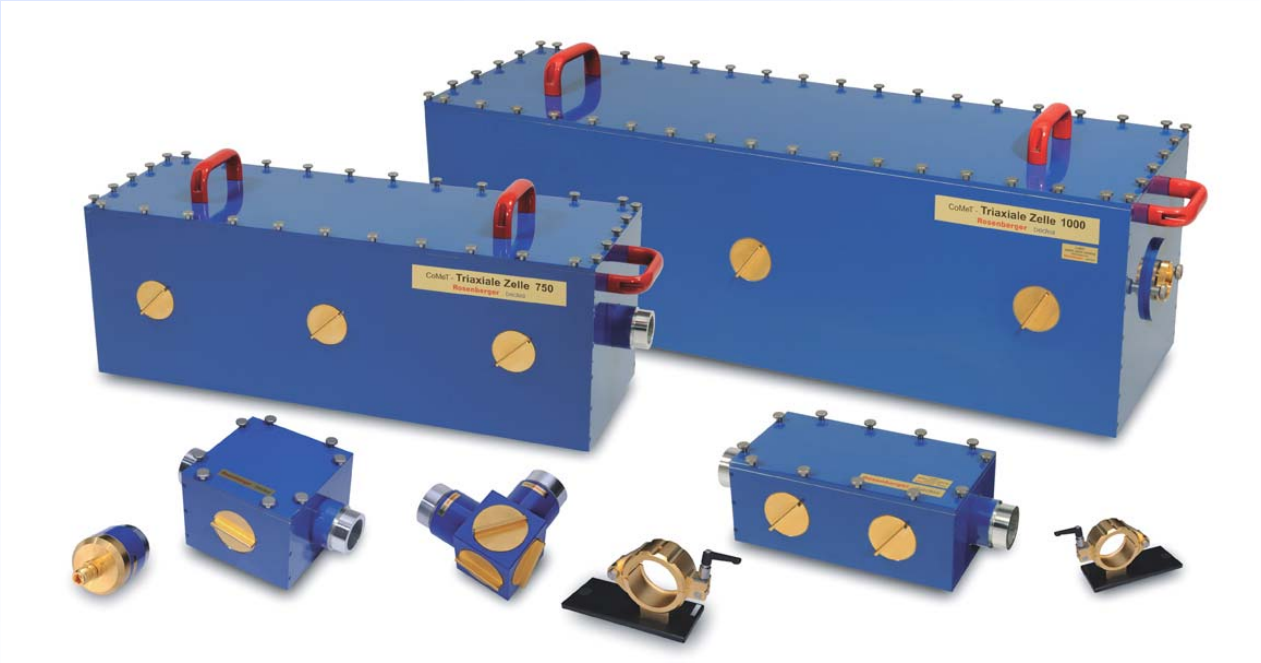
EMC of HV-Cables and Cords with Triaxial Cell

Bernhard Mund, *bedea*, bmund@bedea.com, Thomas Schmid, Rosenberger Hochfrequenztechnik, thomas.schmid@rosenberger.de

Triaxial Cells (CoMeT angled housings)



Bernhard Mund, *bedea*, bmund@bedea.com, Thomas Schmid, Rosenberger Hochfrequenztechnik, thomas.schmid@rosenberger.de

Authors

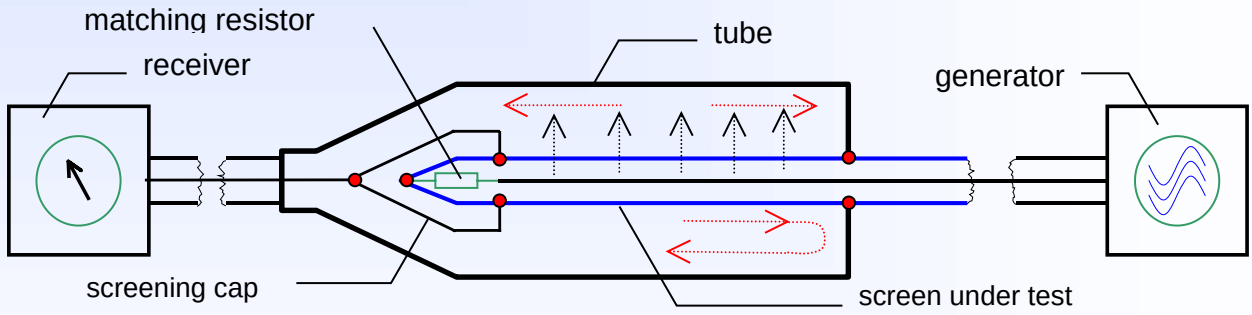
- Bernhard Mund, *bedea* Berkenhoff & Drebes GmbH, Asslar
  - *Radio&TV-Technician, Radio Brand Marburg, 1971*
  - *Dipl.-Ing. Telecomm.- & Microprocessor Technologies, FH Giessen,1984*
  - Head of R&D Department cables & RF- & EMC-Measurements,
  - Chairman of UK 412.3, Koaxialkabel, (German NC),
  - Secretary of IEC SC 46A and of CENELEC SC 46XA, Coaxial cables
- Thomas Schmid, Rosenberger HF-Technik, Tittmoning
  - *Telecommunications-Technician, Deutsche Bundespost, Traunstein 1988*
  - *Dipl.-Ing.(FH) Telecommunication Technologies, FH Munich 1995*
  - Development of RF-Connectors & Components, RF-&EMC-Measurements
  - Member of UK 412.3, Koaxialkabel, (German NC),
  - Member of IEC TC 46 WG 5, Screening eff. & of WG 6, Intermodulation

