Only in this way can you systematically and successfully suppress EMI in an HF (RX/TX) Amateur Radio Station!

-A bit of EMI/EMC theory and optimized, example-driven implementation-

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https://www.qrz.com/db/hb9cvq https://www.euro-emc-service.com

HF = shortwave

Is a noise floor close to S9 ->160m / S8->80m / S7->40m in SSB (or even higher) **normal?**

RX S9= 50µV/**50Ω**=**-73dBm**=50pW

TX=10W=+40dBm, 100W= +50dBm, 1kW=+60dBm

Definitions:

+ EMV: Elektromagnetische Verträglichkeit in der Elektronik **[DE] Devices and Systems**
EMV: Electromagnetic *Vulnerability* **[EN]** Susceptibility in Electronics, Boxes and Systems

+ EMC: Electromagnetic Compatibility in Electronics Equipment and Systems **[EN]**

+ EMI: Electromagnetic Interference in Electronics **[EN]**

Prepared in [EN] additionally to [DE] version for HAM-RADIO, 27-Juni-2026, FN

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 **Eng.,** **Radio Licenses** FCC: **AK4IG** 2011, CEPT: **DK2VQ 1968**, **HB9CVQ** 1984

- Since **1983** professional experience (**private** **Consultant**/registered EU-Auditor/iNARTE 34Y) 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**. **IEEE Senior EMC Life Member** since 2020
- 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**
  Berlin Teltow was an accredited EMC Lab/competent Body EMC
  Today this would be a Notified Body under EU-CE.

Webinar 05/2024 Video: https://www.euro-emc-service.com/en/EMC-Radio-interference.htm [EN]

40+Years in EMC and related Areas- Lessons Learned! -

HAM-Radio Meeting Munich, March 2023: https://www.youtube.com/embed/2J_wSaWFUNA [DE]

7+ Years (part time) **HF-mobile Antenna R&D**

Topics:

1. **Why does EMC** (electromagnetic compatibility) **keep getting more important?**
2. **The only method to use: the EMC Protection Zoning Concept**
3. **On HF always mitigate conducted EMI first, then radiated!**
4. **EMC planning/retrofit, proper EMC design of an HF** (RX/TX) **amateur radio station**
5. **EMC case study HB9CVQ, Berikon/AG, on the 3. floor of a 6-party rental house** - no problem!
   - Measurements: Emission (RX noise floor) -- station off — in the shack and within the house
   - Measurements: Emission (RX interference environment) — station on — to dummy load — in the shack (house ⇒ zero CVQ-EMI)
   - Measurements: Emission (TX interference coupling via dummy load) — at the operating desk (house ⇒ almost zero CVQ-EMI)
   - Measurements: Emission (TX interference coupling via doublet dipole (160–10 m) antenna — station/230 VAC house wiring)
   - Experience: Emission (RX local QRM) — local QRM eliminator DXE NCC-1 (primary/aux antenna arsenal / RX protection)
6. **EMC case study Multi-OP Contest-Station DD1A, Singen**
7. **EMC case study HF-mobile, Audi A6, DK2VQ/m operating experience**
8. **Summary and optimized practical recommendations**

1. Why is EMC getting more important? (1)

- QTH EM-noise-environment/noise-floor; communications S/N ratio
- CE/China: device engineering and standards
- Terminology definitions: EMV/EMC/EMI (Electromagnetic Interference), RFI, EM noise (ITU)
- Emission (general = disturbance; in a telecom channel = interference), Immunity
- **Time/Frequency** domain
- Conducted vs. Radiated EM phenomena
- Wire-Line length vs. Antenna Efficiency; Near/Far field

As of summer 2020, VY2ZM operates the following antennas (excerpt): 160 m: 4-el full-sized phased BS/EF array; single 160 m vertical; 80 m: 4-square vertical array; 40 m: multiple 2–3 el yagis; 20/15/10 m: various; beverages; short vertical RX array, etc.

The Low-EMI: Dream of HF-Noise Silence

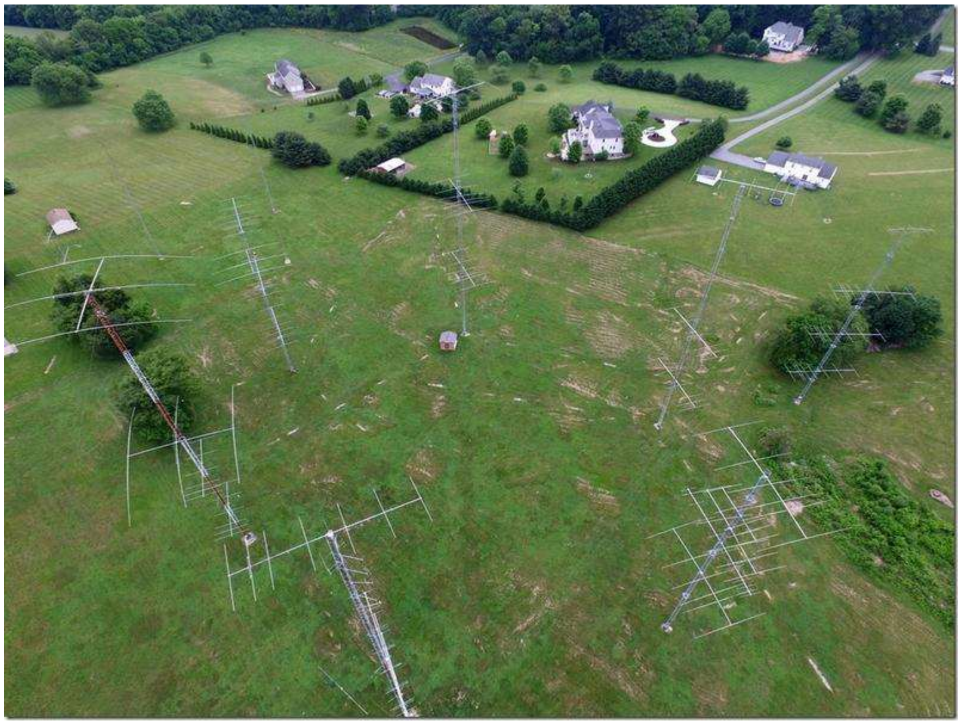
The King of 160m
K1ZM/VY2ZM

1. Why is EMC getting more important? (2)

- **Poorly** or illegally not **EMI-suppressed electronic devices**/installations are a problem almost everywhere today.
- They act as ‘unlicensed’ transmitters to HAMs, especially on HF.
- The result at the receive location (often in the near field) is a **reduced signal-to-noise ratio**.
- Frequently this **local QRM** appears as a broadband noise carpet or narrowband periodic interference (e.g., VDSL 4.3 kHz). PLC should have a 30 dB notch for HF amateur bands.
- The **VY2ZM** photo (Canada) shows an **ideal radio location** near salt water and virtually undeveloped surroundings.

1. Why is EMC getting more important? (3)

- Not everyone has a **W3LPL Super Contest HF-Station**



As of summer 2020, **VY2ZM** operates using the following complement of antennas:

160 - 4el full-sized phased BS/EF Dream Array designed by Peter Hutter and Rob Flory

- Single 160M Vertical (Omni Pattern)

80 - 4 square vertical array producing 5.68 db gain in 4 patterns

- 2el Vertical Array NE/SW

40 - 2el/2el 40m Yagi at 160/80 feet

- 2el 40M Yagi at 130 feet

- 3el 40M Yagi at 85 feet +++ wow 20/15/10m

Various **Beverages** at 880 and 1080 feet
Rx Sixpack of 6 short verticals for 160M NE/SW

1. Why is EMC getting more important? (4)

- At W3LPL (MD, USA), there is sparse development and an impressive, cleverly laid-out antenna farm (photo).

- For comparison, the vast ‘antenna farm’ of VY2ZM (Canada) is listed.

1. Why EMC ? Physics and important EMC Background Info (5)

Equations

James Clerk Maxwell (1831–1879)

$rot(\vec{E}) = -\mu \frac{\partial \vec{H}}{\partial t}$	Faraday's induction law	**Induktions-Gesetz**
$rot(\vec{H}) = \varepsilon \frac{\partial \vec{E}}{\partial t} + \vec{j}$	Ampere-Maxwell law	**Durchflutungs-Gesetz**
$\varepsilon \cdot div(\vec{E}) = \rho$	Electrostatic law	**Gaussches-Gesetz**
$div(\vec{H}) = 0$	Equation of magnetism	**Gaussches-Gesetz des Magetismus**

Time dependence

Dimensions of a **conductor vs. Wavelength** determines basically it's **Antenna Radiation Efficiency**

Solution

Retarded magnetic vector potential

currents

distances

$$\vec{A} = \frac{\mu}{4\pi} \iiint \frac{\vec{j}(\ )}{|\vec{r}' - \vec{r}|} d\tau$$

$$\vec{H} = \frac{rot(\vec{A})}{\mu}$$

$$\vec{E} = \frac{1}{\varepsilon} \int_t \left(rot(\vec{H}) - \vec{j} \right) dt$$

Currents ⇔ EM-Fields

uncontrolled EM Coupling/Radiation !?

Original Source: Frederic Pythoud_METAS_EMV_19.01.2017, SwissT.meeting , Fachtagung EMV Zürich Switzerland

1. Why is EMC getting more important? (6)

Maxwell's equations, simplified for HF amateurs: **alternating currents generate alternating fields**; such **fields induce currents in conductive structures**. Uncontrolled in/out coupling must be prevented by appropriate suppression measures/layout.

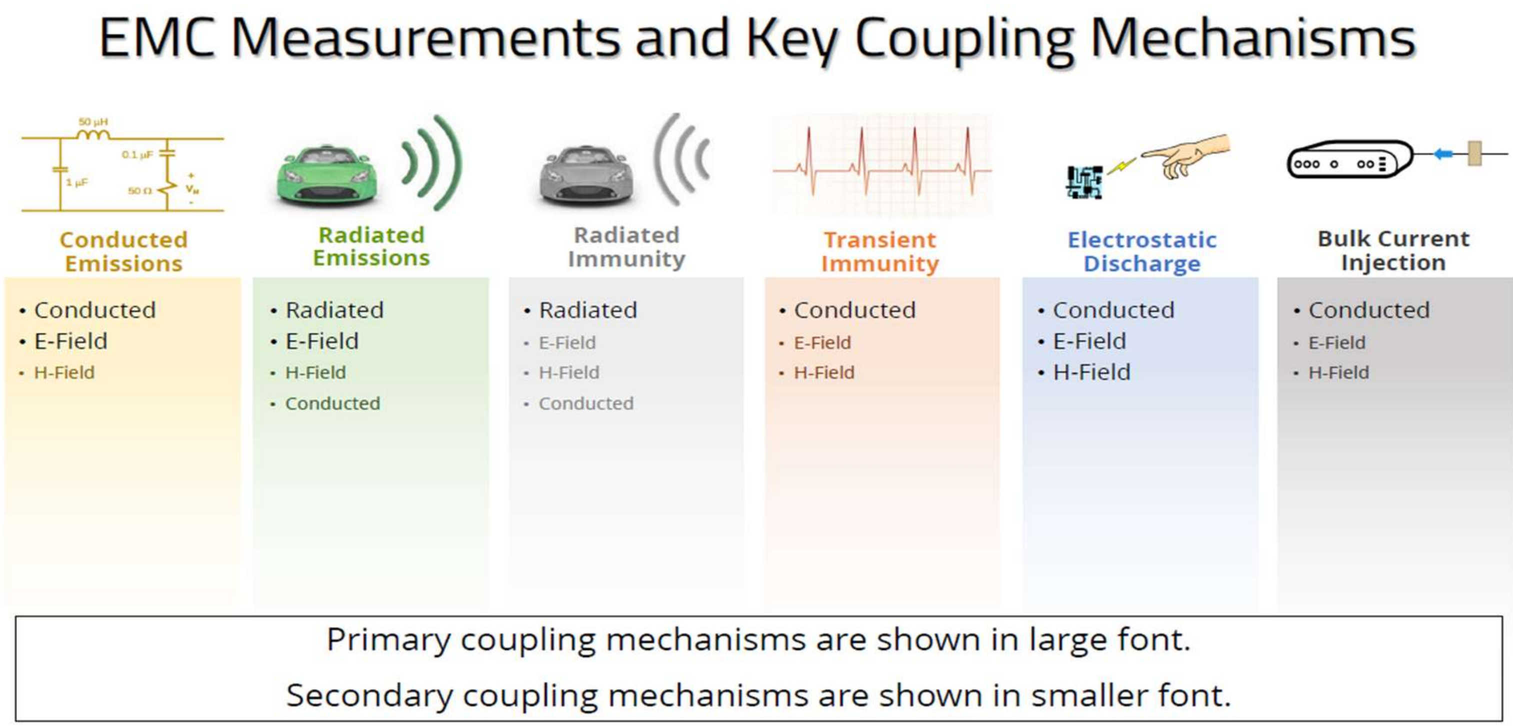
With electromagnetic alternating fields (unlike electrostatics) the **E (electric)** and **H (magnetic)** fields are inseparably linked.

