EMC of Ready Made Connecting Devices

EMC of Ready Made Connecting Devices, Overview

- Ready made Connecting Devices
  - Standards & EMC-Requirements
    for Coaxial and Balanced cable assemblies
  - Hybrid cable assemblies
- Test procedures
  - Radiated emission
  - Coupling attenuation
  - HDMI adapter
- Measurements
  - Comparison between Radiated emission and Coupling attenution
- Outlook,
- Conclusion & Discussion

Radio frequency and coaxial cable assemblies

	Radio frequency and coaxial cable assemblies	
IEC 60966-1Ed.3	Part 1: Generic specification – General requirements & test methods	published 2019-02
IEC 60966-2-4Ed.4	Part 2-4: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3000 MHz, IEC 61169-2 connectors, **(IEC-60169-2 Connector).**	published 2016-05-18
IEC 60966-2-5Ed.4	Part 2-5: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 1000 MHz, IEC 61169-2 connectors, **(IEC-60169-2 Connector).**	published 2016-10-26
IEC 60966-2-6Ed.4	Part 2-6: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3000 MHz, IEC 61169-24 connectors, **(F-Connector).**	published 2016-10-26
IEC 60966-2-7Ed1	Part 2-7: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3 000 MHz, **IEC 61169-47 connectors (F-Quick)**	published 2015-09-08
IEC 60966-2-8Ed1	Part 2-8: Detail specification for cable assemblies of radio and TV receivers-Frequency up to 3000MHz, **Screening class A++, IEC61169-47 connectors (F-Quick)**	46/750/CD

Screening Classes acc. to IEC 60966 & IEC 61196

IEC SC 46A & IEC TC 46/WG9 have established screening classes for coaxial cables and assemblies with Transfer Impedance up 30 MHz and Screening attenuation above 30 MHz.

Screening Class	5 - 30 MHz	30 -1000 MHz	1 GHz – 2 GHz	2 GHz – 3 GHz
C	*50 mOhm/m*	*75 dB*	*65 dB*	*55 dB*
B	*15 mOhm/m*	*75 dB*	*65 dB*	*55 dB*
A	**5 mOhm/m**	**85 dB**	**75 dB**	**65 dB**
A+	2,5 mOhm/m	95 dB	85 dB	75 dB
A++	0.9 mOhm/m	105 dB	95 dB	85 dB

Transfer impedance and Screening attenuation shall be measured with the **"Triaxial test procedure"** according to IEC 62153-4-3 & -4-4 for coaxial cables respectively according to IEC 62153-4-7 for assemblies of EN 60966-2-n series.

For trouble free TV-reception, at least Screening class A is recommended.
Screening classes B and C are not recommended for services with back channel applications below 30 MHz.

Standards for balanced cable assemblies

	Generic cabling systems - Specification for the testing of balanced communication cabling in accordance with ISO/IEC 11801
IEC 61935-2-21	Part 2-21: Cord and work area cord category 6 - Blank detail specification
IEC 61935-2-22	Part 2-22: Cord and work area cord category 6A Blank detail specification
IEC 61935-2-23	Part 2-23: Cord and work area cord category 7 - Blank detail specification
IEC 61935-2-24	Part 2-24: Cord and work area cord category 7A - Blank detail specification
IEC 61935-2-25	Part 2-25: Work area cord with M12 4 poles connectors – Blank detail specification
	Multi-element metallic cables used in analogue and digital communication and control
EN 50288-4-2	Part 4-2: Sectional specification for screened cables characterised up to 600 MHz - Work area and patch cord cables
EN 50288-9-2	Part 9-2: Sectional specification for screened cables characterized from 1 MHz to 1 000 MHz for work area, patch cord and data centre applications
EN 50288-10-2	Part 10-2: Sectional specification for screened cables characterized from 1 MHz up to 500 MHz for work area, patch cord and data centre applications
EN 50288-11-2	Part 11-2: Sectional specification for un-screened cables, characterized from 1 MHz up to 500 MHz for work area, patch cord and data centre applications

EN 50599, 50601, 50602, & 50603 also specifies EMC requirements for balanced patch cords

EMC requirements for balanced cables & assemblies

Frequency range [MHz]	Maximum **Surface transfer impedance** [mOhm/m]	
	Grade 1	Grade 2
1 to 10	$Z_T \leq 15 \times f^{0,176}$	$Z_T \leq 15 \times f^{0,301}$
10 to 30	$Z_T \leq 10 \times f/10$	$Z_T \leq 23{,}392 \times f^{0,6309}$
30 to 100	$Z_T \leq 10 \times f/10$	$Z_T \leq 2{,}1206 \times f^{1,3368}$

Coupling attenuation type	Frequency range/requirement	Frequency range/requirement
	30 to 100 MHz	100 to 1 000 MHz, [dB]
Type I	≥ 85 dB	≥ 85 – 20 × lg10 (f /100)
Type Ib	≥ 70 dB	≥ 70 – 20 × lg10 (f /100)
Type II	≥ 55 dB	≥ 55 – 20 × lg10 (f /100)
Type III	≥ 40 dB	≥ 40 – 20 × lg10 (f /100)

EMC requirements for balanced cables & assemblies according to IEC 61156 series.