Content

Principle of the Triaxial test set-up *CoMeT*

Transfer impedance & Screening attenuation

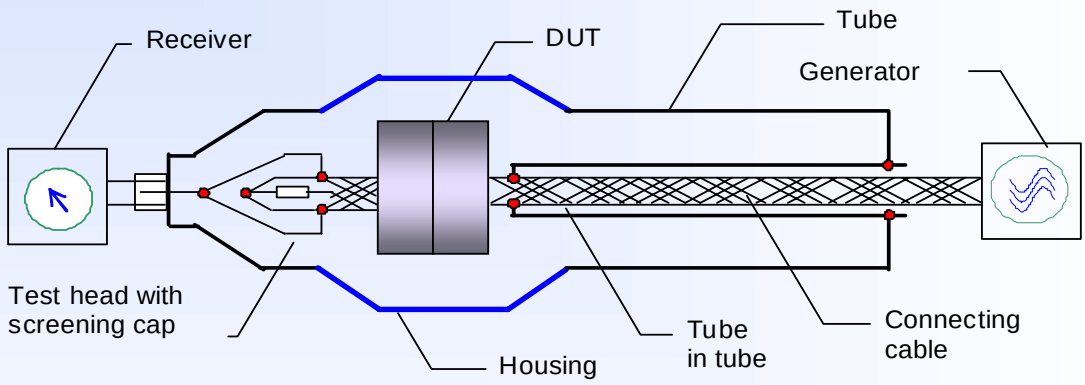
DC up to and above 8 (12) GHz with one test set-up

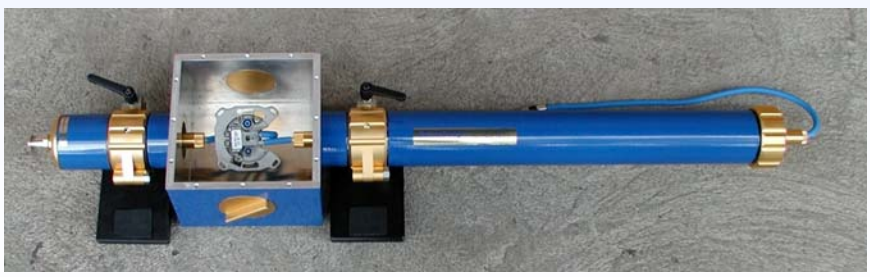


Generator and receiver are included in a modern network analyser

IEC 62153-4-3 Transfer impedance, IEC 62153-4-4 Screening attenuation
IEC 62153-4-9 Coupling attenuation
EN 50289-1-6 EMC on Communication cables

Principle of Triaxial Cell with „Tube in tube“



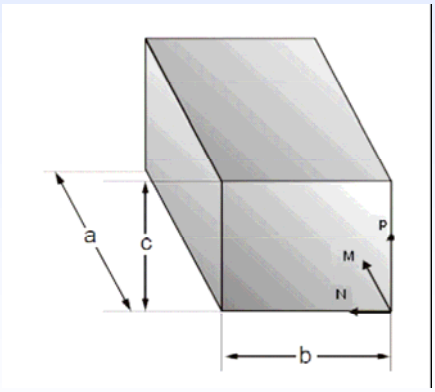


IEC 62153-4-7,
“Tube in tube“ - procedure (Connectors and assemblies) with „Triaxial Cell“ is under consideration at IEC TC 46/WG 5

Higher Order Modes of Cavity

Resonance frequencies:

$$f_{mnp} = \frac{c_0}{2}\sqrt{\left(\frac{M}{a}\right)^2 + \left(\frac{N}{b}\right)^2 + \left(\frac{P}{c}\right)^2}$$



