Can EMC/Wireless/Automotive Consulting per online Video Conferencing be effective?

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Fachtagung Funk und EMV 2022 | SwissT.net

FYI: This documentation is for didactical reasons not fully complete, please listen to the presentation.

Standards do change constantly. Therefore, always check for the latest one applicable !

To ensure strict customer confidentiality, signed NDAs, we cannot reveal specific project details and pictures here.

Short Bio:

Diethard E. A. Hansen (Ph.D.) MS/BS EE

All degrees from Germany: **Dr.-Ing.**, Dipl.-Ing. TU + FH
IEEE **Life Member** (USA)**,** IEEE EMC-Society **Senior Member,**
Senior iNarte EMC/PS **Eng.,** **Radio Licenses** FCC: AK4IG 2011, CEPT: DK2VQ 1968, HB9CVQ 1983

- He has **30+ years** of professional experience (Consultant/registered EU-Auditor/iNARTE USA)
  in **Electromagnetic (EM) Disturbance and Interference Control in Electronics**,
  incl. commercial/ government/ military installations/equipment
- 160+ international technical **papers**/ 50+ **patents** are assigned to him.
- **Assessments/Audits**: 400+ Test-Labs (worldwide), incl. EU-D EMC, RTTE/RED and Automotive EMC
- Since over 30 years active in international **EM standards/regulations**.

- 1983 till 1991 **EMC Lab-Manager** in **R&D** for major, international electro tech. **Industry Company**
- 1991 to 2000 **private Test-Lab**/Certification-Body **Owner + R&D Manager**
  Berlin, Teltow (Germany) was an accredited EMC Lab/competent Body EMC
  Today this would be a Notified Body under EU-CE.

http://www.euro-emc-service.com/view/data/5388/PDF%20Website/Publikationen%20BSP/PUBL_lessons_learned_DRhansen.pdf

This article (**view as entrepreneur/assessor on typical EMC Lab-Operation**) was first published in IEEE EMC Symposium **2001** , Montreal, Canada

Abstract:

Can EMC/Wireless/Automotive Consulting per online Video Conferencing be effective?

- Nowadays acceptance for remote internet online sessions, as one part of “a new normal” in pandemic, has greatly improved, almost anywhere in industry/government/society.
- Real world consulting cases:
- 1. Standards and Regulation (Product has CE-EU, now want US market access)
- 2. Small, smart Internet-Network Access Modules (SOS: EDS, Wireless)
- 3. External E-mobility Car Charging Station (SOS: 60dB over RE Limit)
- We will discuss:
- · Technical and formal conferencing requirements
- · Excessive technical EMC Know-How needed
- · Schedule issues based on different world time zones
- · Technical EMC lab work, hands-on, opportunities and limitations
- · Necessary test equipment at client’s location/ recommendations
- · Customer cooperation and mentality issues, cost effective test instruments
- · Elements for project success, risks, delays, and time saving factors
- · Things we can/not do via online--Guidance in Tech Lab-Sessions
- We will also briefly highlight Consulting Solutions to problems, proven EMC strategies with lessons learned from different industries.
- Client problems how to correctly interpret and apply standards and regulations.
- Concluding Remarks

Contents:

1. A critical Situation Review: Tricky Realities in industrial EMC-Product-Compliance/Testing
2. Acceptance of outsourced Consulting, before and during global crisis
3. Pandemic forcing Acceptance of Digital Interaction, Limits?
4. Anonymized Real-World EMC-Consulting Cases
   - **Standards and Regulation** (**ITE Product CE-EU ok => now USA** market access?)
   - Small, smart **Internet-Network Access Module** (**SOS: ESD, Wireless Immunity**)
   - External **E-mobility Car Charging** Station (**SOS: 60dB over Radiated Emission Limit**)
5. Discussion and Lessons Learned:
   - Project risks/success chances, formal contract procedures, time-killers/savers
   - On-site R&D-Lab requirements (technical, cost-effective testing, know-how, human factors)
   - Recurrent experience/problem findings in projects
   - Technically proven R&D-EMC-Fixing Strategies
   - Things we can/can not do via online
   - Managing/Guidance of technical online Lab-Sessions
6. Concluding Remarks