In the **near field** (e.g., magnetic loop vs. dipole/vertical) the radiator type determines the E/H ratio: **magnetic loop** → low-impedance/inductive;

dipole → high-impedance/capacitive.

In the **far field**, **E/H** is distance independent at **377 Ω** with no phase shift (real power only) between E and H.

1. **Why EMC ?** Physics and important EMC Background Info (7)



Source: Prof. Dr. Todd Hubing, LEARN EMC, IEEE EMC Symposium RENO, NV/US, 2020

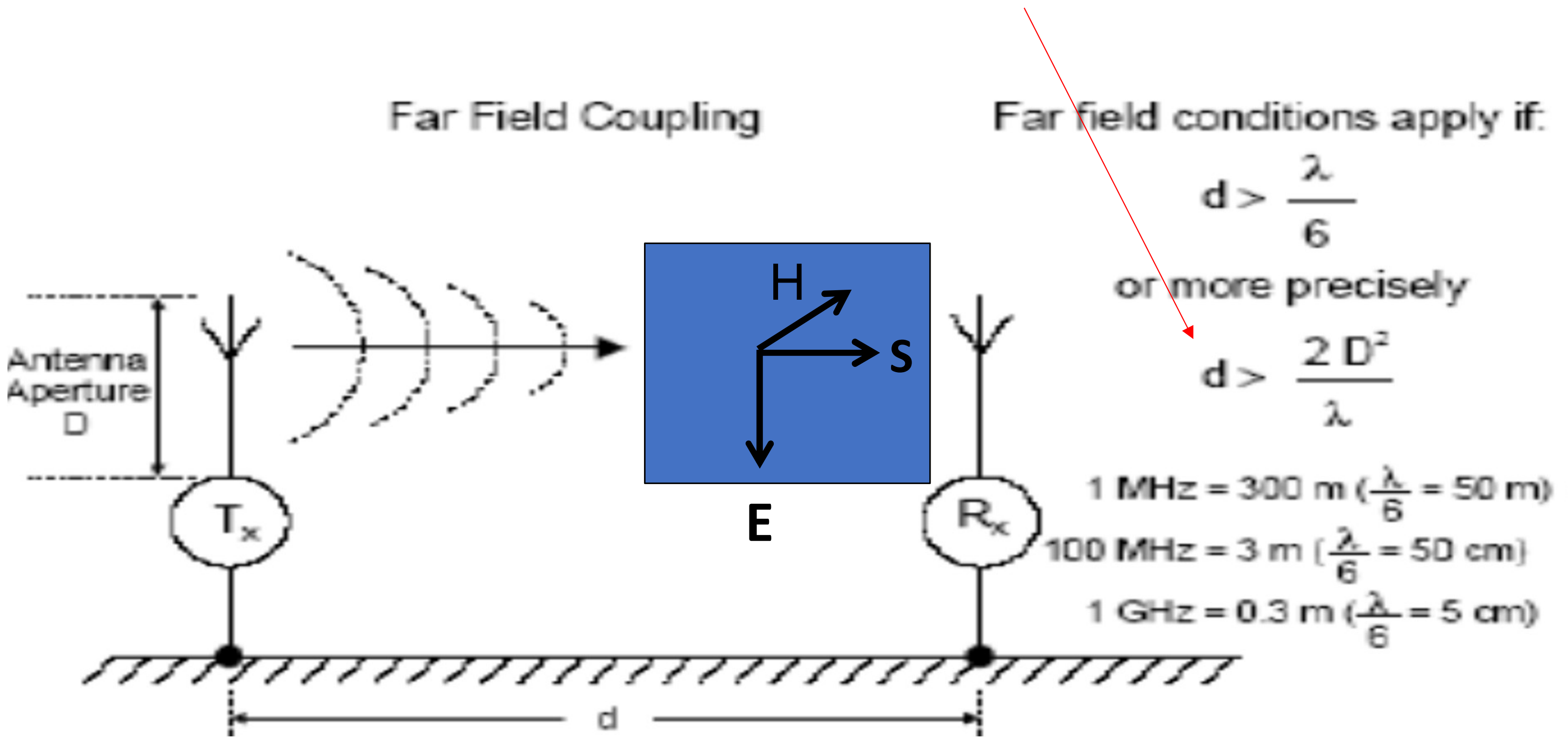
1. Why is EMC getting more important? (8)

- We distinguish **conducted** and **radiated Coupling Effects.**
- Both can cause **Emission** or **Immunity** (susceptibility) issues.
- We also consider **Frequency- and Time-domain** descriptions.

1. Why EMC EM-Field Basics (9)

Near Field / Far Field (FF)

More precise, better for FF (Far-Field) check



1. Why is EMC getting more important? (10)

- Depending on TX/RX distance, frequency (f [Hz] = c [m/s], wavelength [m]) and antenna size D [m], conditions for transition from near to far field are shown.
- In far field: E/H = 377 Ω; vectors are orthogonal to propagation; S is the Poynting vector (S = E × H) and denotes radiated power density.
- Examples: **1 MHz/300 m (MW); 100 MHz/3 m (FM Broadcast)**; **1 GHz/0.3 m (Microwave** e.g., 2.4 GHz Mw-Oven, Bluetooth, WLAN…).

1. Why EMC Basics (11)

Near Field / **Far Field**

$$Z_0 = \frac{|\mathbf{E}|}{|\mathbf{H}|} = \mu_0 c = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \frac{1}{\varepsilon_0 c},$$

where

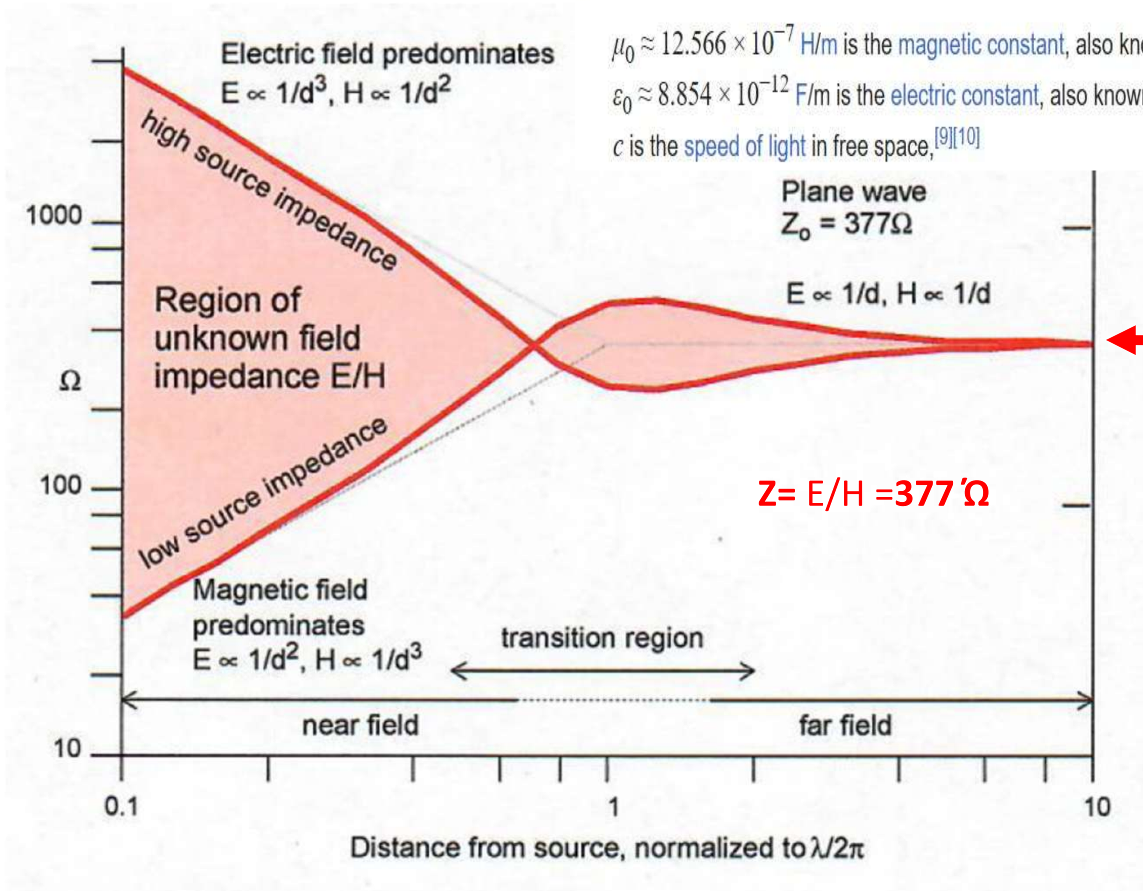
$\mu_0 \approx 12.566 \times 10^{-7}$ H/m is the magnetic constant, also known as the permeability of free space,

$\varepsilon_0 \approx 8.854 \times 10^{-12}$ F/m is the electric constant, also known as the permittivity of free space,

c is the speed of light in free space,[9][10]

Dipole/Monopole Antenna

Magnetic Loop Antenna



Z= 377 Ω

Source: Schaffner Guide 2001

1. Why is EMC getting more important? (12)

- The graphic computes **free-space wave impedance (Z = E/H)** from physical vacuum constants.
- With increasing distance from the radiator (dipole/mag loop), the **E/H ratio approaches 377Ω**.
- Distance normalized by simplest near/far field estimate ($\lambda/2\pi$).

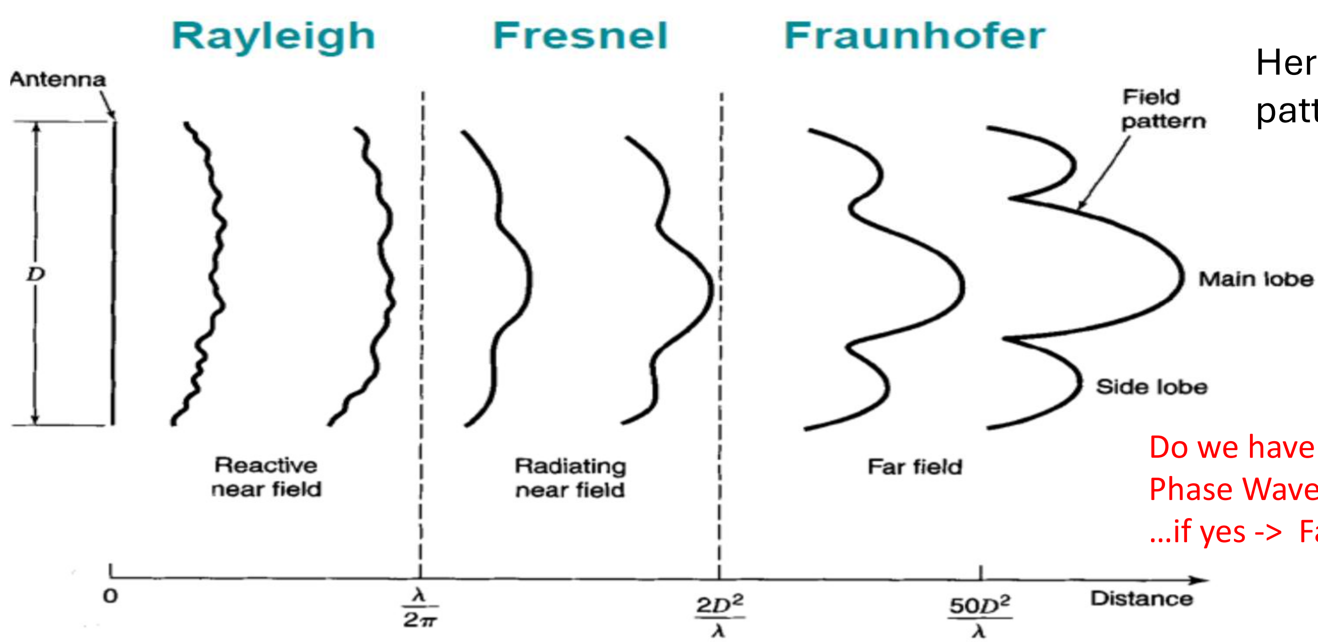
1. Why EMC Basics (13)

Near Field / Far Field

λ/2 Dipole (a Low-Gain Ant., not a High-Gain Parabolic-Dish Ant.) in ca. **2** bis 4 **λ** we reach FF

e.g., on 80m -> over 160m distance needed for a kind of FF-conditions !