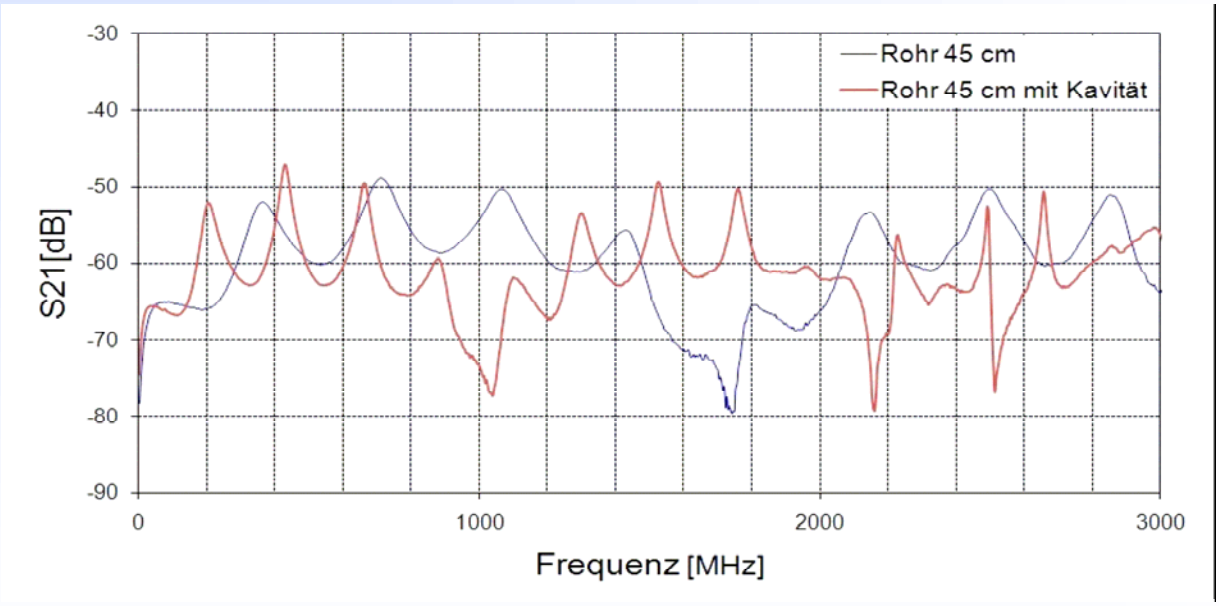
m, n, p: numbers of higher order modes
(whole numbered, 2 of 3 >0)
a, b, c: size of cavity

a = 13.6 cm, b = 13.6 cm, c = 9.9 cm

m	n	p	f in GHz
1	1	1	2,15
1	2	0	2,40
0	2	1	2,63
1	2	1	2,84
2	2	0	3,04
0	1	2	3,22
1	1	2	3,39
2	2	1	3,40
0	2	2	3,71
1	2	2	3,87
2	3	0	3,87

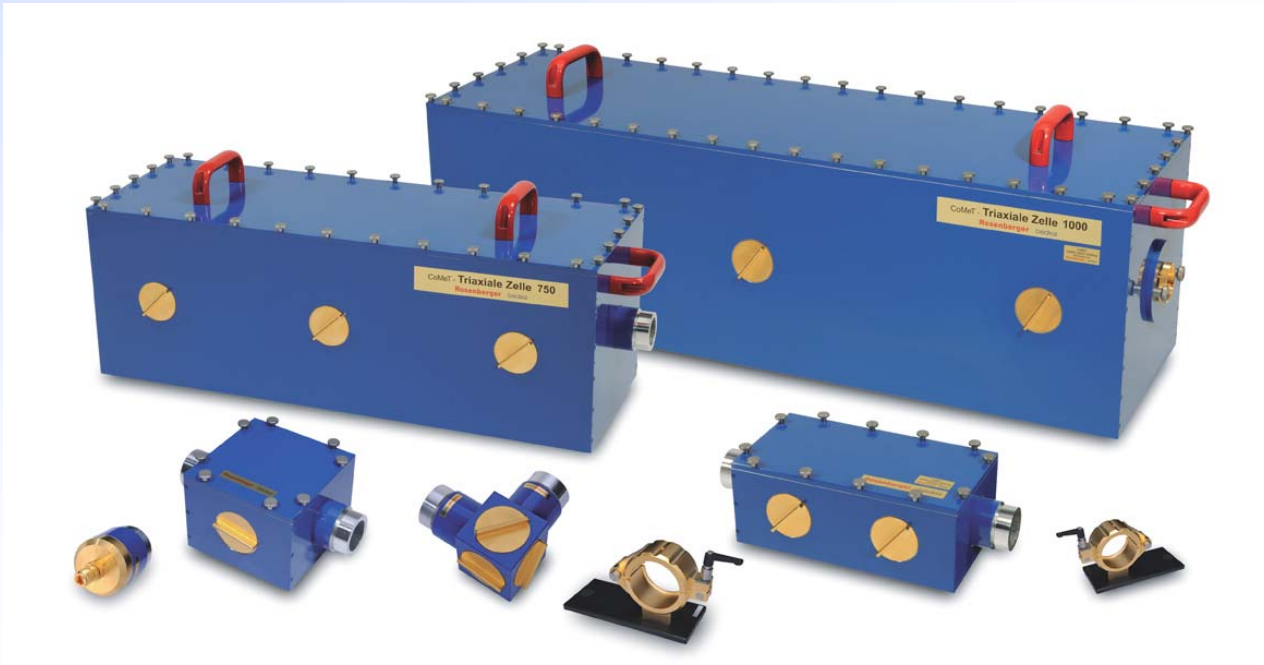
Results from Prof. Münzner et al, University of Ulm

Measurements, Tube vs. Cavity



Results from Prof. Münzner et al, University of Ulm

Triaxial Cells (CoMeT angled housings)



