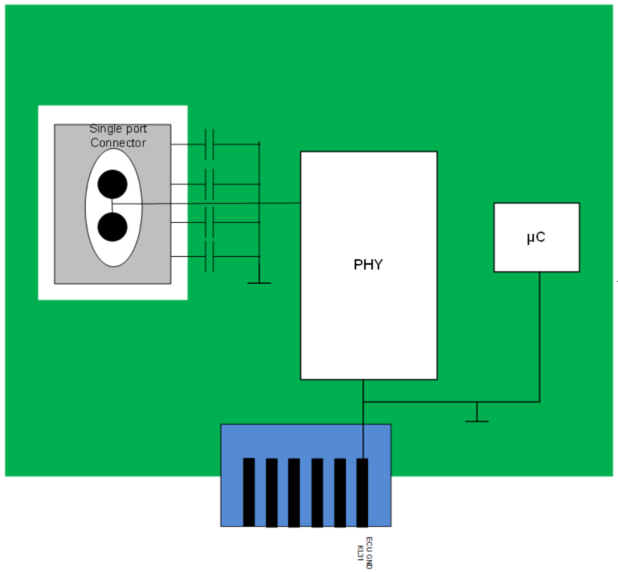


KEY CONSIDERATIONS FOR CABLE SHIELD TERMINATION & GROUND LOOPS

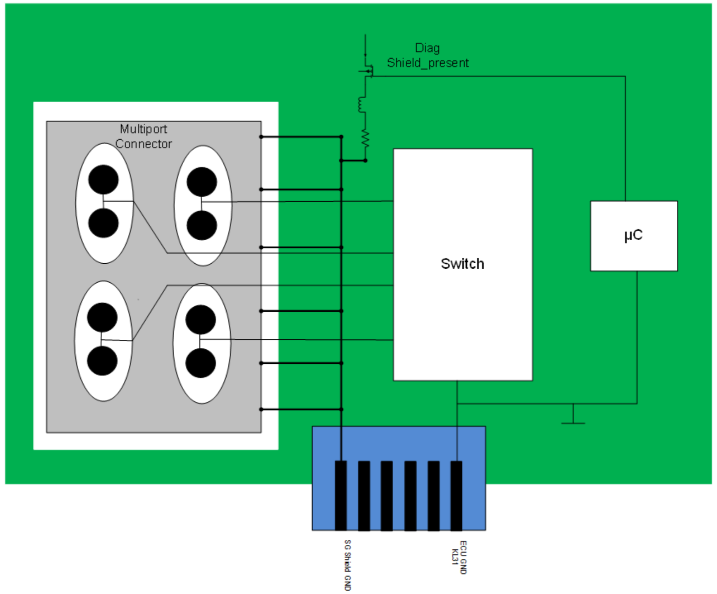
- **AC coupling capacitor(s)** should be used on the second end of the shield
  - This aids in shield connection retention at high frequencies and breaking the ground loop at lower frequencies
  - Adaptations are required for ECU-ECU and for Display connections
- **Shield-ground Low impedance path** is essential for maximum shielding benefits

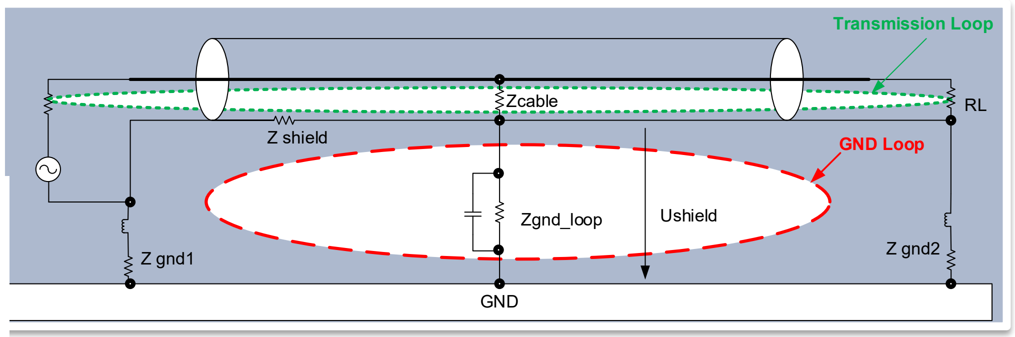
- A shield-ground loop acts as either a receiving or transmitting monopole antenna → **Conducted & radiated EMI coupling**
- Reduction of the shield-ground loop area to the desired “transmission loop” range aids in minimizing the magnetic field strength within the loop and hence the induced noise current

Single port connector termination(e.g at Serializer)

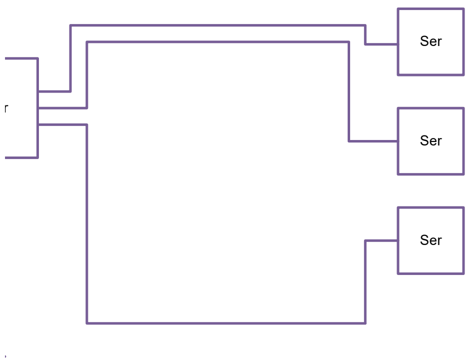


Multiport connector termination (e.g Deserializer)

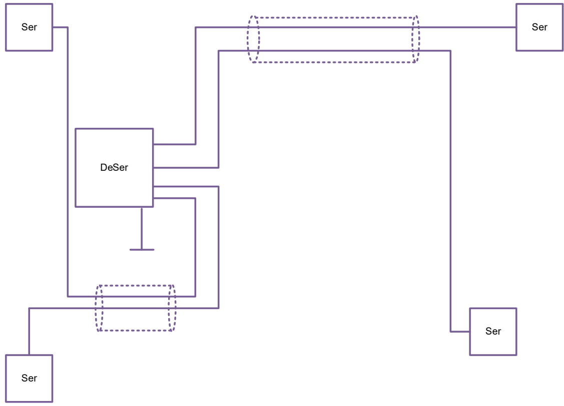




Undesired large loop area



Preferable



05

CONCLUSION

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- Being able to use shielded cables is essential for current and future high data rate communication systems.
- However, **it is of essence that the correct and a well planned system implementation approach is incorporated. This is to commence by pre-defining an overall system grounding configuration and based on that defining a general corresponding shield-ground approach.**

- **Takeaways:**
  1. Generally, ground planes are not ideal and therefore cause impedance variations
  2. Cable shielding has minimum effect on inductively coupled noise but rather effectively addresses electric field noise sources
  3. It is essential to define a system grounding configuration in the initial system design phase
     – Single point shield-grounding within a sub-system also favors elimination of common ground impedance
     – Multipoint system grounding scheme tends to operate better in high frequencies
  4. Cable shielding effectiveness is impacted by the method of its termination
     – Low impedance shield-ground paths are essential for maximum shielding benefits
  5. Cable shielding implementation should also target the root noise sources

THANK YOU FOR YOUR ATTENTION !