The Transfer impedance describes the EMC behaviour of the screen in the lower frequency range, whereas the Coupling attenuation describes (at first approach) the sum of the unbalance attenuation of the pair and the screening attenuation of the screen at higher frequencies.

Test procedures shall be in accordance with the IEC 62153-4-n series.

EN 55032 resp. CISPR 32 limits

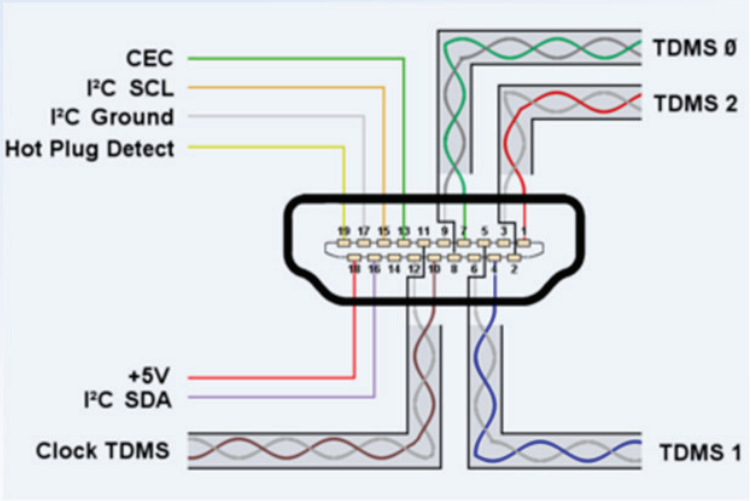
Table clause	Frequency range [MHz]	Measurement		Class B limits [dB(µV/m)]
		Distance [m]	Detector type/ bandwidth	OATS/SAC (see table A.1)
A.4.1	30 - 230	10	Quasi Peak/ 120 kHz	30
	230 - 1000			37
A.4.2	30 - 230	3		40
	230 - 1000			47
Apply only table clause A4.1 or A4.2 across the entire frequency range				

Requirements of CISPR 32 for radiated emissions
up to 1 GHz for Class B equipment, e.g. broadcast receiver(s).

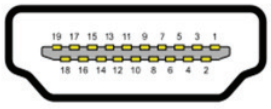
Class B requirements of CISPR 32 are intended to offer adequate protection to broadcast services within the residential environment.

Class B requirements of CISPR 32 are also valid for HDMI assemblies.

HDMI cable assembly



A HDMI cable assembly contains different insulated control wires as well as four screened balanced pairs for clock signal and data transmission.
It is assumed, that major EMC problems are caused by the balanced pairs.

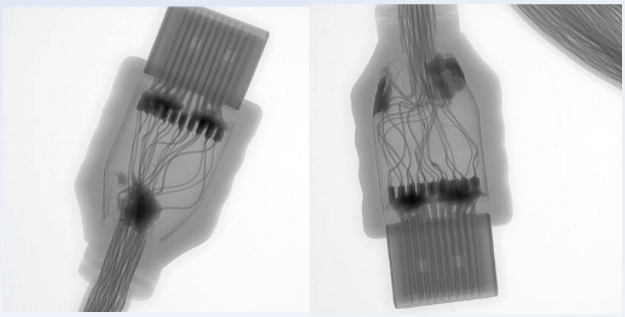


Kontakt Typ A	Kontakt Typ C	Kontakt Typ D	Signal
Pin 1	Pin 2	Pin 3	TMDS Data2+
Pin 2	Pin 1	Pin 4	TMDS Data2 Schirm
Pin 3	Pin 3	Pin 5	TMDS Data2–
Pin 4	Pin 5	Pin 6	TMDS Data1+
Pin 5	Pin 4	Pin 7	TMDS Data1 Schirm
Pin 6	Pin 6	Pin 8	TMDS Data1–
Pin 7	Pin 8	Pin 9	TMDS Data0+
Pin 8	Pin 7	Pin 10	TMDS Data0 Schirm
Pin 9	Pin 9	Pin 11	TMDS Data0–
Pin 10	Pin 11	Pin 12	TMDS Clock+