Higher Order Modes of Cavity

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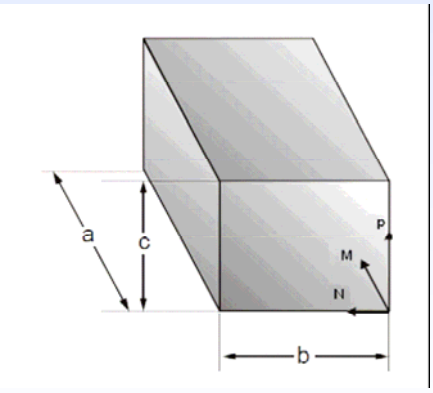

m, n, p: numbers of higher order modes (whole numbered, 2 of 3 >0)
a, b, c: size of cavity

750-er Zelle

a	b	c
750	250	250

m	n	p	f/GHz
1	1	1	0,87
1	2	0	1,22
0	2	1	1,34
1	2	1	1,36
2	2	0	1,26
0	1	2	1,34
1	1	2	1,36
2	2	1	1,40
0	2	2	1,70
1	2	2	1,71
2	3	0	1,84

1000-er Zelle

a	b	c
1000	300	300

m	n	p	f/GHz
1	1	1	0,72
1	2	0	1,01
0	2	1	1,12
1	2	1	1,13
2	2	0	1,04
0	1	2	1,12
1	1	2	1,13
2	2	1	1,16
0	2	2	1,41
1	2	2	1,42
2	3	0	1,53

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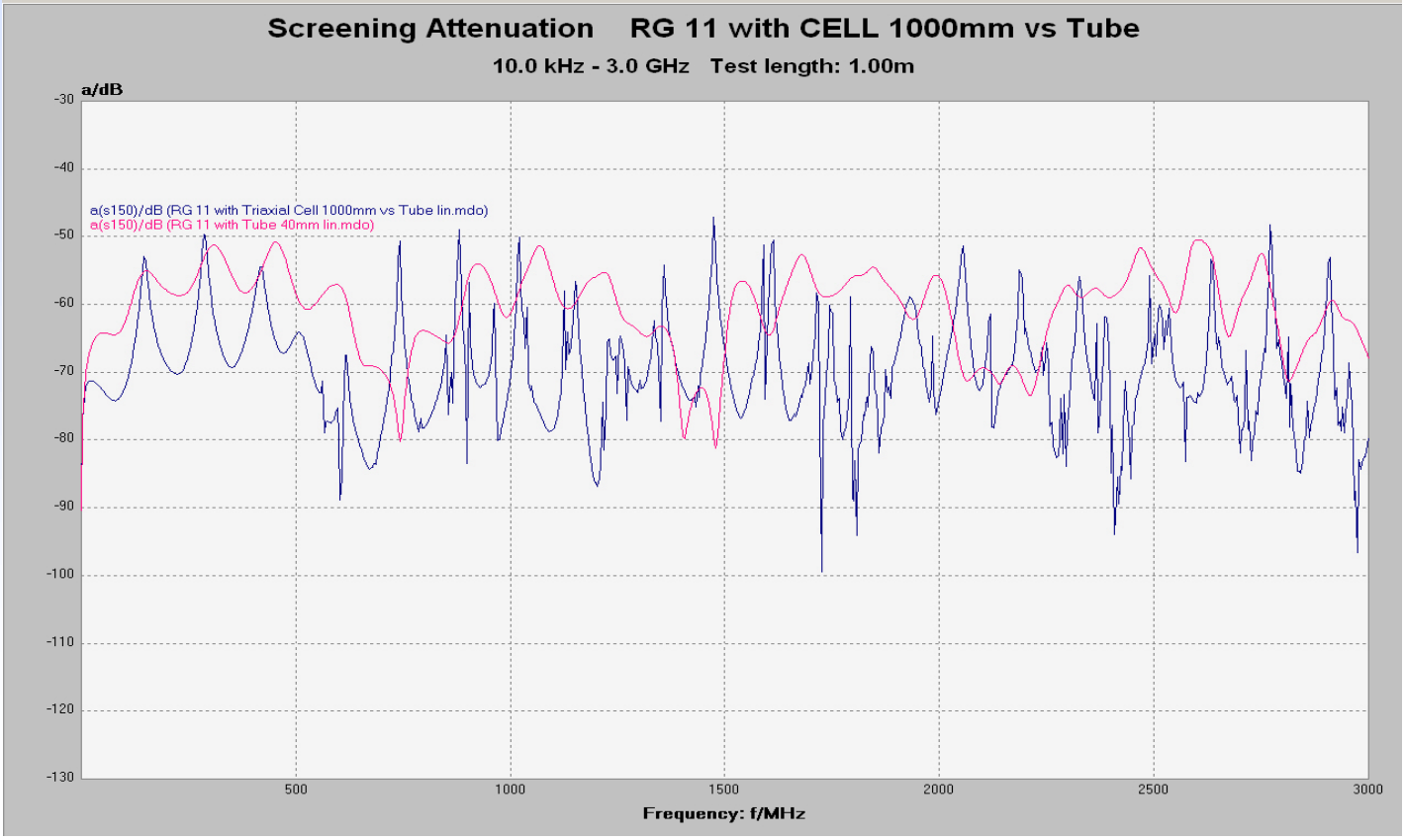