Near Field (NF) **Far Field (FF)**



Here the full radiation pattern is visible.

Do we have a (nearly) Planar Phase Wave-Front->**TEM** Wave ?
...if yes -> Far Field

Z= E/H =**377 Ω**

https://www.tu-ilmenau.de/fileadmin/media/it_hmt/vorlesungen/antennen/antennen.pdf Antennen, Prof. Dr. M. Hein, Summer Lecture 2016

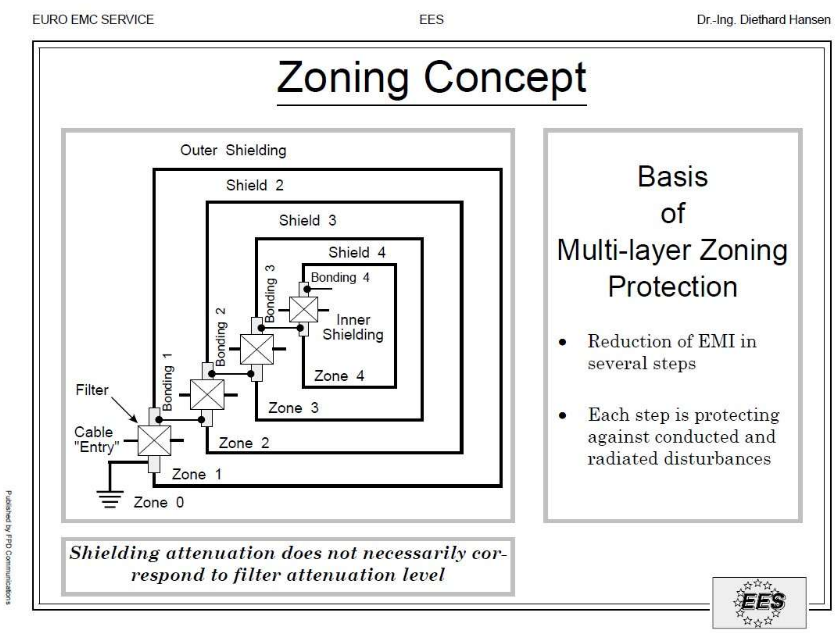
1. Why is EMC getting more important? (14)

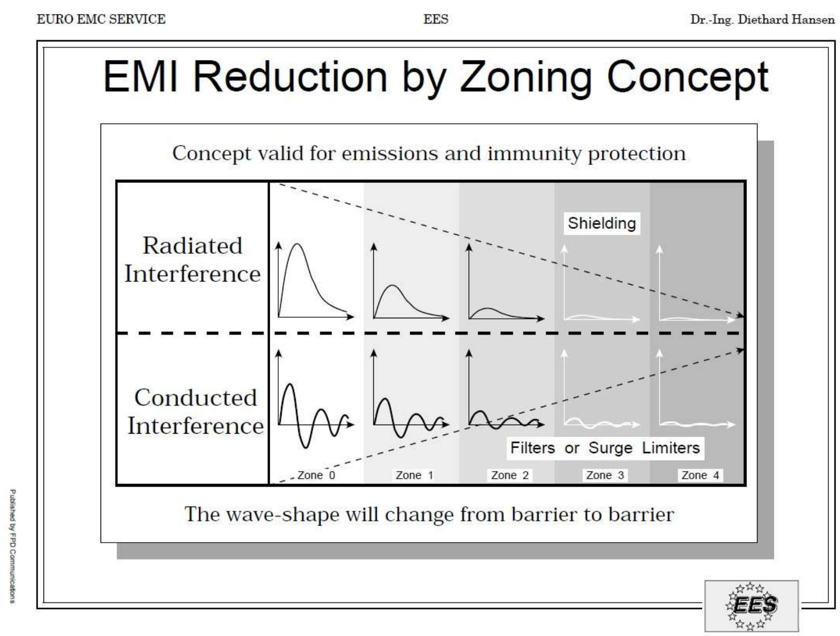
- As one moves away from an antenna, **different zones are traversed until the true far field** is reached.
- For a **simple half-wave dipole** in free space, that's ~**2–4 λ.**
- For high-gain dishes, the distance can be much larger before the radiation pattern is 'fully formed'.
- The exact point depends on the **allowed deviation (e.g., 1 dB ≈ 11%)** from the ideal.
- In **true far field** we have a planar TEM wave; near the source, spherical propagation transitions to an almost planar wavefront at large distances.

2. The only method to use: the EMC protection zone concept (1)

Zone concept / topology concept / 'onion-skin' principle

On HF possibly also (semi-) open zone concept → reference => ground plane





At zone transitions, implement protection:

For external EM disturbances

on lines: via filters/limiters; **for fields**: via staged shielding

EM-Threat from outside the system:

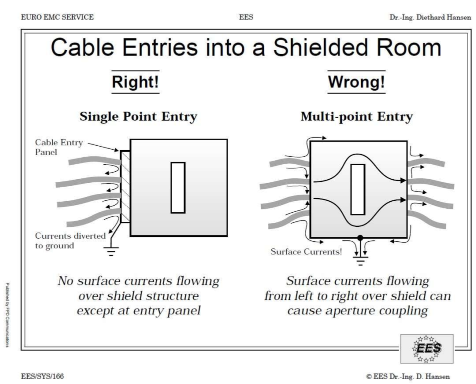
Step-by-step EM disturbances Reduction

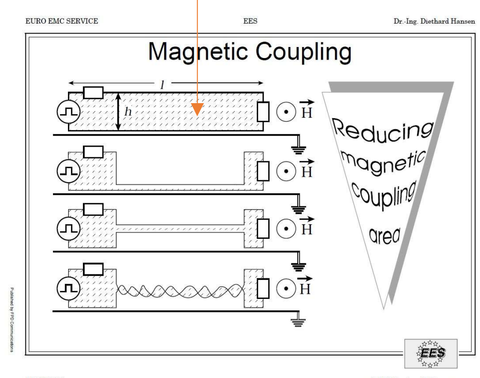
2. The only method to use: the EMC protection zone concept (2)

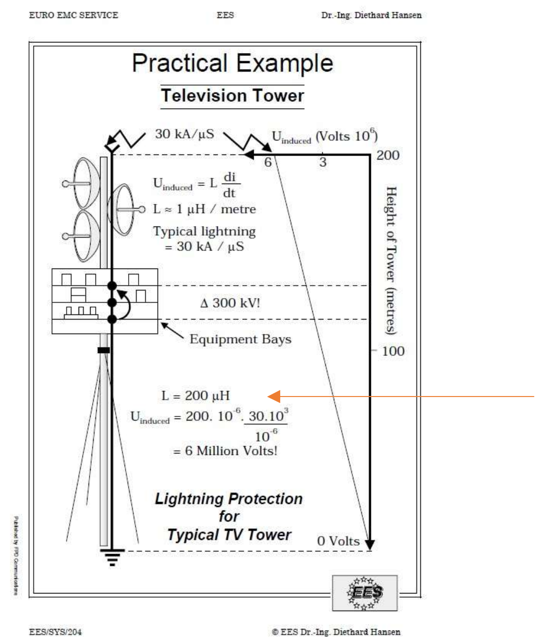
- The EMC protection zone concept divides a sensitive electronic system into areas with different protection (currents/voltages/E,H-fields) requirements (e.g., **20 dB (1:10)**, 40 dB (1:100), **60 dB (1:1000),** 80 dB (1:10,000) and higher), for disturbances from **outside (immunity)** and **inside (emission)**.
- **Conducted disturbances** are reduced with filters/surge protection; field-related disturbances with shielding.
- **Coupling mechanisms differ physically**: long cables have low resonances; smaller shielded volumes have higher ones.
- **Incident waves experience**: reflection, some absorption, and transmission depending on frequency, material, conductivity.
- Ideally, each zone has only one physical entry/exit (**single-point entry**), otherwise uncontrolled shield currents can flow and leak fields via unavoidable apertures (e.g., ventilation).

2. The only method to use: The EMC protection zone concept (3)

- Single-Point Entry (control disturbance current paths by design)
- Nearby HF reference ground planes
- EMC installation impedance isolation; “HF isolated island” concept
- Filters/shields work by insertion loss (with/without)
- Avoid/minimize critical (RX/TX) coupling loops
- Coordinate with lightning protection (e.g., TV tower).







2. The only method to use: the EMC protection zone concept (4)

- By **Single-point entry** disturbance currents will be channelized.
- Introducing **HF reference ground planes minimizes loop areas** and prevents/minimizes unintended antenna structures — especially for sensitive signaling.
- **Filters** are **defined by their insertion loss** (with vs. without filter, in linear ratio or dB).
- Long ground/earth leads >> inductance (~1 m ≈ 1 µH) become ineffective even on lower HF bands
- (e.g., 40 m).
- The goal is to **isolate the shack from the outside world** as an HF island for 160–10 m.

2. The only method to use: the EMC protection zone concept (5)

For **lightning protection** of e.g., a 200 m TV tower with a restaurant, distinguish lightning protection (people/fire/property) from **EMC protection** (disturbance/destruction of electronics).

- A massive down-conductor must safely carry **tens of kA to ground**. Lightning **spectra** are **mainly below 1 MHz**;
- Inductive reactance is still present and causes **huge kV drops (top-to-bottom)**.
- The lightning protection concept (**transient protection, bonding**) controls dangerous voltages to prevent arcing e.g., between floors/levels.
- Lightning bonding aims at potential equalization with far lower HF demands than EMC (which needs meshed ground grids with small cell size to minimize inductance).
- **Both protection concepts must be coordinated** in practice; **always minimize loops.**

3. On HF: mitigate conducted first, then radiated! (1)

• Transmission-Line/Antenna theory, myths vs. facts on efficient grounding/bonding ($V_{ind} = L*di/dt$) => avoid unwanted HF voltage differences between equipment

• Real-world effectiveness of filters/shielding in systems (filter test impedances vs. real installation impedance !)

• Proper clamp/core ferrite selection; frequency-dependent insertion impedance (choke efficiency); current-saturation effects

- **Electrical safety earth** (PE) or **lightning protection is unsuitable for HF!** ($V_{ind} = L*di/dt$).

  Rule of Tumb: 1 m of wire ≈ 1 μH → $X_L = 2\pi f*L$ ⇒ **at 7 MHz, 1 m ≈ 44 Ω**; at 14 MHz ≈ 88 Ω…
- Cables behave as **transmission lines** (telegrapher's equations). For height above ground h > ~0.1 λ, simple theory breaks down
- The **conductor becomes an antenna**: from ~λ/10 (sometimes λ/100), surely if 1/2-wave dipole resonance, 1/4-wave GP resonance, etc.
- Vertical Rods act as monopoles; Loops as loop antennas.

Student HV-lab experiment: Copper floor with spark gap triggered by 8/20 μs surge currents — illustrates $V_{ind} = L*di/dt$.
Driving a short lightning test pulse current over a metal plane will trigger an open spark gap (point to point) soldered onto that ground plane due to finite inductance of the metal floor.