1. A critical Situation Review: Tricky Realities in industrial EMC-Product-Compliance/Testing

- Our focus in this talk is EUROPE
- The benefits of EU EMC-D (CE) are overall recognized by industry [1]

  Market Needs / reliable Product Functions / **Quality** / Legal Issues / **Compliance Cost**/Timing

- In some industry branches we still detect deficiencies (e.g., CE)
- **Big differences in Approach** by Large Corporations, SME, very small Companies
- **Large** Corporations can simply not afford to fail CE compliance -They are mostly well staffed and equipped- Test Labs here are increasingly accredited.
- **SME** rarely have their own, complete test facilities (conducted vs. radiated testing) Need for (some internal) in-house EMC-Competence/Test-Facilities is increasingly recognized.
- **Very small** companies have mostly big problems

  (**Status** of EMC Know-How, Recourses, Standards/Regulations, EMC-Management / understanding cost-effective EMC Strategies –Emissions CE/RE first –>reciprocity (linear systems) Immunity (ESD/BCI?)

[1] EC Study on the Evaluation of the Electromagnetic Compatibility Directive 2014/30/EU (EMCD), Final Report, June **2021**

1. A critical Situation Review: Tricky Realities in industrial EMC-Product-Compliance/Testing

Risks (Compromises / Deficiencies in Standard !)

Only one Example of numerous (partly serious) **Standard Deficiency: IEC 61000-1-2** → Product Liability, Lawsuits!!

R&D: IEEE TR EMC Vol 60, No 5 Oct. 2018, p 1304 ff Kohani + p 1313 ff- Zhou

- Evaluating Characteristics of **ESD events** in wearable **medical devices**:
  Comparison with IEC 61000-4-2 Standard, **Mehdi Kohani et al.**
- Characterization of ESD Risk for Wearable Devices, **Jianchi Zhou et al.**

This constitutes a **conducted** (fast peak current) **as well as radiated** (fast transient) **EMI Problem**

(CE medical directive, US FDA)

- **Old ESD Model in STD not directly applicable anymore** (different impedance situation –todays scenario is different, but not yet considered)

- **Problem: Std-Test-Limit setting for Peak Currents (fast H-fields) was considerably too low**
- **FDA Database**: Being listed here is not desirable! MAUDE - Manufacturer and User Facility Device Experience (fda.gov)
- Patient's safety jeopardized , injuries , **death** (could have been prevented by proper Risk Assessment!)
- **Lesson learned:** EMC environment was chosen wrongly (not updated), no suitable STD (Model) existed in 2018!

1. A critical Situation Review: Tricky Realities in industrial EMC-Product-Compliance/Testing

Risks

Technical issues

- Making mistakes in correct **standard selection**/technical **interpretation**
- Making mistakes in **regulatory procedures** (EU , North America, worldwide)
- Everywhere in EU (CE) Regulations there is now a detailed **risk assessment** mandatory!
- Almost everywhere in Norms there is now a trend to fully state **measurement uncertainty**
- MU is presently however only applicable to the test stand (calibration set-up- without EUT interaction)
- MU is not yet considering the interaction e.g., Test-EUT (size) to Test Antenna

Time to market delays

- Failures in product approval/compliance testing cause time consuming redesigns

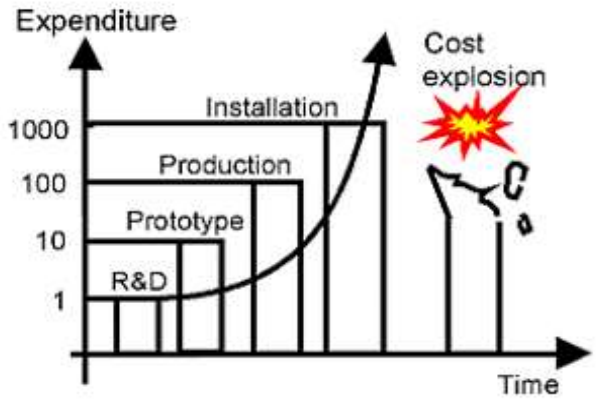
Legal issues

- *Contract penalties are costly, product liability and reputation are critical*

FYI: Shall do EMC Production Sampling ---Product Placing on the Market calls for up-to-date Stds!