EMC of HV-Cables and Cords with Triaxial Cell
Rosenberger bedea

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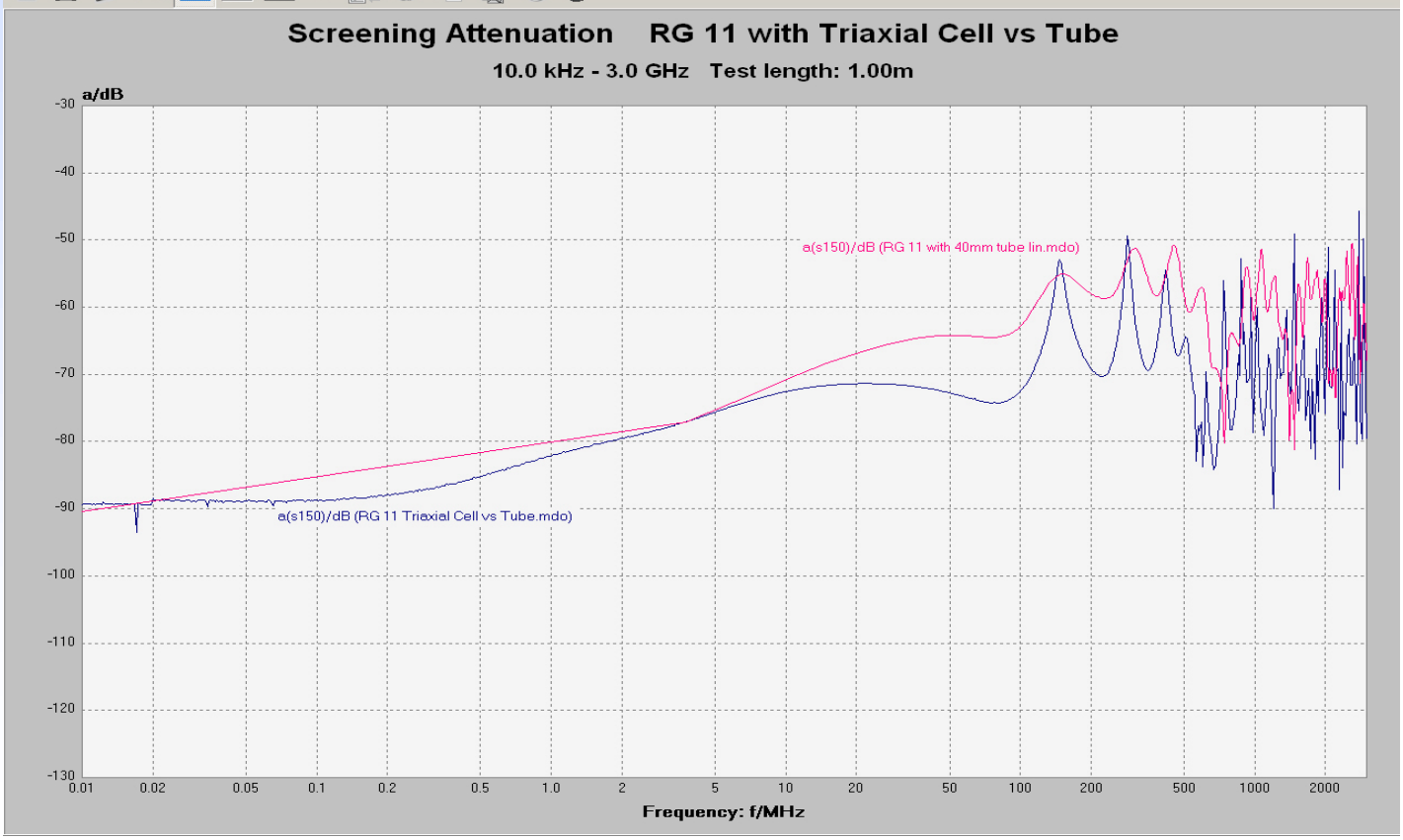