3. On HF: Mitigate conducted first, then radiated! (2)

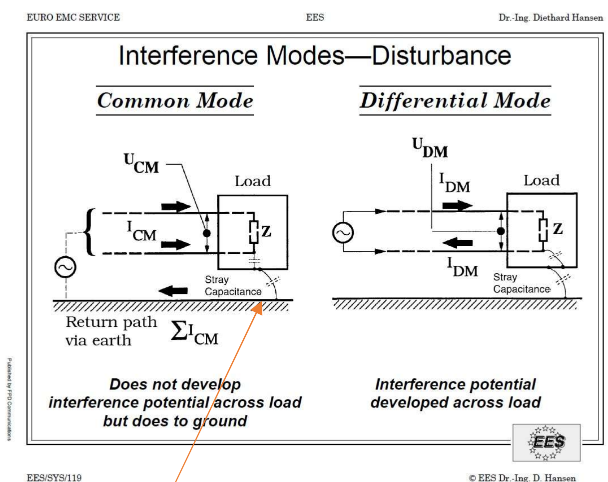
- Lightning protection goals differ from EMC/EMI goals.
- Physically, first separate line vs. field (antenna) theory.
- A conductor becomes an **efficient radiator from ~λ/10** (sometimes λ/100).

- The induced voltage drop $V_{ind} = L*di/dt$ → inductance of the ground lead is decisive: 1 m ≈ 1 μH (X_L ≈ 44 Ω at 7 MHz; 88 Ω at 14 MHz). Only by creating wide-area meshes can inductance and thus voltage drops be lowered.
- But if the area approaches ~1/10 of antenna dimensions, equipotential equalization no longer holds; Standing waves form and the protection concept collapses.
- Remedy: create smaller ground 'islands' and integrate smartly.

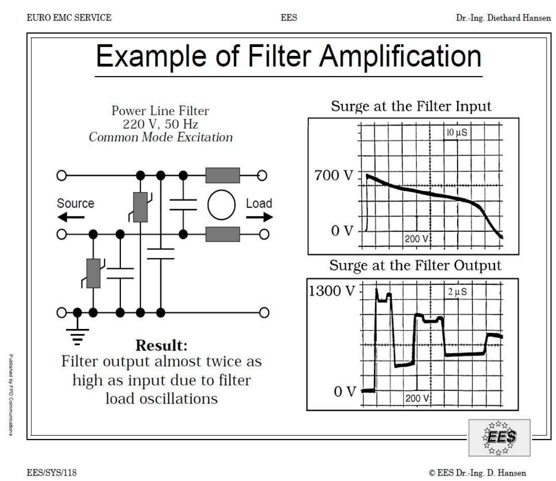
- **Do not blindly trust catalog filter/shield attenuation numbers**; they are lab values under standard impedances and only partially relevant in systems (e.g., mains filters see different impedances/wiring).
- For shielding, distinguish **near/far-field tests** by standard vs. by application.

4. **EMC** planning/retrofit, proper **EMC design of an HF (RX/TX) station** (1)

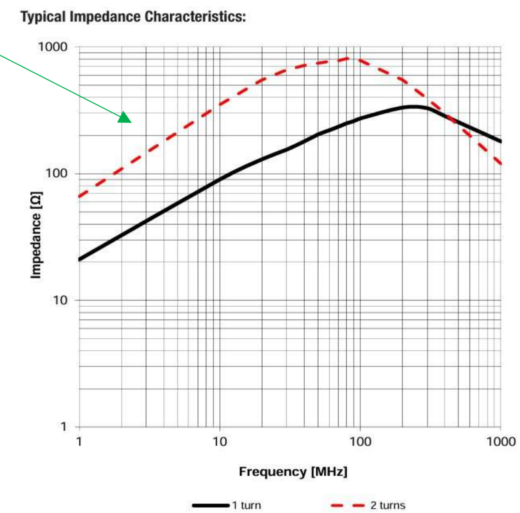
- HF equipotential bonding in the station: TRX, PA; thin aluminum ground plate under the operating desk; decouple PE/safety ground/earth for HF!
- Common-mode (CM) vs. differential-mode (DM) currents
- CM-Chokes: Mains filters; computer/USB ferrites (raise shield L/R → increase Z); rotor control; coax etc…



At HF CM is basically always dominant



Filters in Systems can cause adverse effects e.g., resonances



Würth 74271722S (Core is for1.8MHz ok)
Snap on Ferrite , 620 µr D Kabel max. 12.5mm

4. **EMC** Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (2)

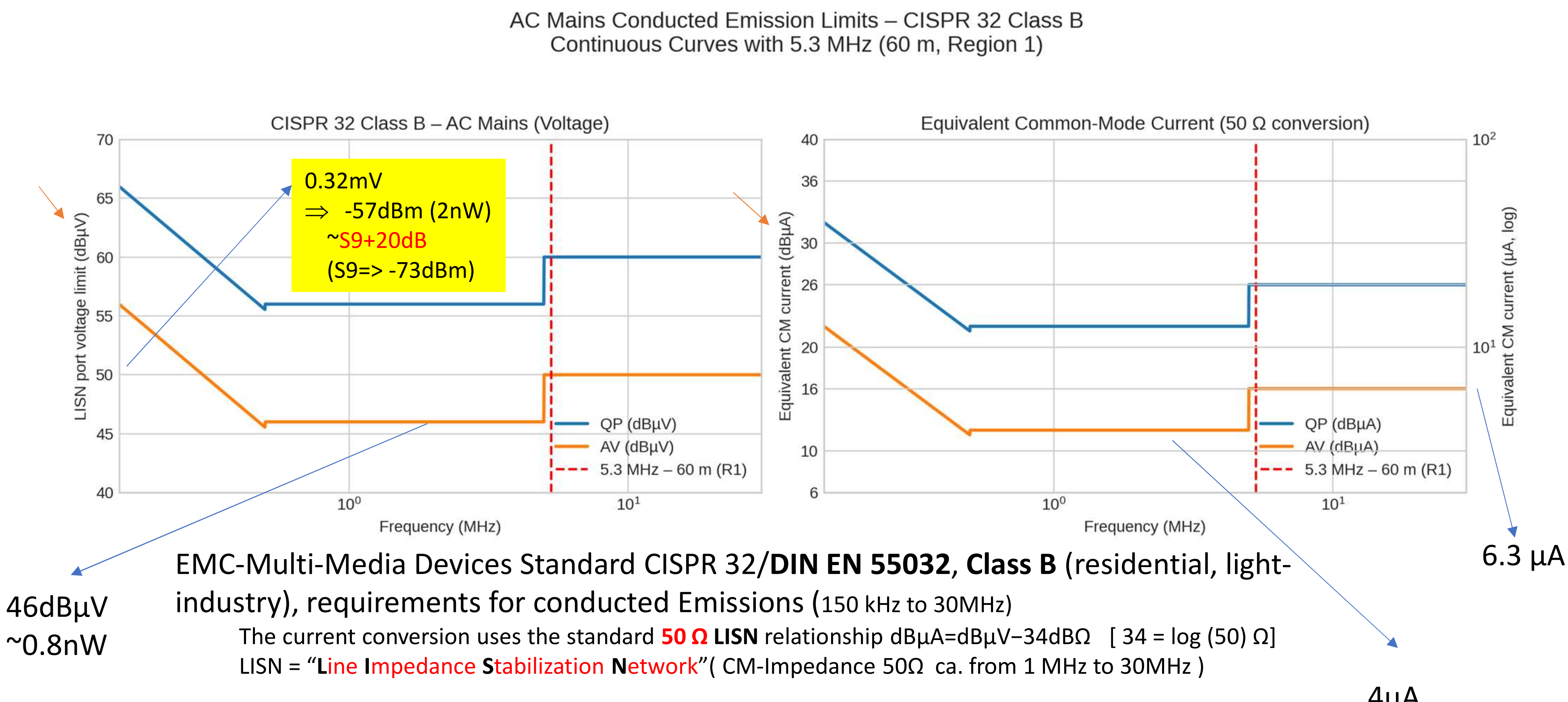
- Mains filters suppress **CM and DM** disturbances.
- Pay special attention to filtering of PE; otherwise, large coupling **loops can form via cable shields (ground plate/single-point entry) to antennas — bad for both TX and RX.**

- In **real filter installations**, **length/load-dependent resonances (Q~3–5)** can occur in frequency domain; in **time domain**, max **factor is 2** (e.g., total voltage reflection at open).

- With **snap-on ferrites**, **compress the air gap** with a cable tie to maintain long-term performance.
- With **high-permeability cores**, use **no more than 3–4 turns** (parasitic C); that already yields kilo-ohm impedances for CM choking.

- **Ferrites work at current** antinodes (**low impedance** — verify with current clamp/H-field probe), not at voltage antinodes along a line.

4. **EMC** Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (3)



EMC-Multi-Media Devices Standard CISPR 32/**DIN EN 55032**, **Class B** (residential, light-industry), requirements for conducted Emissions (150 kHz to 30MHz)

The current conversion uses the standard **50 Ω LISN** relationship dBµA=dBµV−34dBΩ [34 = log (50) Ω]

LISN = "**L**ine **I**mpedance **S**tabilization **N**etwork"(CM-Impedance 50Ω ca. from 1 MHz to 30MHz)

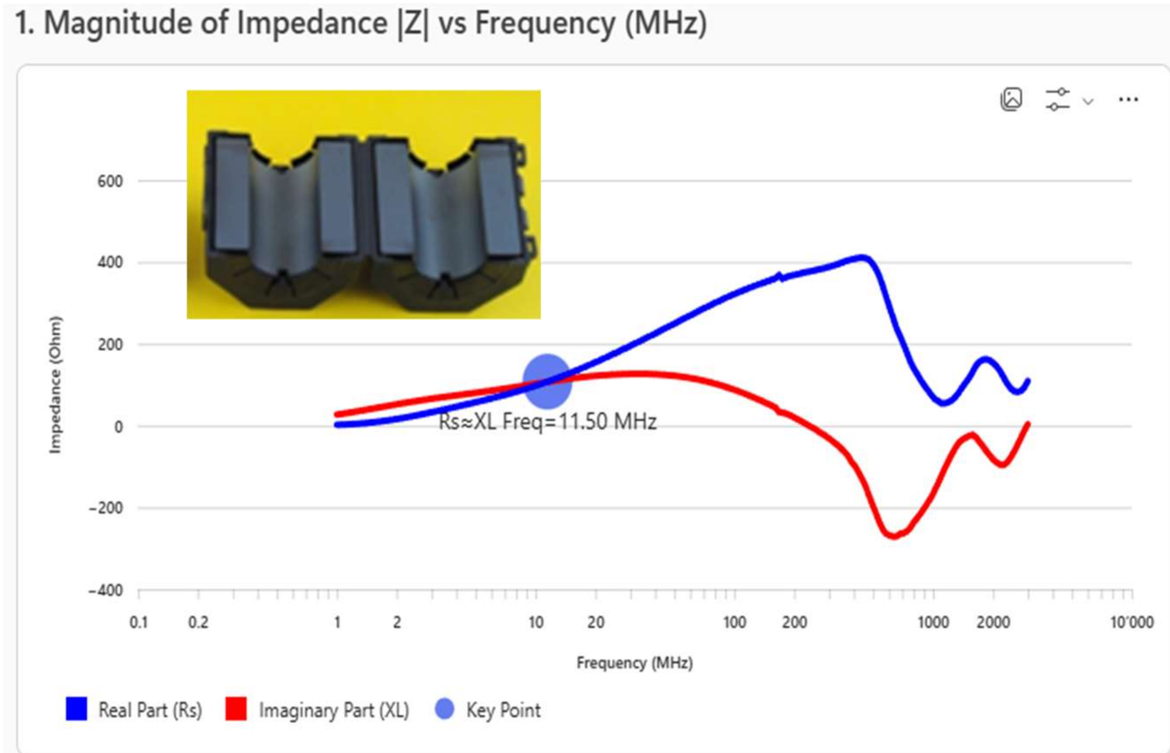
4. EMC Planning/Retrofit, proper EMC Design of an HF (RX/TX) station (4)

On HF, CM almost always dominates. HF CM current flows on the outside of coax. A **ferrite** on the outside does not affect signal inside; added outside impedance **reduces** uncontrolled **loop currents**.

- **Ferrite** (Shield-L,R-> increases Z), choke off coax, control/rotor-cable....

Graph: 1 Turn/Winding (N=1), 300g heavy Snap-on Ferrite-Core : **Fair-Rite Part #0444177081**
D_{inner} ca. 25mm

Tip: with a single large snap core (Fair-Rite #0444177081, ~25 mm ID), 3–4 turns are often enough on HF to achieve ~20 dB (≈1 kΩ) CM reduction.