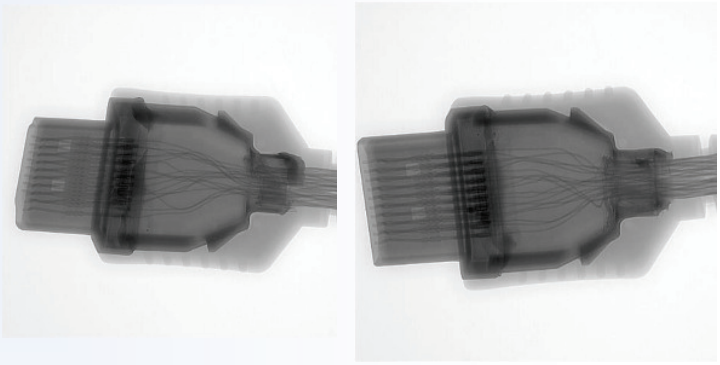
Kontakt Typ A	Kontakt Typ C	Kontakt Typ D	Signal
Pin 11	Pin 10	Pin 13	TMDS Clock Schirm
Pin 12	Pin 12	Pin 14	TMDS Clock–
Pin 13	Pin 14	Pin 15	CEC
Pin 14	Pin 17	Pin 2	reserviert (HDMI 1.0-1.3). HEC Data- (HDMI 1.4)
Pin 15	Pin 15	Pin 17	SCL (I²C serieller Takt für DDC)
Pin 16	Pin 16	Pin 18	SDA (I²C serielle Datenleitung für DDC)
Pin 17	Pin 13	Pin 16	Masse für DDC / CEC / HEC
Pin 18	Pin 18	Pin 19	+5 V Versorgungsspannung (min. 55 mA)[38]
Pin 19	Pin 19	Pin 1	Hot-Plug-Erkennung (alle Versionen), HEC Data+ (HDMI 1.4)

Source: https://de.wikipedia.org/wiki/High_Definition_Multimedia_Interface

X-ray images of HDMI connectors



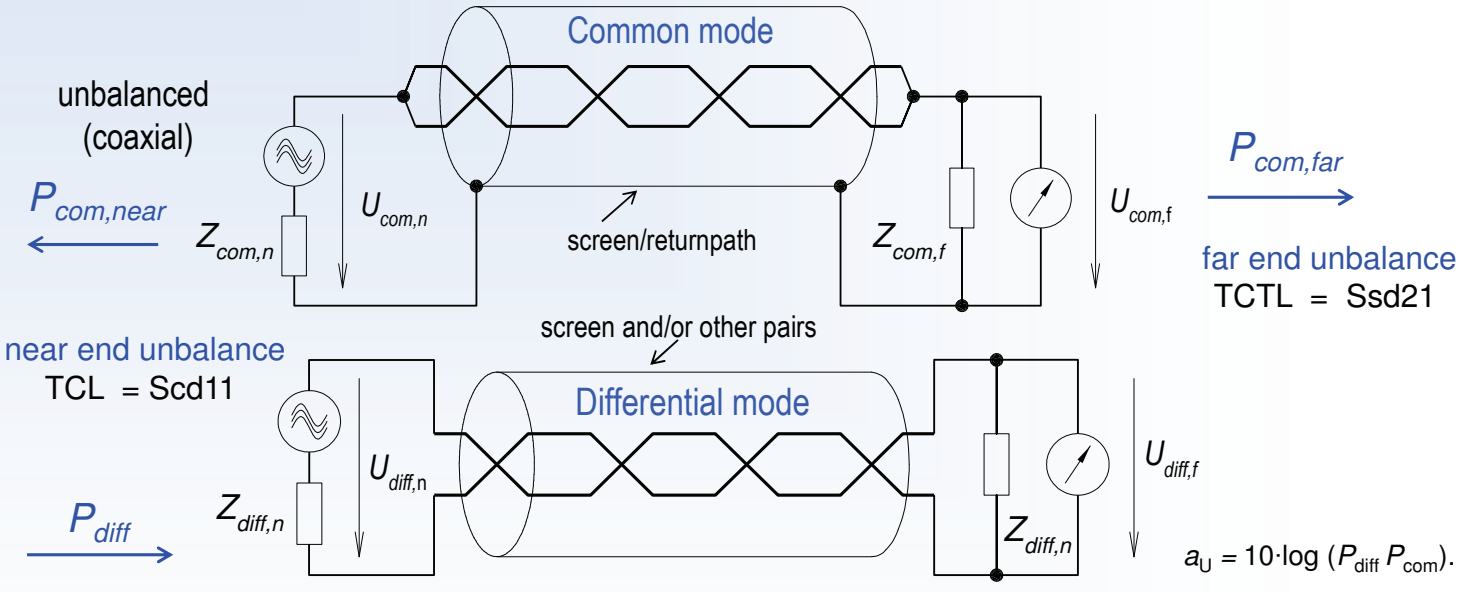
HDMI Connector with poor screen connection
(Vestel EMC laboratory)