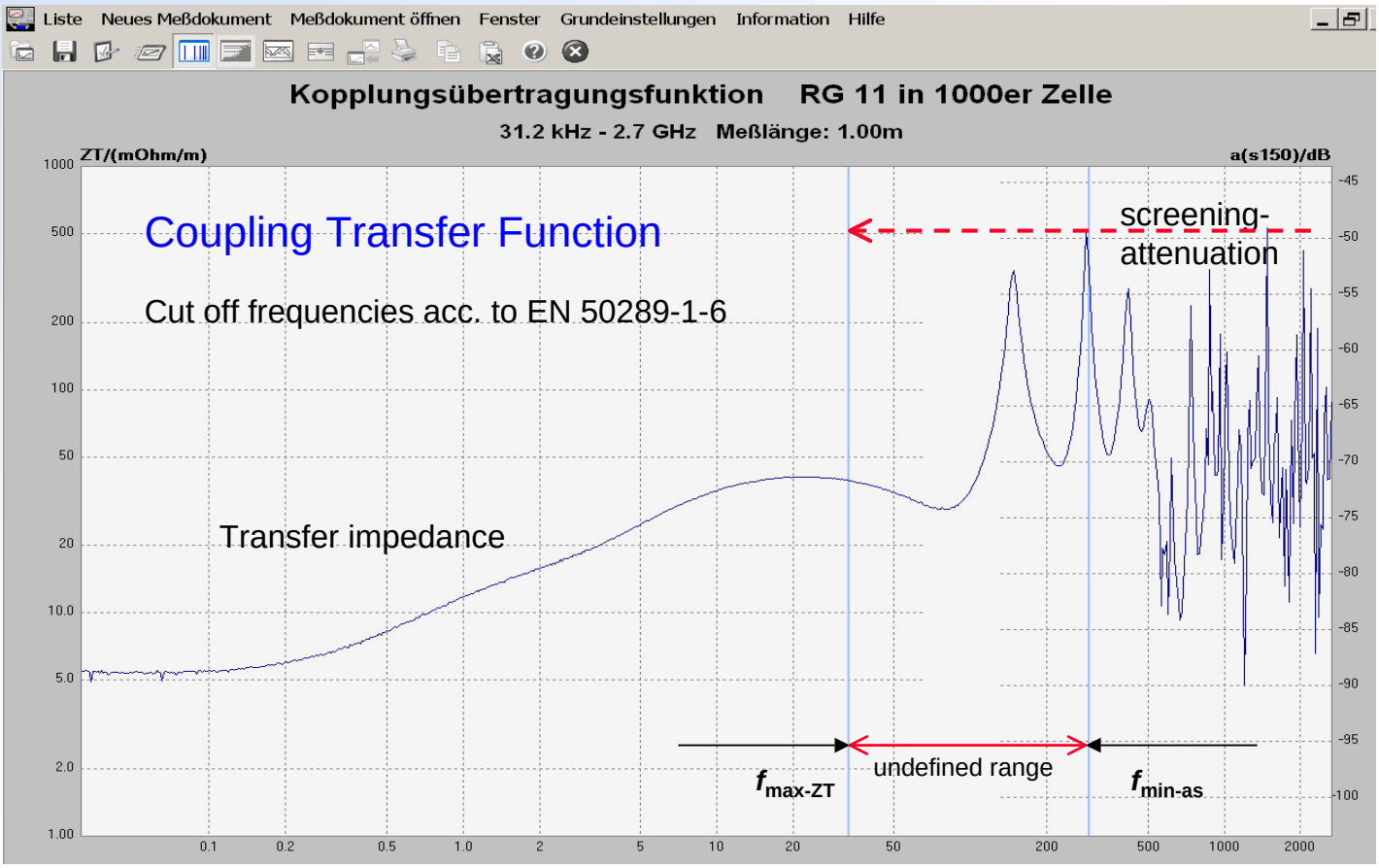
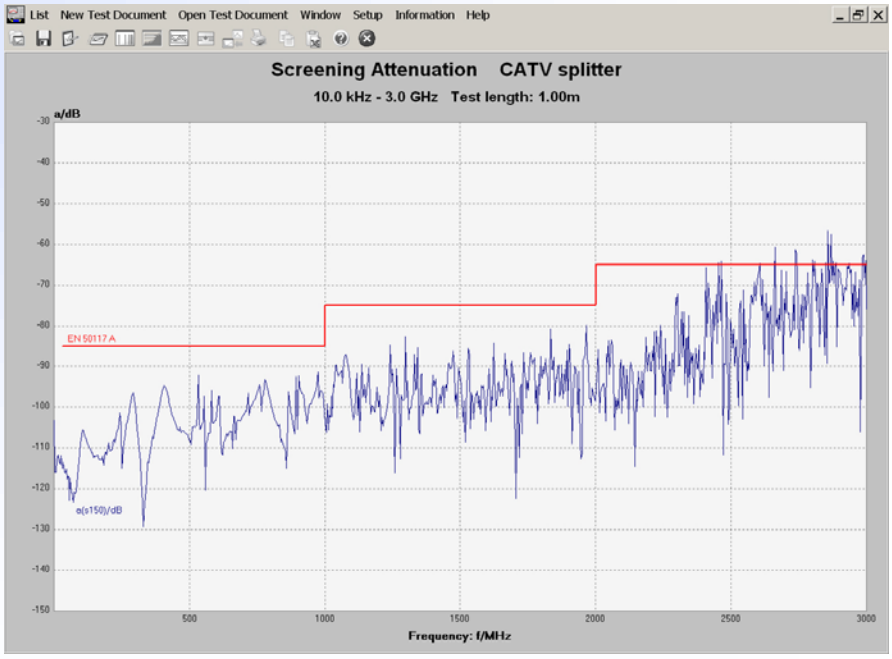
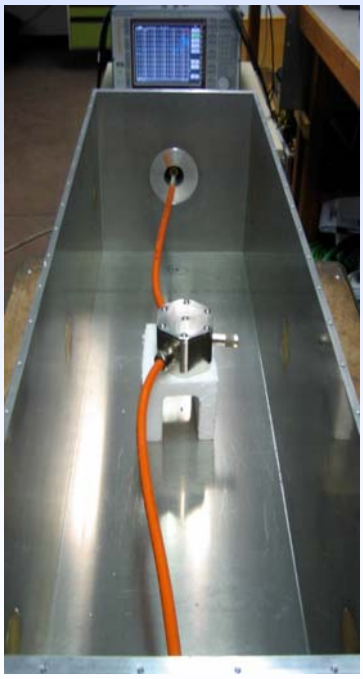