4. EMC Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (4a)

- How much CM (choke R_c) suppression (dB, $\mathbf{I}_{with}$ / $\mathbf{I}_{without\ choke}$) do you need at the antenna (Z_a)?

Why the design target is "big Z choke" (2–5 kΩ resistive)

Treat the choke as a series element in the CM loop. If the antenna-side CM impedance is Z_a and the choke is mostly resistive R_c, the **current ratio** is roughly:

$$\left|\frac{I}{I_0}\right| \approx \frac{|Z_a|}{|R_c + Z_a|}$$

- With $R_c = 3\,\mathrm{k}\Omega$, $Z_a = 50\,\Omega$ **→ –35 dB.**
- With $R_c = 3\,\mathrm{k}\Omega$, $Z_a = 200\,\Omega$ **→ –24 dB.**
- With $R_c = 3\,\mathrm{k}\Omega$, $Z_a = 1\,\mathrm{k}\Omega$ **→ –9.5 dB** additional beyond the first 20 dB (i.e., even better).

RA=200Ω
RC= 1000Ω
=> -16 dB

This math is why **K9YC** and **ARRL** guidance converges on **multi-kΩ, largely resistive** chokes for HF—it keeps CM current small even when the antenna-side CM load is inconveniently low or reactive. Measured Data For Ch... +1

4. **EMC** Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (5)

Why ferrite effectiveness varies

+ Ferrite effectiveness in a system is frequency- and location-dependent
+ Current/voltage distributions (standing waves) exist along cables.
+ A ferrite (modeled as series L+R with some stray C) works well at current antinodes (low Z).
+ Measuring with a **50 Ω VNA** or **HF-impedance meter** is useful for material orientation but can be **tricky** at very low/high impedances (de-embedding and fixture stray C).
+ In systems, it's better to measure CM current insertion loss on-site with an HF current clamp.
++ Example: 1. replace a 60 cm 'choke section' with plain coax for 0 dB reference,
2. Then insert the choke section and measure current reduction in dB.
3. **Insertion loss [dB] = 20·log10($I_{CM,ref}$ / $I_{CM,choked}$).**
+ Where to get an **HF current clamp**? Buy (pro: >€500) or **DIY** (<€50)
++ Transformer principle: Primary 1 turn; Secondary N (e.g., 6–10 turns) with ~50 Ω load;
Measure with spectrum analyzer (use attenuator; beware TinySA max +6 dBm).

4. **EMC** Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (6)

DIY current probe: https://www.interferencetechnology.com/wp-content/uploads/2012/04/Wyatt_NA_DDG12.pdf

Trafo Prinzip => Primary (1N) : secondary N (6 to 10) und parallel e.g. 50Ohm Load-R) 1N

Commercial EMC monitoring Current Probe

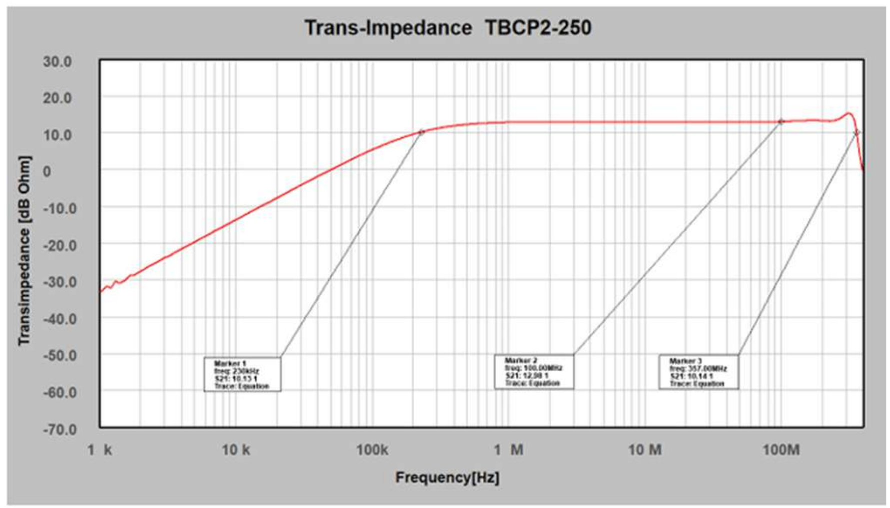


Figure1: typical transfer impedance: 1 kHz to 400 MHz

Ohm's Law I=V/R linking [µV, µA]

=> In Log System:

dBµA= dBµV - dBOhm

[dB] = 20 x log (ICM no Ferrite / ICM with Ferrite)

Ratio 1:10=> 20dB

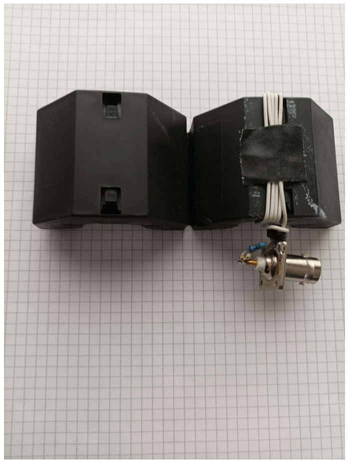
4. EMC Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (6a)

Measurement caution with TinySA (Spectrum Analyzer battery operated)

Quick reference: DIY probe math (N=10 turns, Rb=50 Ω)

- $I_{CM} = N \cdot V / R_b = 10 \cdot V / 50 = 0.2\ \mathrm{A/V}$
- 1 V → 200 mA
- 100 mV → 20 mA
- 50 mV → 10 mA
- 20 mV → 4 mA

Improvement (dB) = $20 \log_{10}(I_{\text{after}} / I_{\text{before}})$



TinySA max input ≈ +6 dBm (≈113 dBμV, ≈0.45 mV into 50 Ω) — always use an attenuator (20dB+?) to avoid damage

4. **EMC** Planning/Retrofit, proper **EMC Design of an HF (RX/TX) station** (7)

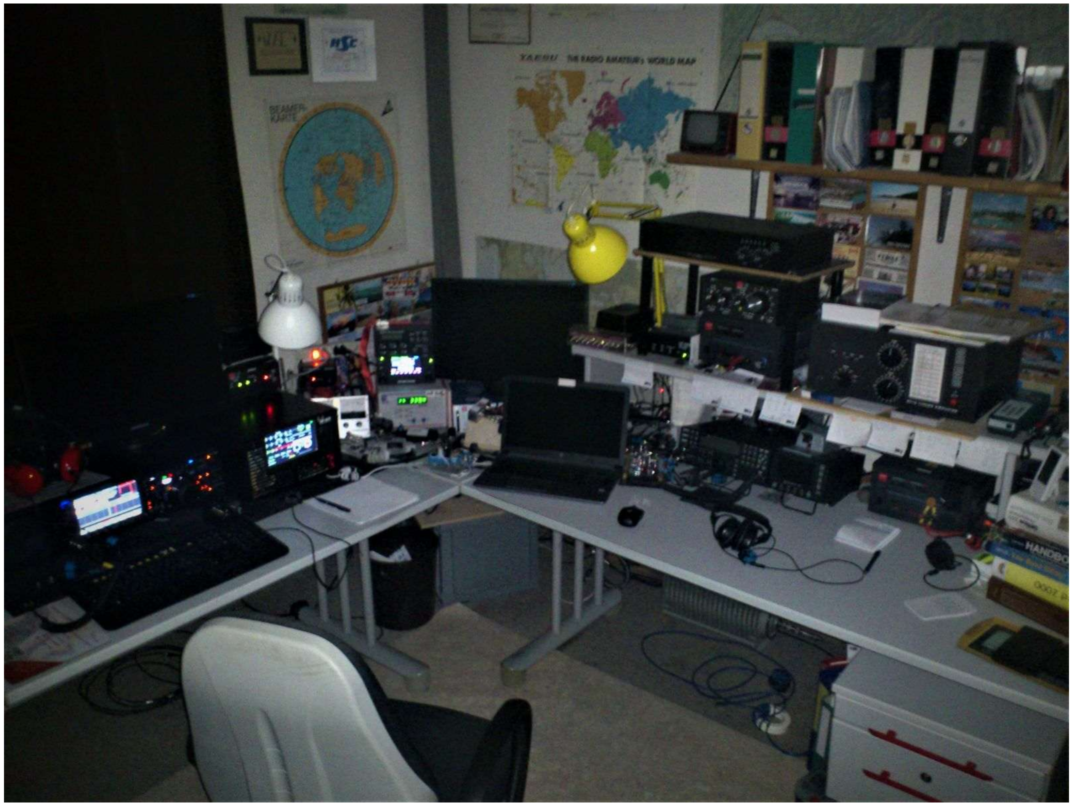
-Ground-plate HF-Reference and Cable Management-

- Use a sheet ground-plane (<1 mm Al; skin depth on 160 m ≈ 63 µm) under the desk to minimize loop areas.
- Bond gear with **short studs** through the wood top to the plate.

- All cables to/from the desk are choked off: all coax, control lines , rotatory cable mains filters preferably with surge arresters etc.
- **On the desk**: TRX USB, PTT, CAT, headphones, mic, audio, external DC PS.
- Beware: some external 13.8 V supplies tie PE to DC−; TRX chassis may be at minus => then not all current returns via the black lead; some flows via PE; CM ring cores can saturate and lose effect.
- If the **TRX has an internal AC supply**, a CM choke on the 3-wire mains lead is fine.
- Warning: **unknown flea-market cores** should be e.g., VNA-pre-characterized
- **VNA test fixtures** can introduce some errors via stray C to the instrument front panel; build a well-defined **transmission-line jig** and calibrate properly.

5. EMC case study HB9CVQ — Berikon/AG — 3rd floor of 6-unit rental — no problem! (1)

DB18E SteppIR (40–10 m) @19 m; 2×36 m tuned doublet (160–10 m) @24 m. Single-op: FTDX101MP; RF2k-S or K3S; P3; KPA500/ACOM1k.



5. EMC case study HB9CVQ (2)

- Home QTH with antennas and shack (upper right).
- The installation is an HF-isolated island with external lightning protection.
- Internal lightning bonding in emergencies via a triggered spark gap (tested 100 kA) to a separate earth system.
- Outside: proper mast down-conductor to a regularly measured 14m deep earth.
- In the shack two phases are used (PA, TRX).
- K3S, P3, KPA500, ACOM 1K is reserve only
- No SO2R at present.

5. EMC case study HB9CVQ (3)

View above the beam at 24 m: NW, S, E, SE (photo).

5. EMC case study HB9CVQ (4)

- HF-capable bonding in station (TRX, PA), ground plate under wooden desk, short bonding studs;
- CM-Choke in PE safety earth
- good Mains filters; computer/USB ferrites; rotor control; coax
- CM/DM currents well controlled

1) Discuss differing effects for emission vs. immunity.
2) Semi-open zone concept on corner desk (OP1/OP2 positions) — has already a semi-critical resonance already above 21MHz.
3) CM ferrites everywhere: mic, headphones, key, PTT, coax, mains.
4) Two single-phase feeds (TRX, PA); mains filter cases lie flat on ground-plate (minimize L).
5) Narrow cable channel to attic and roof antennas (with spark gap for lightning — otherwise this would form an EMI loop via coax shield to bonding, grounding, earthing).
6) Next improvement a properly bonded metallic cable tray (HF-reference plane) from shack to attic/roof antenna distribution/installation (minimizing stray effects/loop areas/effective antenna height issues)

5. EMC case study HB9CVQ (5)

- The Zoning Concept can be implemented on HF even as a semi-open design with only a reference ground-plate (no full Faraday cage needed).
- On receive (**emission case**), noise sources (local QRM) are typically outside the shack/flat; induced currents are in the **µA range**.
- On transmit (**immunity case**), the antenna near field induces currents in the installation;
- The RX-oriented EMC measures also help here; currents scale with TX power and can quickly be **10mA to 100+mA range**.
- For RX-noise compensation, a DXE NCC-1 two-channel phasing system is used; physically, it can ideally cancel only one phase-aligned source (−180°) in the near field (local QRM Eliminator).

  Practice shows compromises and success of ~3–4+ S-units (**≈18–24 dB**) local QRM suppression. In Lab/Theory suppression may exceed 40dB.