HDMI Connector with good screen connection
(Vestel EMC laboratory)

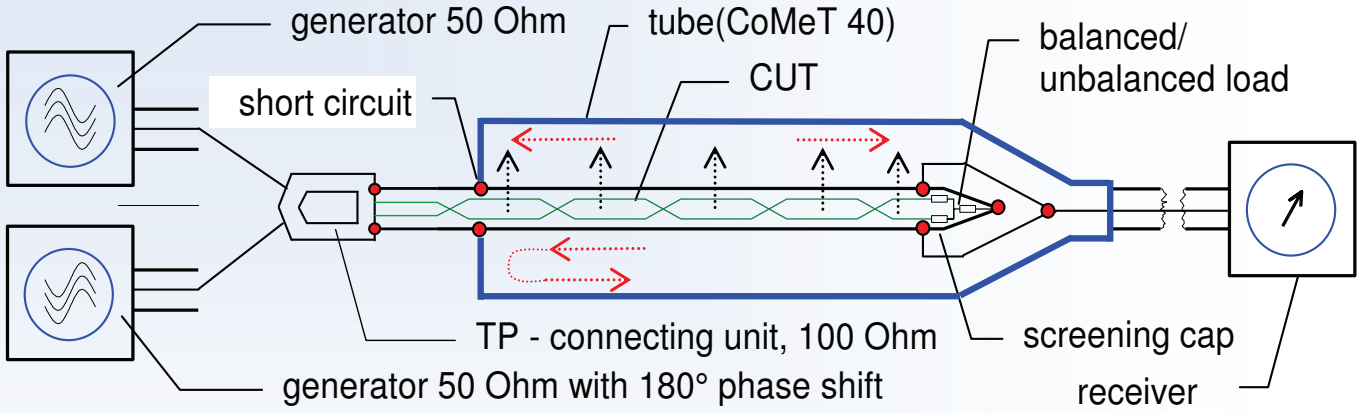
The photos above show X-ray images of HDMI Connectors with poor and with good screen screen connection.
An overall screen of theassembly improves the the EMC behavior of an assembly if it is connected with low impedance to the housing of the connector. Connection of the cable screen to the housing of the connector shall be applied over the complete circumference.
Improper made connections will reduce EMC of the whole assembly.

Common mode & differential mode



Balanced cables can be operated in the common mode as well as in the differential mode.
The "Unbalance Attenuation" of a pair describes in logarithmic scale how much power couples from the differential mode to the common mode and vice versa. It is the logarithmic ratio of the input power in the differential mode P_{diff} to the power which couples to the common mode P_{com}:

Screening & Coupling attenuation with Triaxial procedure



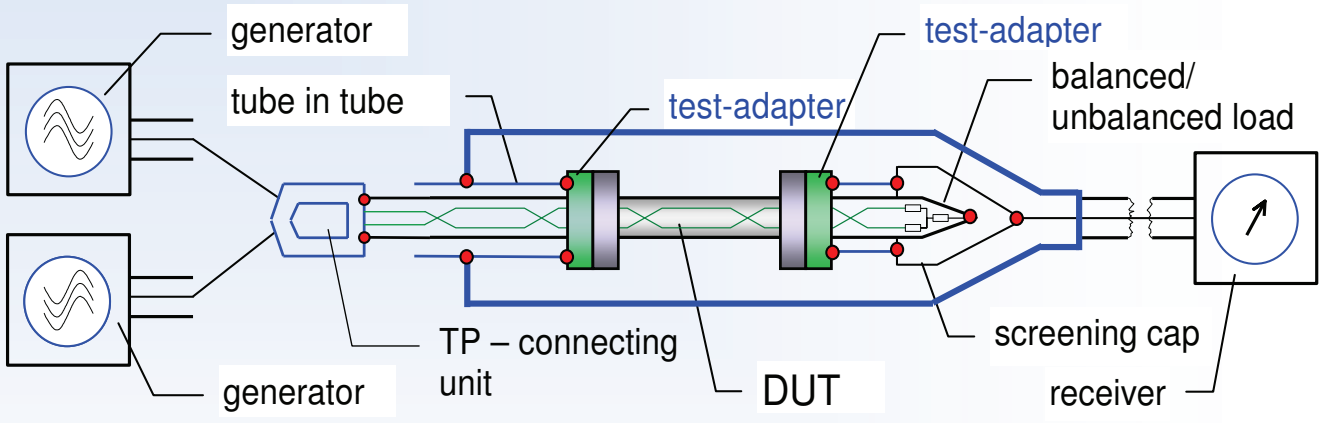
The principle for coupling attenuation measurement is the same than the basic triaxial procedure with generator and receiver included in a vector network analyser and a short circuit at near end.