1. A critical Situation Review: Tricky Realities in industrial EMC-Product-Compliance/Testing

Risks



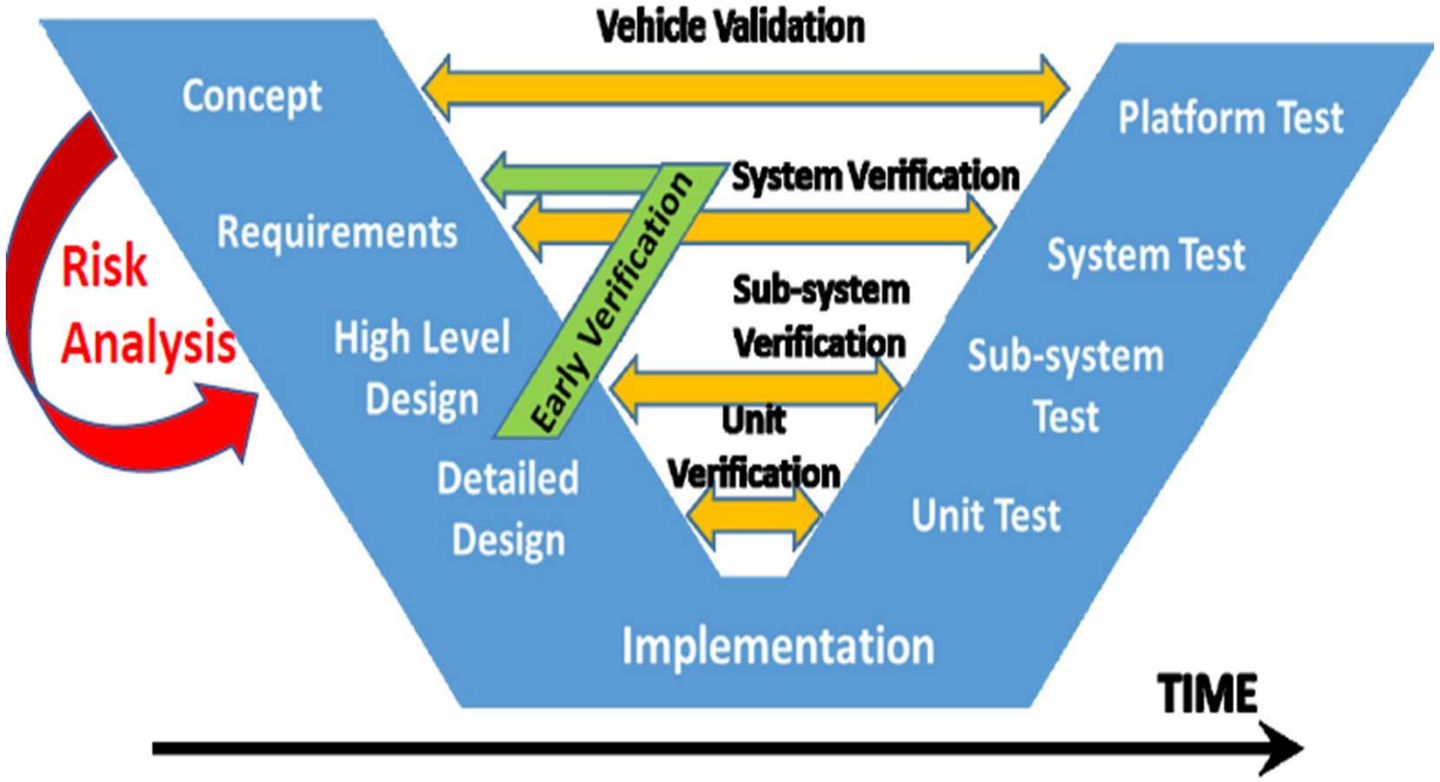
- Stop EMC Budget/Cost Explosion

Considerations for an EMC Test strategy:

- We find often severe EMC Project-Management Problems e.g., very critical in functional safety
- **Rule 1**: ca. 60% are mostly **conducted** EMI Problems
  up to about 30MHz, exception mag. Near- Field Coupling
- **Rule 2**: Above ca. 30MHz **radiated** (far more complex RE) **EMI Problems** normally dominate here.
- **Rule 3**: Absorber Test Chambers have often performance problems ~ **30 to 200 MHz .**
  Why? Cavity Shielded Room local resonances appear, due to degraded lower frequency absorber performance
- **Rule 4:** Very critical RE e.g., in Systems with **GHz clocks/buses/RF/uW-Sources** or **ns risetimes** in power electronics (ns => broadband pulse spectrum may excite potentially existing system resonances)