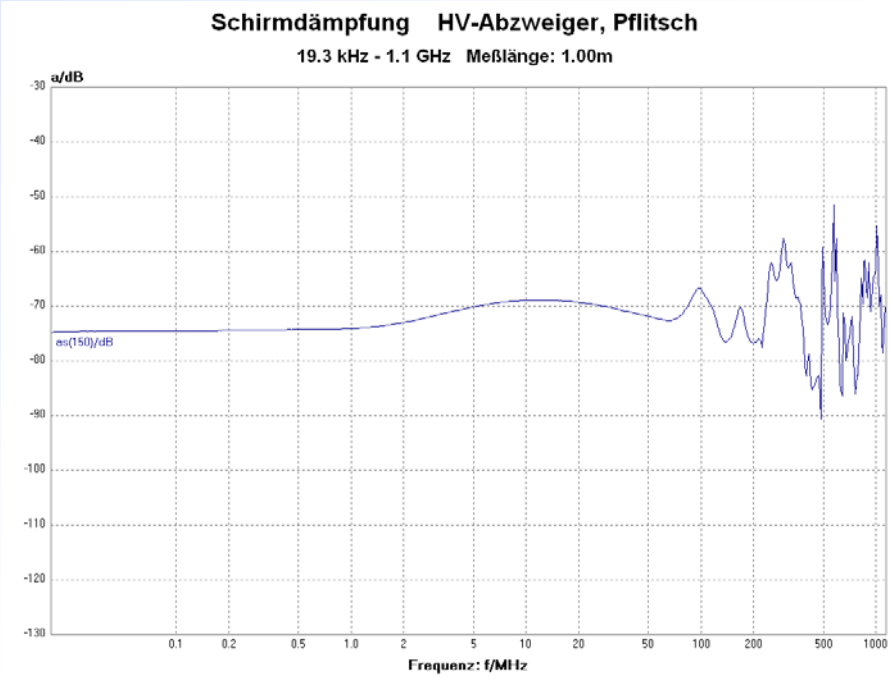


CATV power splitter with Triaxial Cell

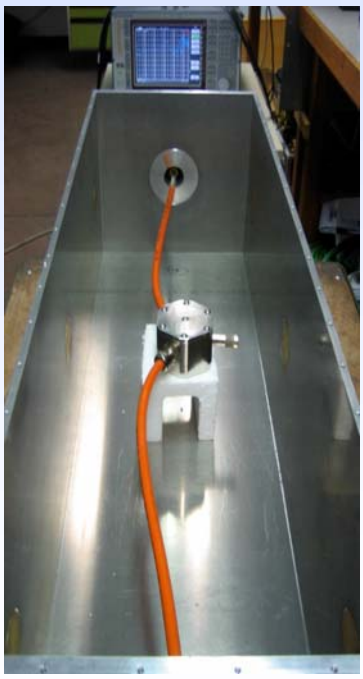


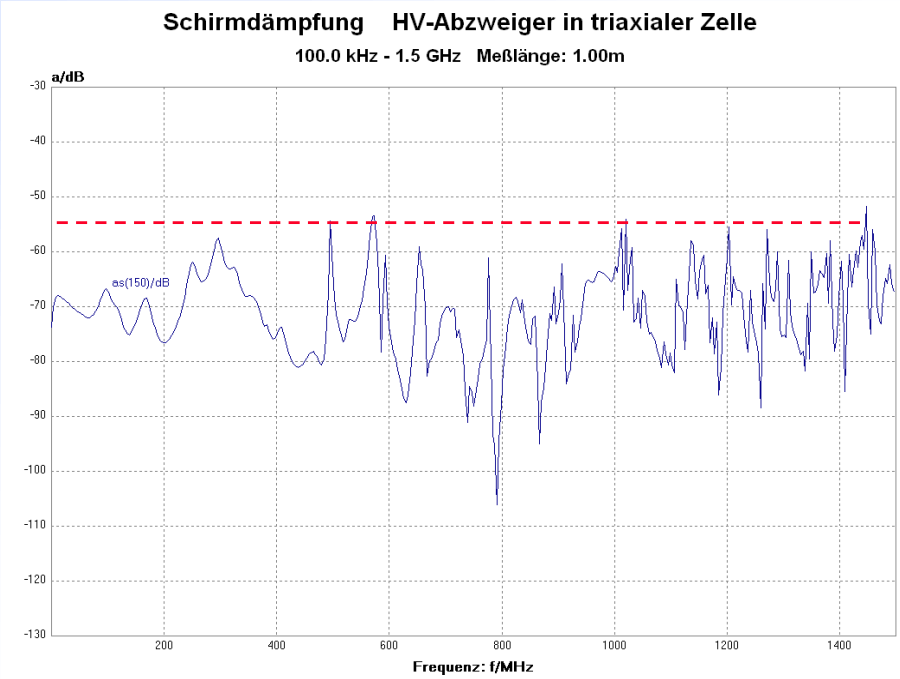
Power splitter for HV-cord (Pflitsch)