The set-up above shows the balunless measurement of coupling attenuation acording to IEC 62153-4-9 up to 2 GHz.

The balanced 100 Ohm signal at the CUT is achieved with two 50 Ohm generators with 180° phase shift.

IEC 62153-4-9Ed2, Coupling attenuation – Triaxial method

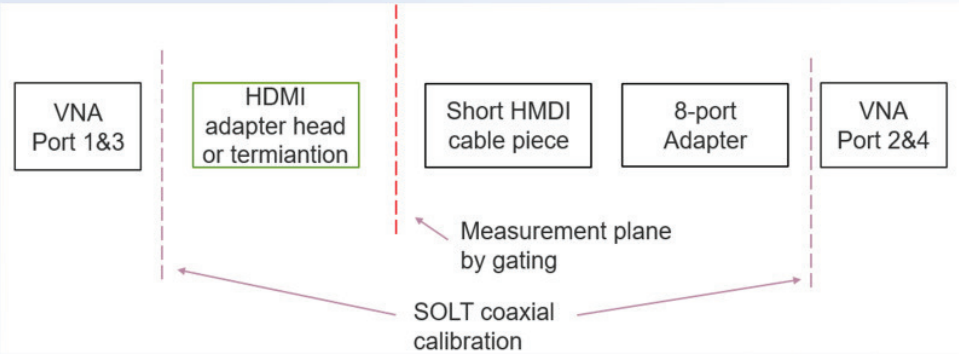
Coupling attenuation on balanced assemblies

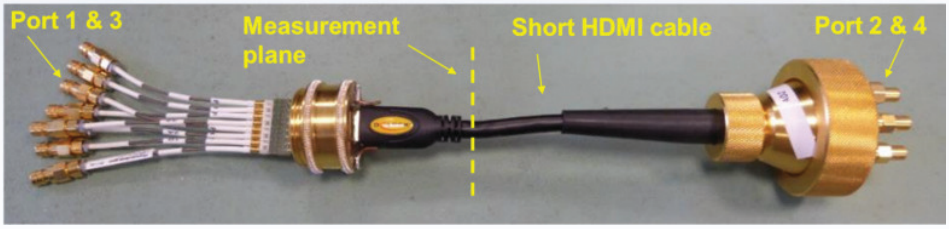


This setup shows the measurement of coupling attenuation of screened balanced cable assemblies according to IEC 62153-4-7.

To measure coupling attenuation on balanced cable assemblies, appropriate test adapters are required. Test adapter will influence the test result and shall be prepared as carefully as possible.

HDMI test adapter characterisation





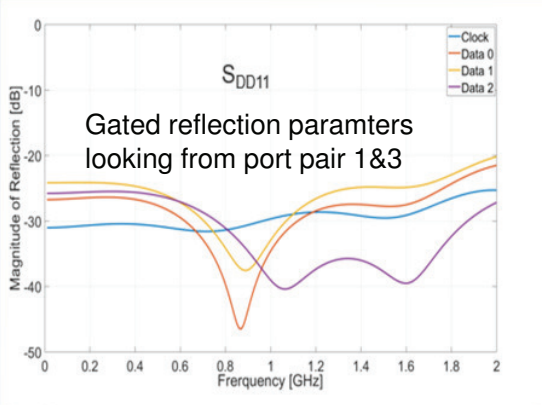
Measurement set-up used for characterization of the HDMI adapter head and for the HDMI adapter termination

For investigation of HDMI cable configurations using the Triaxial test method, two different dedicated HDMI test adapters have been designed and characterized in measurements applying a 4-port vector network analyzer.

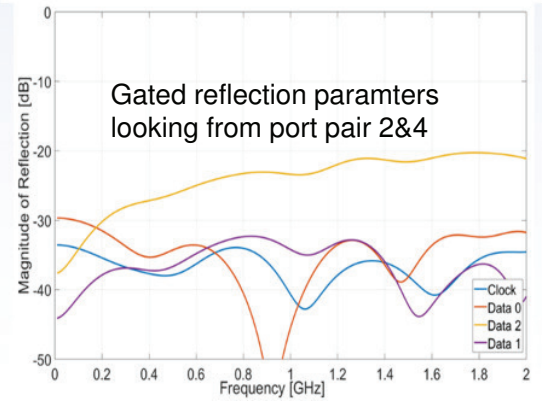
For observation of the S-parameters of the head & the termination adapters, one 8-port coaxial adapter and a short piece of HDMI cable have been used.