1. A critical Situation Review: **Tricky Realities in industrial EMC-Product-Compliance/Testing**

Risks (Compromises / Deficiencies in Standard !) → Product development in steps with only partial systems available for tests



Are you fit for the future?
Automotive Challenges
E-Mobility, Autonomous Driving, 5G etc.
"Functional safety issue"
System Complexity very high! -> Testing not enough!
Rather detailed System Engineering Approach needed here.

Source: IEEE EMC 2020 WS
A. Ruddle, MIRA UK

2. Acceptance of external Consulting, before and during global crisis

Before global crisis

- In contrast to North America outsourcing Consulting is often less popular in EU
- The "**not invented here**" syndrome?
- One very important factor in external consulting is **trust building**/ help increasing " help yourself" in the company by **training on the job** (catalyzer function)

- The Consultant (Service Provider) will only recommend, give expert advice …
- The Company Staff decides finally!

During global crisis

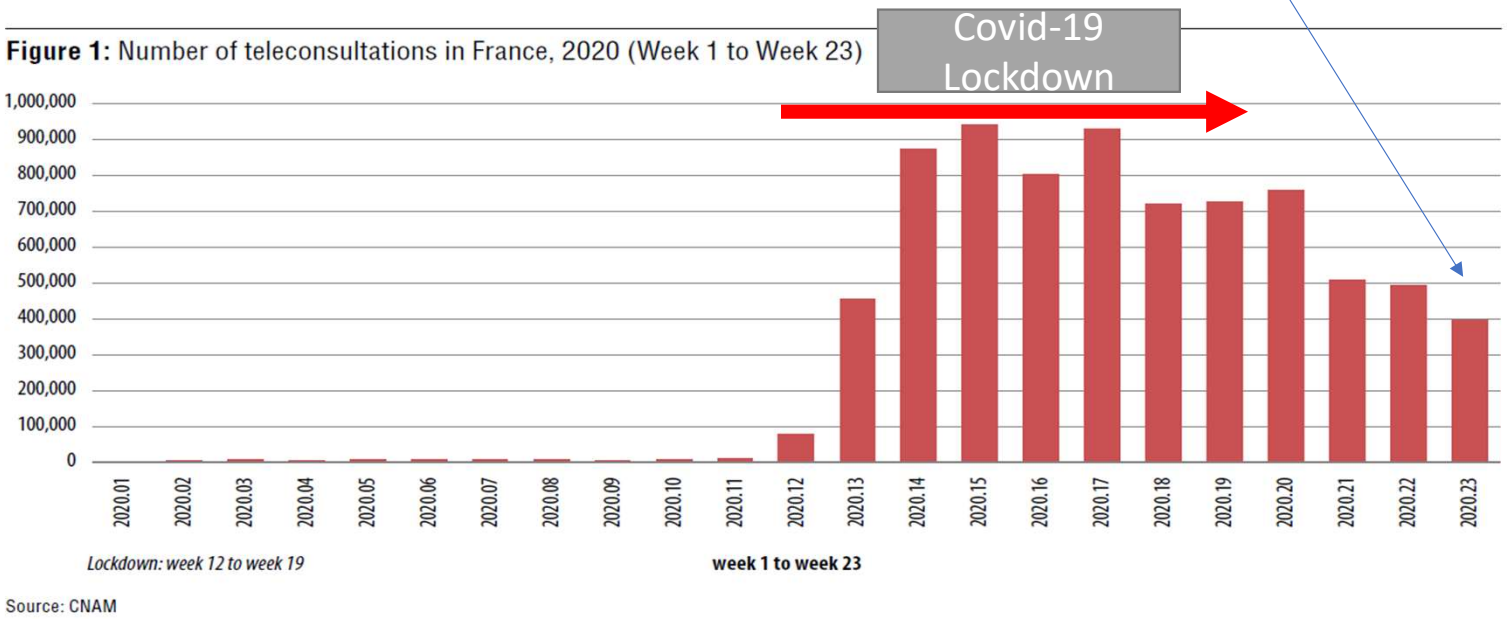
- after a certain shock period, we see more SOS-Projects…