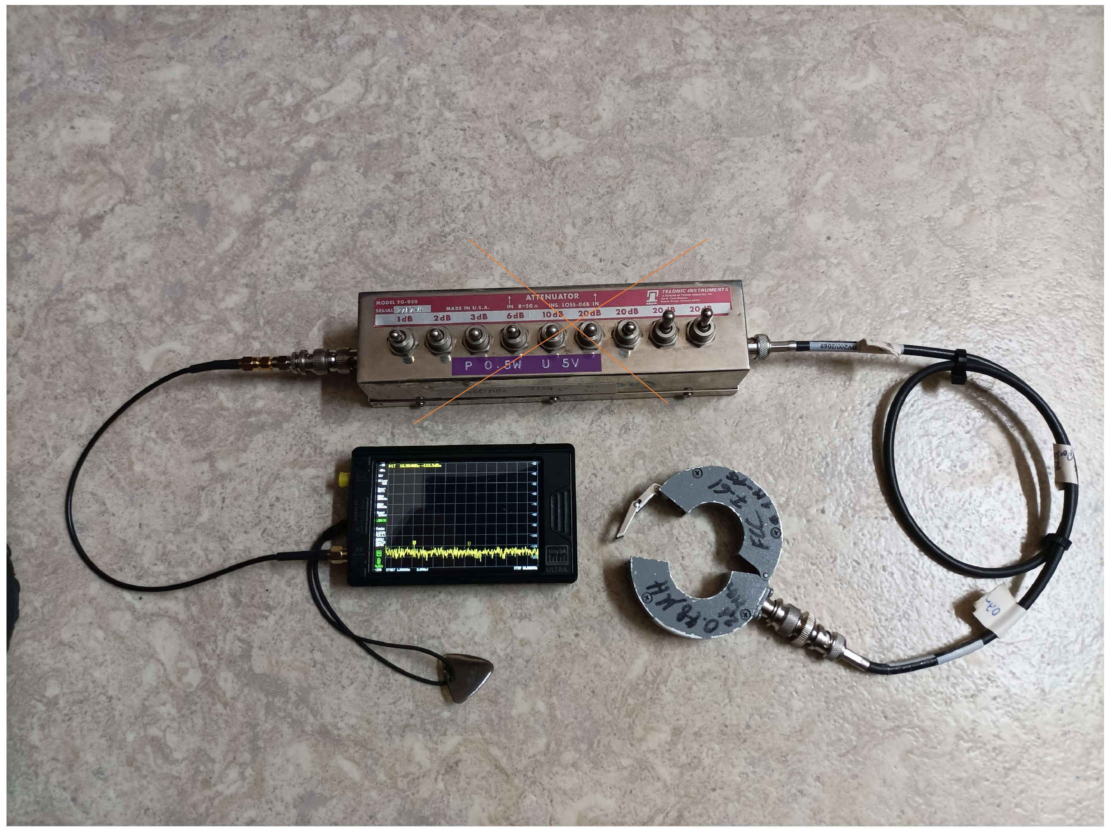
5. EMC case study HB9CVQ (6)

Practical setup for conducted emission/coupling measurements (see source photos/equipment list).

Always do a "Null Check" (current probe closed, TX-field exposure) of the system not to suffer uncontrolled coupling.

Finding:
Metallic Attenuator Box presents too much surface and caused stray effects, field coupling into TinySA.

Solution: Use a small 2Watt BNC 20+ dB Pad. The TinySa ultra showed no problems even at 1kW TX power at maybe 30m distance to the 20m Beam antenna. (Alternative: Use snap-on ferrites CM cable choke)



5. EMC case study HB9CVQ (7)

The dBm Ladder according to W2VJN (2009), excellent info

https://www.vibroplex.com/techdocs/INRAD/MII_W2VJN.pdf

RX: S9 =-73 dBm

TX: 1 kW= +60dBm (HB9 HF-max. legal limit mostly)

Dynamic range already here 73+60= 133dB !

An S-Unit below S9 (IARU=>6dB, Jap. Manufacturer =>3dB)

6dB=> 4xPower, HF S-Meter calibration => in RMS (S9: 50µV/50Ohm)

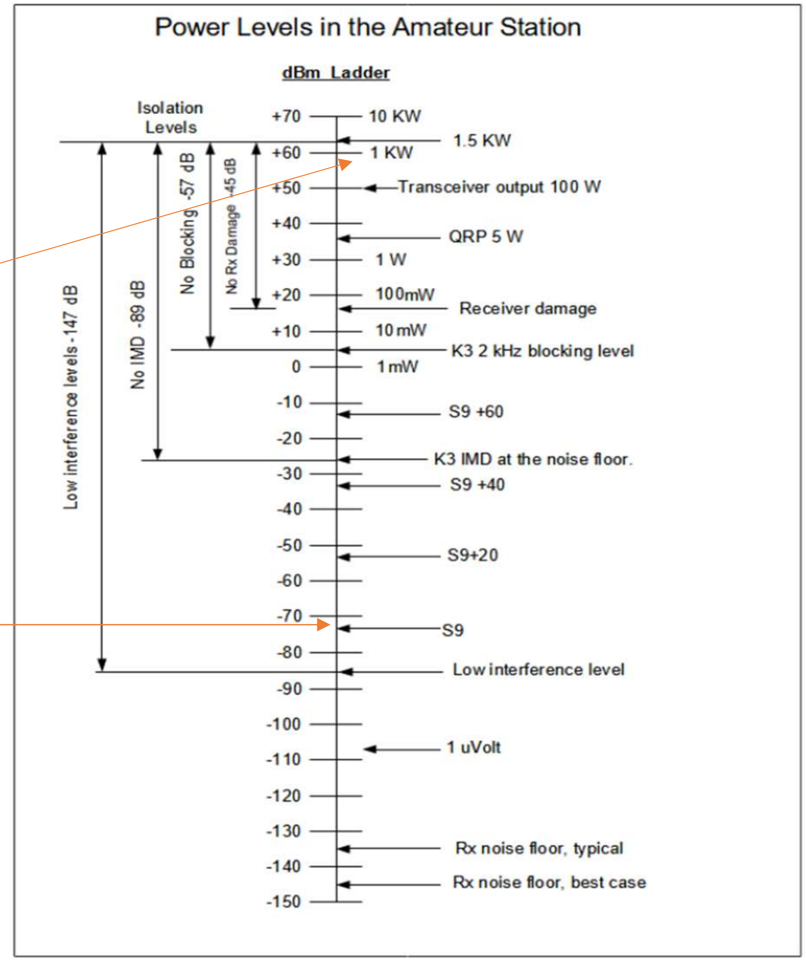


Figure 1 The dBm ladder.

5. EMC case study HB9CVQ (8):

How good is the EMI suppression?

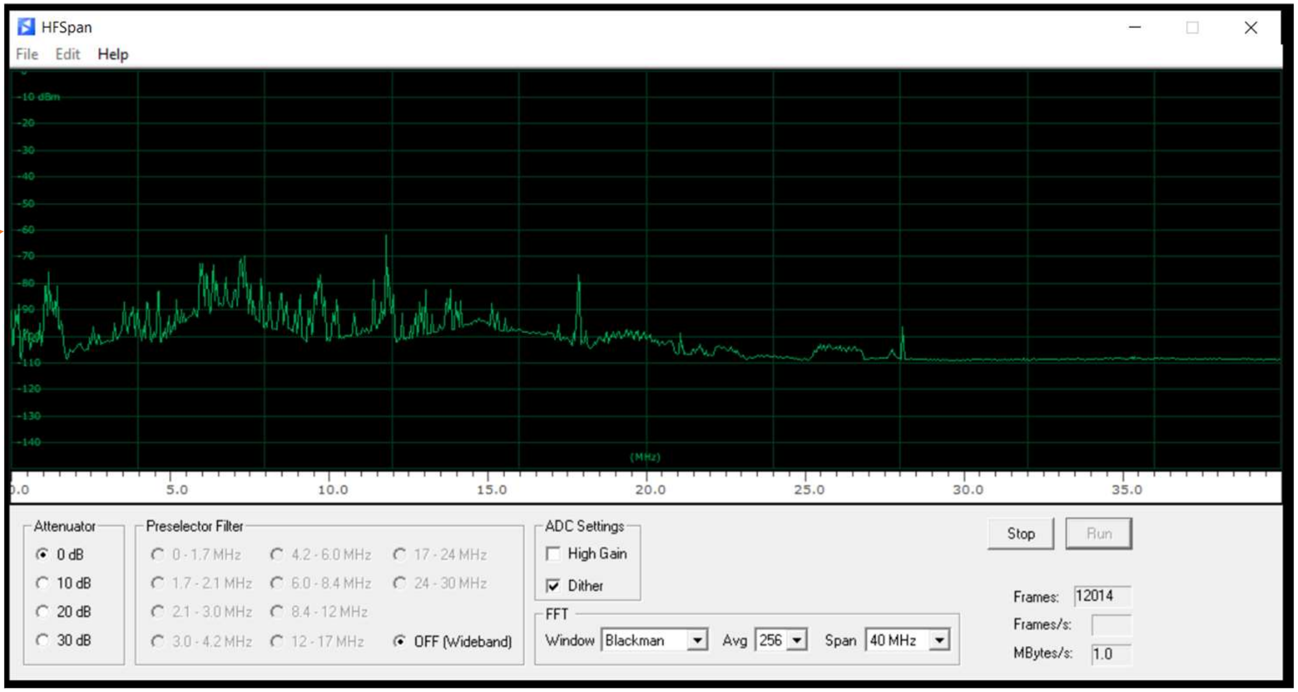
Station desk: 1× antenna cable bundle to attic; 1× phase TRX; 1× phase PA; 1× earth lead with spark gap.
CM-current measurements — emission (RX noise floor) — **station OFF** — in shack

-60dBm/50Ω =>47dBµV (12MHz, I-Probe 23dBΩ): 24dBµA=**16µA (13nW)**

11-Jan-2026, 17:52 MEZ
Per Current Probe FCC-61

Perseus in BB-Mode, Laptop, all battery operated

All other currents are smaller



5. EMC case study HB9CVQ (9):

How good is the EMI suppression?

CM-Current Test:

1. **Emission** -Station ON-> into **Dummy Load** =>**TX-10W-CW→ no relevant coupling , proving EMC concept is Ok**

2. **Emission** -Station ON-> into **Dipole Ant.** => **TX-10W-CW→ the antenna illuminates the LV installation (attic first)**

Induced CM power (dBm->calculated decoupling dB) on the **cable bundle to attic**, **referenced** to **TX 10 W (+40 dBm)**
shown is approx. **decoupling [dB] by band**:

160-80-60-40-30-20-17-15-12-10 m
62-60-60-50-52-45-50-**43**-60-50 dB

The bundle is about 30 m long ⇒ possible 2λ resonance around 15 m band (only **43 dB** decoupling there).
+40 dBm − 43 dB = −3 dBm (~0.5 mW, 50 Ω) induced ⇒ **~3 mA**. Scaled to **100 W** ⇒ **~9 mA**; to **1 kW** ⇒ **~30 mA**.