This measurement set-up allows the investigation of the head and termination adapters as mated pair.

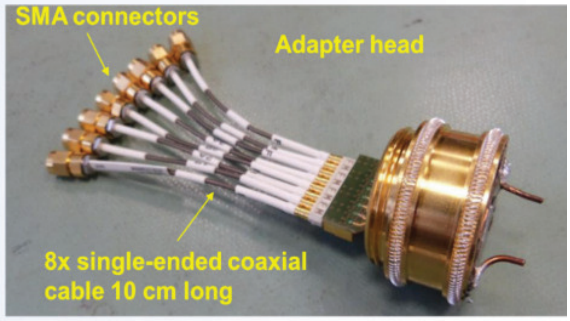
HDMI test adapter termination, gated reflection properties



Gated reflection paramters looking from port pair 1&3



Gated reflection paramters looking from port pair 2&4



HDMI adapter head
for usage on the generator side

Applying time domain gating one can remove the influence of the short HDMI cable and the 8-port adapter on the reflection loss and therefore the reflection loss of the HDMI adapter only might be observed.

Limits of the adapter head & adapter termination parameters

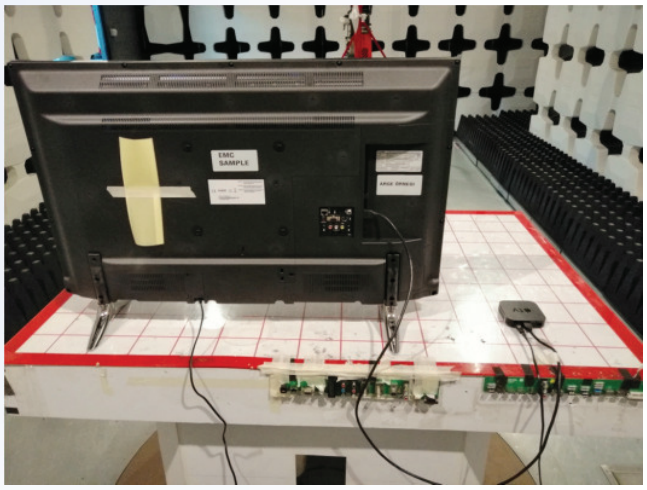
Adapter head characteristics	10 MHz to 0.6 GHz	0.6 GHz to 1 GHz	1 GHz to 2 GHz
Differential return loss, (Z0 = 100 Ω)	> 21 dB	> 21 dB	> 18 dB
Differential transmission loss	< 0.25 dB	< 0.35 dB	< 0.6 dB
Common-mode return loss (Z0=25 Ω)	> 4 dB	> 4 dB	> 4 dB
Common-mode transmission loss	< 0.23 dB	< 0.32 dB	< 0.6 dB
Unbalance attenuation, near end, (Scd11)	> 30 dB	> 25 dB	> 20 dB
Unbalance attenuation, far end, (Scd21)	> 30 dB	> 30 dB	> 20 dB

Adapter termination characteristics	10 MHz to 0.6 GHz	0.6 GHz to 1 GHz	1 GHz to 2 GHz
Differential return loss, (Z0 = 100 Ω)	> 25 dB	> 20 dB	> 20 dB
Common-mode return loss (Z0 = 25 Ω)	> 9 dB	> 4 dB	> 4 dB
Unbalanced attenuation, near end, (Scd11)	> 25 dB	> 25 dB	> 25 dB

Two measurement procedures allowed the characterization of the designed HDMI head and termination adapters.
The main characteristics obtained from the studies are summarized in the tables.

Measurements show low transmission loss for common and differential mode and good unbalance attenuation values at near and far end.

Measurement of radiated emission on HDMI assemblies

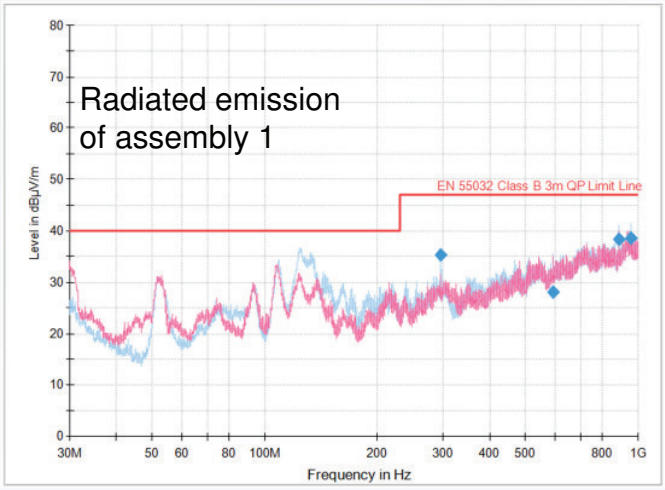


The test configuration for radiated emission measurements contains a LG TV set and an Apple TV box. Different HDMI cables were used for the connection of these devices. All other ports were left open.