Why? Project delays, supply chain trouble, increased staffing shortage, new technology challenges

3. Pandemic forcing Acceptance of Digital Interaction, Limits?

- Let's take an example from **France Healthcare** [2]

  Medical Doctors **Online <u>Remote Patient Consultations</u>** (Video/Telephone)



[2] Euro health –Vol.26-No.2- **2020**

4. Anonymized Real-World EMC-Consulting Cases

Standards and Regulation (small **ITE Product CE-EU ok => now USA market access?**)

- Based on the previous (France) medical example this ITE-case should not be and surely was no problem to help effectively by **EMC-Tele-Consulting**
- Explaining differences between e.g., CE and FCC Regulations …incl. legal issues
- ANSI C63.4-2014, ANSI C63.4a-2017 …OSHA (electrical safety UL…) …+++
- Easy, just a video EMC consultation, **no R&D- Lab work needed**
- (No fixing/pre-compliance testing on-site involved)

4. Anonymized Real-World EMC-Consulting Cases

Small, smart Internet-Network Access Module (SOS: ESD, 2.4 GHz Wireless Immunity)

IEC 61000-4-2 (2008) Problem:

- Critical Case, **failed several times accredited EMC lab testing**
- Cigarette Pack sized enclosure, Input – Output Network cables + WLAN Module
- Fast Transient ESD (<ns) protection diodes already implemented
- Online Test Lab report review, Circuit/Layout Analysis
- Problem identified in transient current path coupling

=> EMC Fixing/Modification Solution: Better shielding (acc. to EM-Zoning/Topology Protection Concept)

Product now passed successfully accredited (ISO EN 17025 2017) EMC/Radio Lab Test

This Fix solved also the failed lab test for of the WLAN module: **Radiated immunity and TX unwanted emissions in spurious emissions 4.3.1.10.3***

IEC 61000-4-3 (2020)

EN 300 328 V2.2.2 * (06/02/2020 List RED Harm. Std-22-07-2021)

- **No guided, on-site consultancy with R&D lab testing** needed to be carried out here, only remote analysis

4. Anonymized Real-World EMC-Consulting Cases

External E-mobility Car Charging Station (SOS: 60dB over Radiated Emission Limit Class B under 100 MHz)

IEC 61851-21-2 Ed. 1 (2018) Problem: off-board electric vehicle charging system

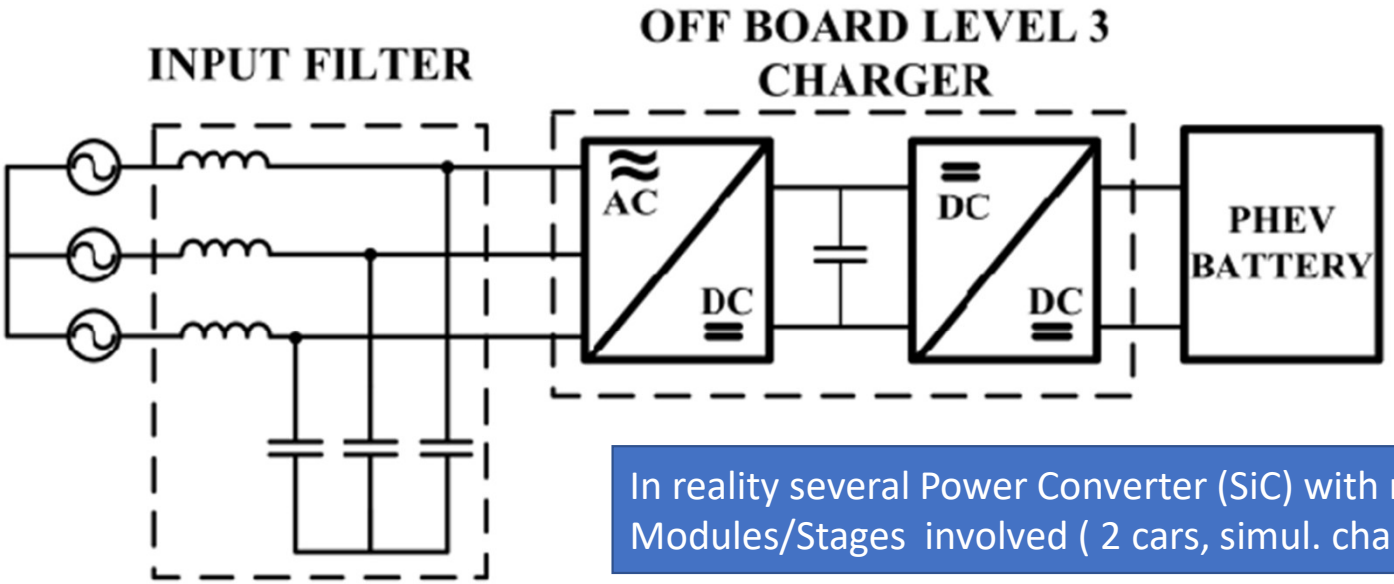
Normative Reference: IEC 61000-6-3: 2006 AMD1 2010 Generic Std., emission residential => CISPR 22 (2008)