5. EMC case study HB9CVQ (10):

Local RX-QRM eliminator DXE NCC-1 (Main, Aux-Antenna Arsenal, RX-Input Protection)

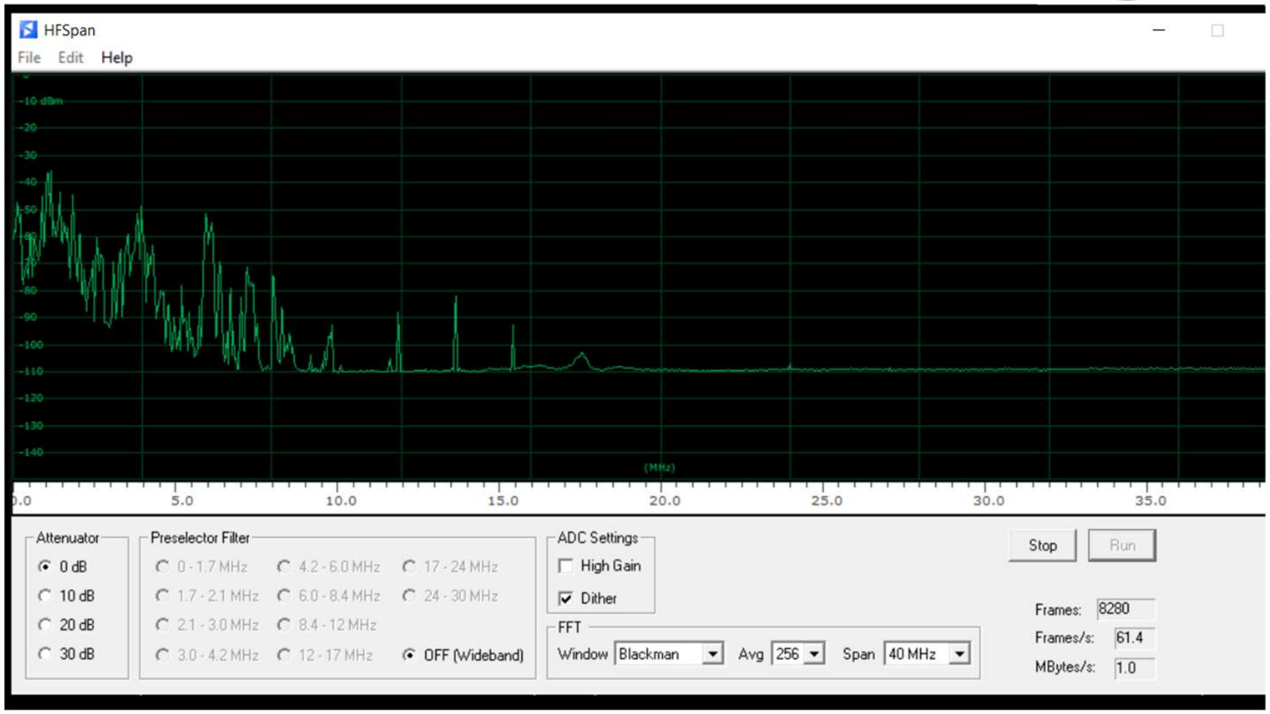
Principle: improve **SNR** -truly works best for a single interference source. In the lab up to ~45 dB; in practice usually ~24 dB (≈4 S-units).
Procedure: optimize the noise-aux channel, invert by −180°, vector-sum via power combiner; match main-antenna and aux-antenna levels within ~1 dB while considering RX S/N. Often ~15 dB preamp is required for the aux ant.
Various small aux antennas were installed in the attic (short dipole; active mag loop ALA1530; Mini-Whip). Place ferrites along the coax to the aux antennas.
Sometimes, for **very close (~50 m) noise sources, a mains LISN** (50 Ω, 50 µH) with surge protection is **used**; it usually needs gain (~20 dB). Caution: LISN draws high 50 Hz leakage (e.g., 700 mA at 230 V/50 Hz) → RCD (30 mA) will trip. **Using the mains as a (poor) receive antenna (≈ −25 dBi)** aggregates multiple sources with random phasing. Attempts to reduce far-field OTH radar on 17 m achieved ~−20 dB but required constant phase readjustment due to ionospheric variability — better done by software/automatic diversity RX.

5. EMC case study HB9CVQ (11)

Signal level examples (Main antenna Dipole)

14-Jan-2026-2000CET-**1872 kHz (160m) t**uned «inverted Vee» @24m

-35dBm



5. EMC case study HB9CVQ (12)

Signal levels (RX **aux active mag Loop**, 1m diameter, location attic)

13-Jan-2026-1650CET-**horiz-ALA-1530 mag. Loop** -55cm to tile-roof-250cm above concrete floor-Avg256

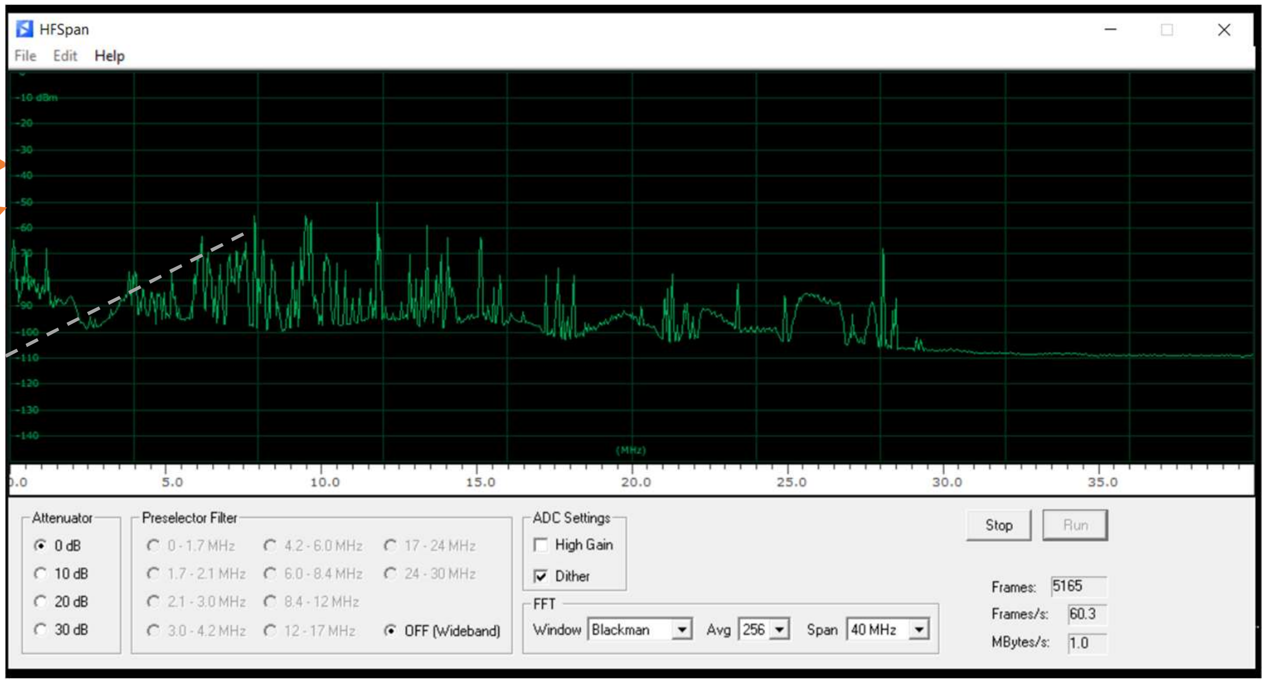
Main Ant DP

-35dBm

Aux Loop

-50dBm 12MHz

Absolute calibration: 51dBµV/m



Around 17:44 CET, propagation checks showed nearly equal signals.

5. EMC case study HB9CVQ (11)

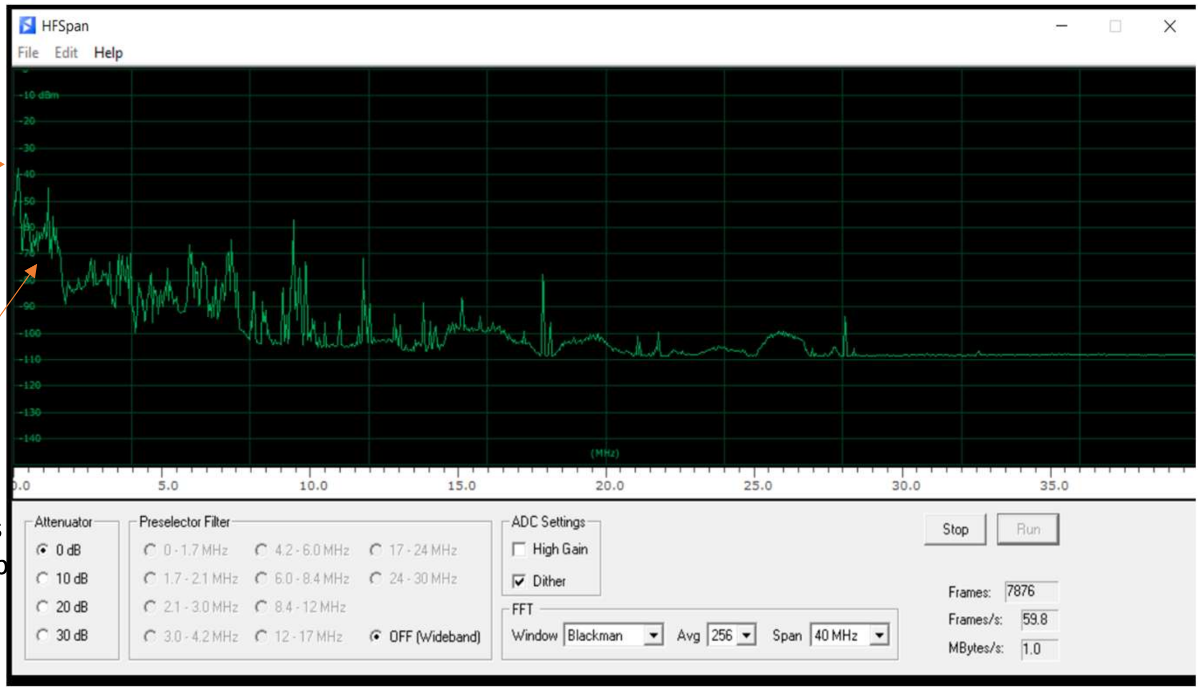
Signal levels (aux Mini-Whip PA0DRT, same location as before, attics**)**

13-Jan-2026-1731CET-**Mini-Whip-**with CM-Choke-150cm above concrete floor-Avg256

Main Ant DP

-35dBm

more sensitive at lower frequencies than the mag loop in this setup.



6. EMC case study Multi-OP CW **contest station** DD1A**,** Germany, Singen (160–10 m, ~750 W) (1)

• Multiple antenna masts; close antenna coupling (40 m @26m 2 el.; up to 4 el. beams; 20 to 10m stacks; 80 m GP; 80 m inv-V; 160 m L-antenna; home-built multi-in-band automation; multiple RX loops; beverages)

• BW mast, Versa Tower, old Armed Forces mast — critical direction-dependent antenna coupling.

• TRX, PA filters, 3-phase mains • **3 operating positions** — each on a single mains phase!
• **Simultaneous TX on different HF bands** (band-pass filters at TRX and after PA)

• Beverage RX antennas; ultra-narrow, high-IP BPFs (e.g., 3 positions for 80 m CW).

• One complete station per mains phase; mains filters; lots of large 300 g CM snap ferrites (DX-Wire K25, 25 mm ID).
• Almost consistent single-point entry EMC concept (no reference ground plane yet, connections to below club station DK0SV !).

• After HF, mains, CM-ferrite choking, we still found the individual TS-590 13.8 V DC supplies to be a critical back-door RX coupling path (via PE/SL/coax shields). Remedy: stronger DC-CM filtering without saturation and larger K24 cores (only 3–4 turns; more turns → capacitive crosstalk on core turn to turn → reduced choking function).