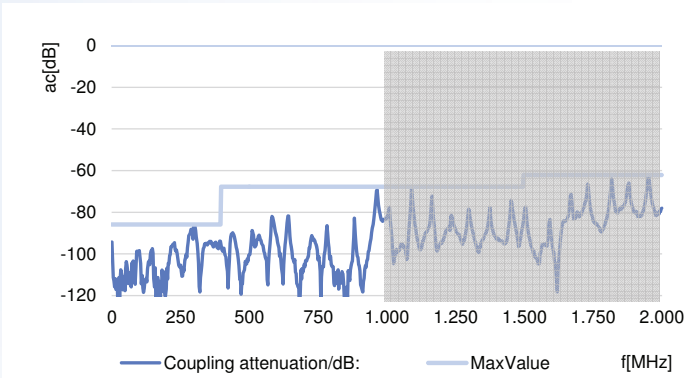
The signal provided by the Apple TV box was a moving color bar signal with maximum resolution. Measurements of radiated emission were performed by Vestel EMC laboratories.

photos Vestel EMC labs

Radiated emission vs. coupling attenuation, assembly 1



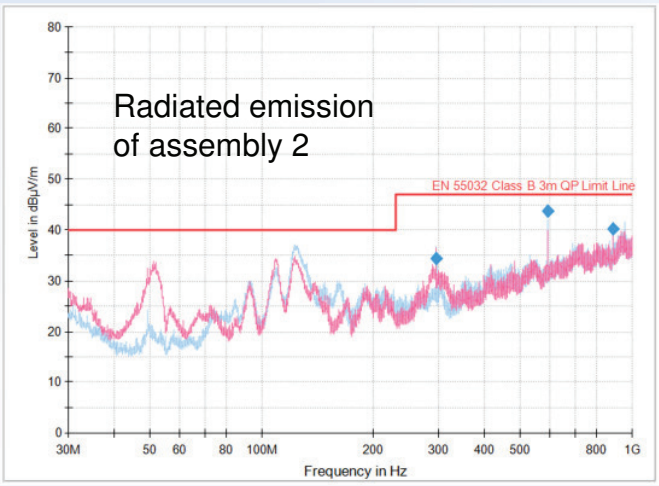
Coupling attenuation of assembly 1



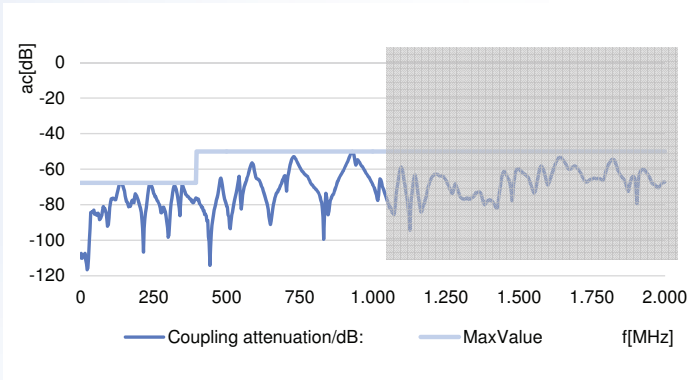
Radiated emission on HDMI cables were measured according to the set-up of slide 16;
Coupling attenuation was measured with the triaxial test procedure according IEC 62153-4-7.
The red line in the left graph shows the limits of EN 55032 respectively CISPR 32.
The blue line in the right graph shows the max. values of the coupling attenuation.

Assembly 1 fulfils the requirements of EN 55032 respectively CISPR 32 well,
the measured coupling attenuation shows a value of about 68 Dezibels.