- Input: 3 x 400V AC 50Hz Phase (< 100 KW) , Output: 2 unshielded charging cables to 2 E-Mobility cars (HV car battery)
- System is in a metallic rack mounted (cubicle, enclosure)
- EES-Job 1- in Pandemic Lockdown: Do remote R&D EMC Consulting to find the source/modules of the RE
- EES Job 2- in Pandemic Lockdown: Try to reduce excessive emissions (RE 60dB!).
- System was explained in detail by customer **(Block/Circuit Diagrams/Modules/Mechanical Design, Cables)**
- **Accredited EMC Test Lab. Report** (d=10m) was presented
- R&D Lab had some EMC Test equipment (**good** EMI Measurement Receiver, current probes, high current LISN, i**nsufficient** EMC-Management, lack of System/Subsystem/PCB EMC know-how, **missing fixing tools**)
- Manufacturer's **R&D Lab spent many month on unsuccessful fixes** with capacitors everywhere and some unsuitable ferrites.
- Up to **6**, partly experienced, **R&D Lab. Engineers** (power electronics/control electronics, FW, SW) **involved**

4. Anonymized Real-World EMC-Consulting Cases

External E-mobility Car Charging Station (SOS: 60dB over Radiated Emission (RE) Limit Class B below 100 MHz)

Oversimplified, basic Idea shown by Block Diagram [3]:



In reality several Power Converter (SiC) with multiple Modules/Stages involved (2 cars, simul. charging)

[3] https://www.researchgate.net/figure/Basic-diagram-of-an-off-board-fast-charger_fig8_252050972

4. Anonymized Real-World EMC-Consulting Cases

External E-mobility Car Charging Station (SOS: 60dB over Radiated Emission (RE) Limit Class B below 100 MHz)

Consulting Strategy/Checks/Guided Testing:

- Customer explains the overall system (Block, major Circuit Diagrams, test equipment on-site, implemented EMC)
- EMC relevant questions asked by EES (Layout, cable routing, AC-input/DC-output filters, overall shielding…EM Topology-Zoning concept)
- Analysis of Test Report (Reveals excessive RE below 100MHz, Sources ?, Input or output cables length?)
- Detailed analysis of their own, previous R&D Lab tests-> a time safer (done dBuV/m, d=3m, Bicone-Antenna in the Lab **!!??**, Results appear questionable and inconsistent, **a problematic approach**)
- Quick Remote Check of the existing EMC equipment (calibration, sanity, LISN GND, mostly ok)
- Important, **EES recommended, low budget** **test equipment missing** (Near Field Probes, Pre-Amp, simple Network Analyzer, suitable Ferrites to choke of CM from used coaxial measurement cables, incorrect use of current probes **dBuA = dBuV - dBOhm**). **Missing Equipment ordered/received for next Video Session**. Engineers got familiar with it.
- Following now EMI-Current Coupling Path search/tests:
- Test#1: 3 Phase Input Filters (high Amps LISN) work ok, conducted mains limits met as in Test Lab.