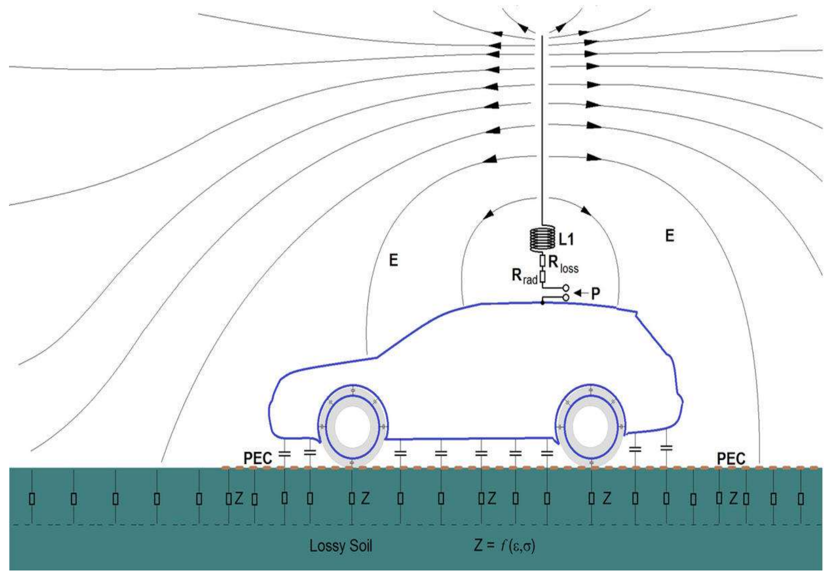
6. **EMC case study** Multi-OP CW **contest station** DD1A (2)

- The last **mitigation** weekend Jan-2026 was complex and time-consuming.
- Core **property size** roughly **40x25 m** with 3 ant. masts, + external 80GP/160m L antenna, all RX-Antennas
- On 3 mains phases run 3 filtered HF stations.
- Consistently, all (antenna) TRX/PA ports were suppressed with coax CM chokes and band-pass filters (automation, multi in-band !), on all 3 operating positions.
- These BPF filters typically give 30–40 dB isolation to the adjacent band-usually sufficient to push TX **harmonic signals** down, if no further uncontrolled EMI coupling exists.
- TX=>**1 kW** (+60 dBm) - 60 dB (2 filters) -20dB (stubs) -10dB to 20 dB Antenna decoupling =-30dBm (**~S9+40dB**)
- RX=> ideally should sees -30 dBm -80dB (2x BPF, 1x Stubs) = -120dBm (S1).
- Reality mostly at DD1A: S9+20 (-53dBm) **on harmonics** and +/-5 to 10kHz around ☹ **.** It was even worse in the past.
- **Fixing** by better, stiffer grounding system and better isolation to club-station below using partly same antennas
- At least **additional** (**target S7: -85dBm**) **32 dB suppression** needed by e.g., improved ground plane/single point entry
- Short circuited λ/4 Stubs add to CM pollution!
- Antenna isolation can not be change due to property. Poor TX phase noise can principally also play a role.
- **Isolation/improvement of cross-talk needed mostly for RUN 1 to MULT-Operator in MS/M2 contests.**

6. EMC case study Multi-OP CW **contest station** DD1A (3)
-EMI-Mitigation-

- A key finding: **RX back-door** coupling via the DC supplies and **loops (PE/SL/coax shields).**
- TX field strength (self-illumination) induces disturbance currents.
- The initial 20 dB **mains-filter spec** at external DC supplies was insufficient. Worse, at first two TRXs shared one 13.8 V DC supply and coupled uncontrollably; separating and choking yielded an acceptable solution.
- **Passive** (active needs BPF) **RX antennas** were now also better EMI suppressed by 40dB CM chokes
- All 3 Op-Position (TRX USB, PTT, CAT, etc.) were choked and mains filters with PE suppression installed.
- Antennas are too close together (limited property); directional antennas couple direction-dependently (USA/Asia).
- External lightning protection on the 24 m Bundeswehr mast is installed.
- Despite TRX-BPF → PA-BPF → stubs → antennas, we still see heavy crosstalk (see slide 48)

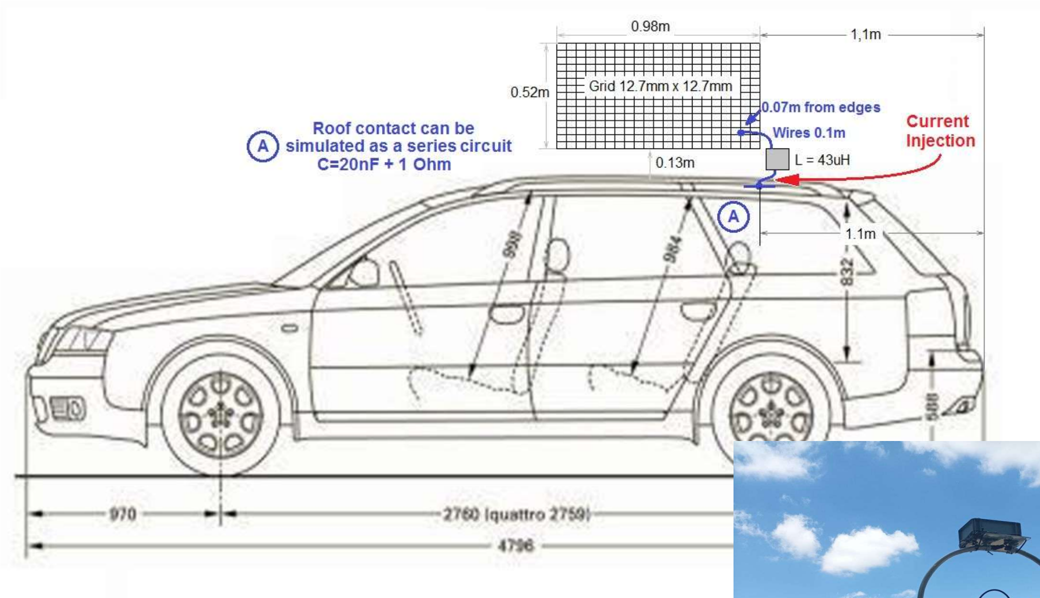
7. HF mobile challenge — Audi A6, HB9CVQ/m, DK2VQ/m (1)

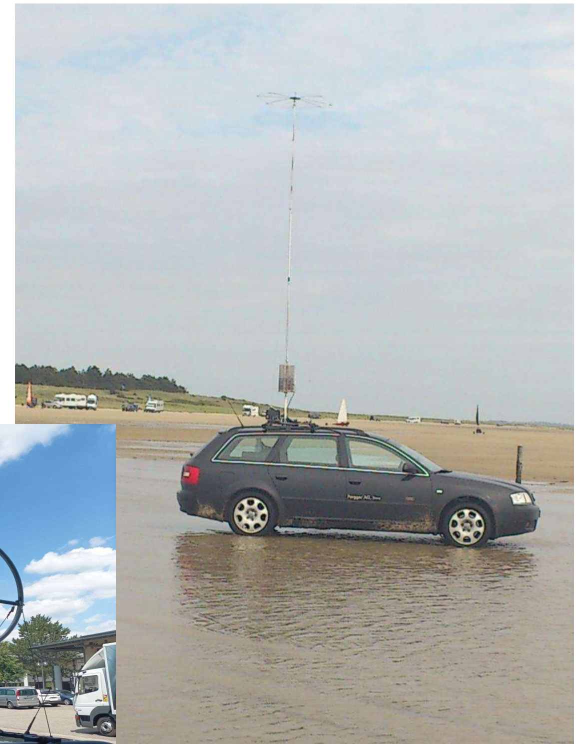


7. HF mobile challenge — Audi A6, HB9CVQ/m, DK2VQ/m (2)

- A self-developed **80 m mobile antenna** proved very efficient under the circumstances by minimizing stray capacitance to the roof.
- Vehicle **EMI self-suppression** on an Audi A6 (2003) reduced initial S9++ (CW BW 400 Hz) to S3 with considerable effort.
- EMC-wise, the **passenger compartment** (K3S CW-only, 50 W HF) was treated as a 'Faraday cage'. Shielding to the outside measured ≈ −**30 dB on 40 m**, location-dependent (worst near steering wheel).
- The RG-58 U feedthrough to the antenna was bonded to chassis right at the passenger-door entry **(zone concept).**
- At the roof, a ring core choke was placed at the feed. There is an E-field gradient of ≈20 dB between floor pan and roof. **Strict single-point grounding inside avoids loops**.
- A **separate 90 Ah radio battery** was HF-decoupled and charged from the alternator via a DC-DC converter (constant 13.8 V).
- External AC power was never needed during 50 W operation across 30k+ km.

7. HF mobile challenge — Audi A6, HB9CVQ/m, DK2VQ/m (3)





various low bands antenna types tested

7. HF mobile challenge — Audi A6 (4)

- Various antenna prototypes were tested; efficiencies varied widely.
- Magnetic loops were particularly inefficient.
- **Radiator length is critical** but **limited by traffic regulations** (max 4 m from ground to tip). If the roof is ~1.5 m high, little remains.
- **Ground losses** on 80 m (night) and even 40 m (day) are **unfavorable.**
- On **160 m**, both technically and operationally, it's **practically hopeless** (QRPP).
- The EMC zone-protection concept worked reliably across all R&D prototypes.
- One might consider **bonding the car to radials** or even a ground rod when stationary - testing showed little to **no benefit**. This approach is even less feasible in aircraft in flight; you would need an impossible kilometers-long ground lead. (Note: VLF aircraft-to-submarines do use km-long trailing antennas.)
- EMC-wise we do HF potential equalization referenced to any metal fuselage.

7. HF mobile challenge — Audi A6 (5)

- Vehicle suppression (gasoline engine; in 2003 Audi had limited EMC measures): initially up to S9+20 dB of noise
- Relatively short (vs. wave-length) low-band mobile antennas on the roof (best place)
- Autonomous 12 V charger for radio battery
- QRV CW only on low bands, max 50 W HF output
- Due to **low antenna efficiency** ⇒ effectively QRP

  (e.g., 160 m ≈0.1%, 80 m ≈3%, 40 m ≈10% — 50 W → ~5 W radiated)

+ Vehicle self-suppression done with **HF current clamp**; multiple bonding straps on engine, exhaust, etc.
+ **Multiple ground points** in the vehicle create loops; the main 12 V battery negative is on chassis; create a central bond near passenger door where coax shield, TRX K3S chassis, and antenna ground (via metal roof rack to roof rails) are finally brought to the car chassis.
+ EMC disturbances depend on driving state and external environment (QTH). On 40 m CW (400 Hz BW) at 120 km/h on an open highway (K3S/P3, optimized ATAS-120S), the S-meter dropped to S3.
+ **Classic vehicle EMC issues**: ground corrosion, mechanical vibration, temperature; height limit <4 m tip-to-ground; strong wind forces; other vehicles' EMC (>> V/m fields).
+ Potential administrative problems: Operating authorization while driving, insurance/liability, etc.

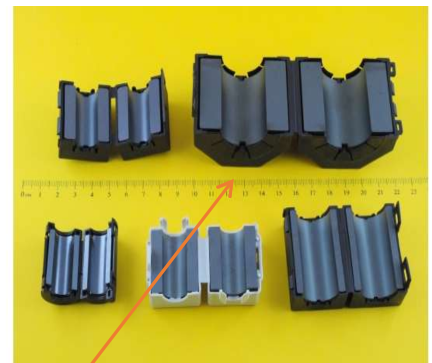
8. Summary and optimized practical recommendations (1)

- Method: lines before fields; find root causes/sources — think system-level EMC! HF-island approach.
- Success is possible if you know what you're doing and have battery-powered, trustworthy instruments.
- Implement the EMC zone-protection concept systematically; create a shack HF island.
- **Avoid**/minimize **coupling-loop areas**; **provide HF reference ground planes**.
- High suppression efficiency (for E, H, I, V) is often challenging at first.
- **Attenuation** for current/voltages E-, H-Fields: **[dB] = 20*log$_{10}$(Vref / V e.g. choke)**;
- **Attenuation** for power: **[dB]= 10*log$_{10}$(Vref / V e.g. choke)**;
- **RX** case: the environment (EM emissions) creates conducted coupling/disturbance currents (dBμV/m, dBμA).
- **TX** case: your own antenna creates the coupling field (V/m, mA).
- Optimized EMC with good cost/benefit for both TX and RX is achievable.
- *Don't think of ground rods first! 'Long' ground leads and lightning protection are useless for EMC*.
- Long water/heating pipe systems often act as disturbance-collecting antennas.
- Desk ground-plate, short bonding straps, mains filters with surge protection, ferrites, etc. ☺

8. Summary and optimized practical recommendations (2)

- Typical example of **cost/benefit for suppression** in both TX and RX — **affordable**.
- **Systematic EMC design**: desk ground-plate; short studs/straps; single-phase mains filters with surge protection; common-mode chokes; snap ferrites/ring cores — component selection, etc.

Useful vendors: https://auth-nt.de https://www.dx-wire.de



Robust und flexibel

EM 800

???

- 1 – 16 A (250 – 4000 W)
- Entstörspektrum 10 kHz – 500 MHz
- Sperrdämpfung bis 70 dB
- robustes Metallgehause
- interne Klemmen (1,5 mm²)
- Überspannungsschutz integriert
- diverse Anschlußkabel optional

Tip: Fair-Rite part no. #0444177081,
~25 mm ID, useful ~1 MHz→~500 MHz.
On HF, 3–4 turns usually suffice for ~20 dB.

HAM Radio YLs, OMs

Thank you all for your Time

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

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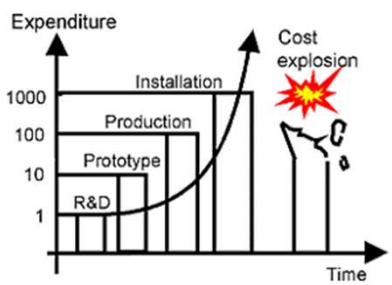

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