Radiated emission vs. coupling attenuation, assembly 2



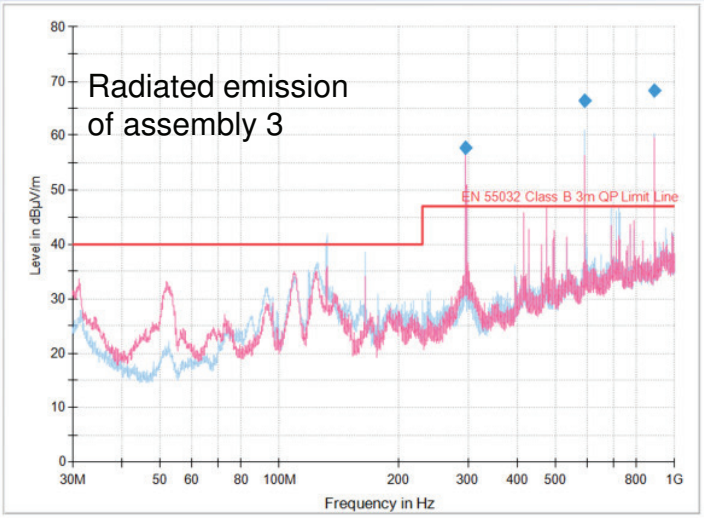
Coupling attenuation of assembly 2



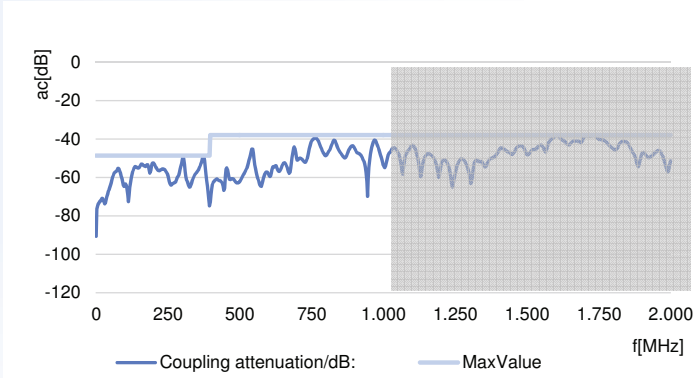
The measured emission of assembly 2 is closer to the limits of CISPR 32 than assembly 1.

The measured coupling attenuation of assembly 2 shows a value of about 50 Dezibels,
what is lower than the coupling attenuation of assembly 1.

Radiated emission vs. coupling attenuation, assembly 3



Coupling attenuation of assembly 3



The measured emission values of assembly 3 are out of the range of the CISPR 32 limits.
The measured coupling attenuation of assembly 3 up to 1 GHz is about 40 dB which is the lowest value.
The measurements on three different assemblies shows a good correlation between radiated emisison and coupling attenuation measurement.
The higher the emission value, the lower is the coupling attenuation.
That means, Coupling attenuation measurement provides a simple and easy opportunity for the qualification of EMC behavior of HDMI assemblies.

Conclusion

- EMC of **R**eady **M**ade **C**onnecting **D**evices (RMCDs) are relevant for the EMC behavior of complete systems.
- Standards & Screening effectiveness limits of coaxial and balanced assemblies are specified international, e.g. by IEC and CENELEC cable committees.
- No international standards and screening effectiveness limits are known for e.g. HDMI assemblies, although CISPR 32 specifies limits for radiated emission.
- EMC of hybrid cable assemblies can be measured either as radiated emission according to e.g. CISPR 32 or as Coupling attenuation according to IEC 62153-4-7.
- To measure coupling attenuation on HDMI cable assemblies, appropriate test adapter with good performance were developed.
- The comparison of radiated emission and coupling attenuation shows good correlation.
- Coupling attenuation measurement provides a simple and easy opportunity for the qualification of EMC behavior of HDMI assemblies.
- Standards & Screening attenuation limits shall be developed for all kind of cable assemblies.
- Qualification schemes for all kind of cable assemblies shall be discussed.

Literature

[01] IEC TS 62153-4-1, Metallic communication cable test methods - Part 4-1: Electromagnetic compatibility (EMC) - Introduction to electromagnetic screening measurements

[02] IEC 62153-4-7, Metallic communication cable test methods - Part 4 - 7: Electromagnetic compatibility (EMC)

[03] IEC 62153-4-9, Metallic communication cable test methods - Part 4 - 9: Electromagnetic compatibility (EMC) - Coupling attenuation of screened balanced cables, triaxial method

[04] Coaxial Cable Television Interference to Aviation Systems, Eurocontrol report from 2001-03-15

[05] Thomas Hähner, Bernhard Mund, & Thomas Schmid, History and recent trends of Triaxial test procedure, Proceedings of the 67th IWCS Conference, Providence, RI, US, October 2018

[06] Thomas Hähner, Bernhard Mund, & Thomas Schmid, Screening effectiveness of unscreened balanced pairs, EMC Barcelona 2019

[07] M. Kotzev, T. Schmid, M. Schwaiger, Time and frequency domain analysis of an 8-port adapter for multiconductor cable screening measurements, EMC Europe 2018

[08] Mark Arthurs, Cem Cengiz Keskin, Radiated emission comparision report, Sony/Vestel EMC Laboratory

[09] Sezgin Hilavin1, Cem Cengiz Keskin, Analysis of Repeatability and Uncertainty Issues in Radiated Emission Tests Regarding HDMI Ports, Proc. of the 2016 International Symposium on Electromagnetic Compatibility - EMC EUROPE 2016, Wroclaw, Poland, September 5-9, 2016

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