4. Anonymized Real-World EMC-Consulting Cases

External E-mobility Car Charging Station (SOS: 60dB over Radiated Emission (RE) Limit Class B below 100 MHz)

Shorted Consulting Strategy/Checks/Guided Testing for EMI Source Location:

- Test#2: Same procedure as #1 now with current probe => Cross check result looks good, **Rack Input ok**
- Test#3: Rack **Output** (car charging cables), with current probe **fails badly.**
- Following now is **EMI source location** search:
- Test#4: Using *Near Field Probes* (*time/frequency domain*, Oscilloscope and EMI-RX spectrum mode)
  => Identification major EMI sources SiC (tr=10ns) **converter module heat sinks** (RF-EMI hot !!)
- Following is now **Coupling Path (loop)** detailed Analysis:
- Test#5: Locating/**simulating the potential coupling path with NVA** (charging station off)
  => RF-hot heat sinks –>Stray Capacitance to metallic Cabinet -> "Loop" PE- Car Charger Cables
  => Source=SiC modules, **Antenna => car battery charging cables** (length matches roughly accred. TR resonance)
- Test#6: **Measuring Stray Capacitance** of one Module/Heat Sink to Enclosure => 150 to over 330 pF each!! => ~ **nF…**
- Rough **Cross/Sanity Check:**
- The 3 major Si Switch-Converters (AC/DC, 2x DC/DC) couple capacitively to rack (PE) @ **100MHz: Xc = 1.6 Ohm**

4. Anonymized Real-World EMC-Consulting Cases

External E-mobility Car Charging Station (SOS: 60dB over Radiated Emission (RE) Limit Class B below 100 MHz)

Rough "theoretical" estimation: **RFI current-> EMI field strength-** Sanity Check of findings

- 30 to 100 MHz Class B limit: **30**dBuV/m @ d=10m (**40**dB/uV/m => 100uV/m @d=3m)
- Roughly 20dBuA RFI Antenna CM-Current just meets Class B here [4], [5] E-field from single wire I_{CM}
- $$|E_{c_{max}}| = 6.28 \times 10^{-7} \frac{I_{cur\ probe}\ Lf}{R} \quad V/m$$

Limiting assumptions do apply!

Ecmax = electr. Fieldstrength of emission, R= distance in m, Icur probe = measured CM current A, f= frequency in Hz, L= length of radiator in m

- Assumptions: e.g., Wire length small against Wavelength, approximation as Hertzian Dipole, FF, no near ground plane
- **Other findings from** [6]: Higher CM current fail radiated Emission Spec.
- (a) For FCC or CISPR/CE **Class (B)**, **Icm < 10 dBµA** at F > 30 MHz, **D=3m**
- (b) For FCC or CISPR/CE **Class (A)**, Icm < 20 dBµA at F > 30 MHz, **D=10m**

If wire/cable length L > 0.25 or 0.5 Lambda:
100uV/m @3m => I_{CM} max allowed = only 5uA !!

$$E_{(\mu V/m)} = \frac{60 I_{\mu A}}{D}$$

[6] Michel Mardiguian, Controlling Radiated Emissions by Design, 3. Ed. Springer, **2014**, ISBN 978-3-319-04771-3 (eBook)

[5] C.R. Paul et al.: IEEE TR EMC, Vol. 31, No. 2, May **1989,** pages 189 to 193

[4] C.R. Paul et al.: Radiated Emission from Common Mode Currents, Proc. IEEE EMC, **1987**, Atlanta , Ga, USA

4. Anonymized Real-World EMC-Consulting Cases

External E-mobility Car Charging Station (SOS: 60dB over Radiated Emission (RE) Limit Class B below 100 MHz)

Rough "theoretical" estimation: **RFI current-> EMI field strength** - Sanity Check of findings

- 30 to 100 MHz EN 55022 Class B limit : 30dBuV/m @ d=10m
- Anything higher than 20dBuA (10**uA**) Current will **fail Class B** – on any "EMI" Antenna (e.g., Charge Cables)
- Test Lab result: d=10m, E_{max}=90dBuV/m (30dB Limit+60dB SOS)
- We found in R&D Lab Tests I_{cm} => up to over 70 dBuA (ca. 3mA below 100MHz) on external cables
- Cross-Check: Si-Converter Modules **Xc= 1.6Ohm**@100MHz => EMI/RFI Driving Voltage = > ca. 5**mV**
- These orders of magnitude seems reasonable (probably about 10dB contributions from another , yet unidentified, EMI sources)
- The Q-factor of the car charge cable (resonator) in the NVA Test (phase =0 is a resonance) was changing based on cable positioning. This confirms further potential measurement uncertainties for this crude estimation.
- The resonant frequencies, however, fitted very nicely with the accredited EMC-Test Lab. Report.
- Now System Fixing/ Redesign is ongoing. => unfortunately, => further Project Delays
- EMC-SOS and following redesign actions may blow a prior allocated project budget
- Having no proper EMC-Project-Management Plan upfront is extremely critical

5. Discussion and Lessons Learned

- Some technical and formal **video conferencing requirements, remote EMC consulting**

  Consultant: Fast Internet/Laptop/Cam/Headset

  Client: Similar, but importantly using a "portable" Cam, individual headsets for each session participant
- Excessive (20 to 40Y?), broad, technical EMC Know-How (world class level) needed on the Consultant's side
- Precautionary design of **contract**/payment conditions acc. to international customer cooperation and local mentality issues
- Never try to **predict consultation outcome** by looking into the crystal ball, first start one prepaid test session.
- Appropriate **session schedules** (no marathon runs) based on different world time zones
- **Identify in first session**:

  Elements for **project success**, **risks**, delays, and **time saving factors**

  What level of **on-site EMC Know-How** can be expected? Do we sense problems in correctly choosing /apply appropriate product/system **standards and regulations-** this could jeopardize everything**?**

  Listen, Listen, Listen and ask short/precise/polite questions (EN-language problems?) , not every client's wish/idea can be fulfilled!

  Identify **available/needed test equipment** at client's location
- **Recommendations of essential, low budget test equipment** (up to 2 to 5 or 9K EURO), supply chain issues, used equipment market (e.g., Spectrum Analyzer, Oscilloscope, LISN, Current Probes, Near-Field Probes/Preamp., Small Antennas, Ferrites etc.)
- Now start possibly quoting " Frame Contract" with several sessions.
- **Remotely guided, successful technical EMC R&D-Lab work**, hands-on, **can be done** (opportunities and limitations)
- Things we can/not do (miracles) via online?—Guidance/Management of Tech Lab-Sessions (sometimes not easy, simultaneous test-jobs, several engineers/technicians on-site) All this is simultaneously an **"EMC-Training on the job"** for the customer**.**
- **Always remember**: How can we optimally **help the client professionally**, project focused, unbiased, fast and cost-effective ?

6. Concluding Remarks

- **Clients** with **no** proper **EMC-Project-Management Plan** upfront**: always very critical**
- Manufacturer: Must do suitable **Product Risk Assessment** (incl. System Function/Application, Specs HW/SW, MIS-/USE, EM environment, **Regulations?, Norms?**, exercise proper Product Compliance Procedures)
- Invest small early and save big later !
- Try to **avoid EMC SOS** (house is on fire) actions, if possible. Get early support/expertise in Design!
- Consider also good EMC-Training (online ok) to increase potentially missing internal EMC know-how.
- Find your concept of what **know-how/test equipment is needed in-house**, what can be **outsourced** ?
- Excessive (40Y?), broad, technical EMC Know-How (**world class**) needed on the **Consultant**'s side for successful **Tele-Remote EMC Consulting**
- Even **Remote EMC-SOS can be done** –but should be last choice, (consultant: Do not only band-aid fixes, do EMI **troubleshooting systematically**; this takes time and **client is maybe already impatient**)

  SOS-Essential is low budget test equipment (up to **2 to 5 or 9K EURO**), supply chain issues => used equipment market ? (e.g., Spectrum Analyzer, Oscilloscope, LISN, Current Probes, Near-Field Probes/Preamp., Small Antennas, Ferrites etc.)
- Remember: **EMC Labs** (ISO/EN 17025: 2017 accredited) are under **accreditation Operation-Mode not allowed to do any consulting**. They only test, based on their accred. scope, products comply or not with a given standard (outcome yes/no) .

Thank you all for your Time

***Understanding* is the first step to find your**

own, specific EM- Problem Solution, effectively!

Any Questions / Comments / Discussion ?

Call us, we help professionally since over 30+ years

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