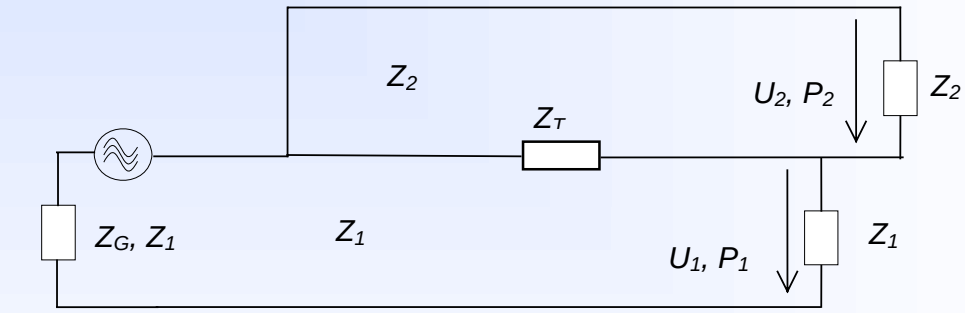
Power splitter for HV-cord (Pflitsch)

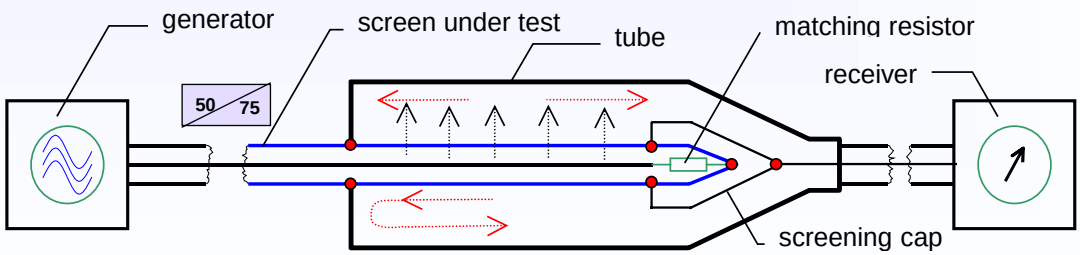




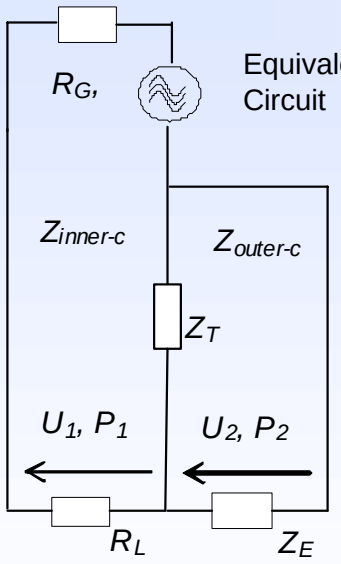
Measuring with mismatch (Thomas Schmid)

Revision of der IEC 62153-4-3, Transfer impedance, Triaxial test procedure

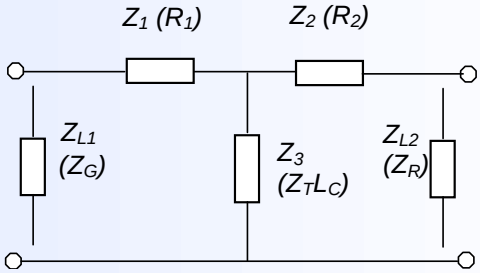




Equivalent circuits for Triaxial test procedure



$$Z_T = R_T + j\omega M_T$$



T-circuit

R1 = matching resistor of inner circuit
R2 = matching resistor of outer circuit
ZT = Transfer impedanc of DUT
ZG = generator-resistor
ZR = receiver-resistor
LC = coupling length

IEC 62153-4-3,Ed2:
(simplified, $Z_T << Z_G Z_R$)

$$Z_T = \frac{(R_1 + Z_G)\cdot(R_2 + Z_R)}{2\cdot\sqrt{Z_R \cdot Z_G}} \cdot \frac{S_{21}}{L_C}$$

measured

S-Parameter for T-circuit

Comprehensive derivation of S_{21} resp. Z_T frrom T-circuit

$$S = \begin{bmatrix} 1 - \frac{2\,(Z2+Z3+Zl2)\,Zl1}{Zl\,Z2+Zl\,Z3+Zl\,Zl2+Z3\,Z2+Z3\,Zl2+Zl1\,Z2+Zl1\,Z3+Zl1\,Zl2} & 2\,\frac{\sqrt{Zl1}\,Z3\,\sqrt{Zl2}}{Nenner} \\ 2\,\frac{\sqrt{Zl1}\,Z3\,\sqrt{Zl2}}{Nenner} & 1 - \frac{2\,(Z1+Z3+Zl1)\,Zl2}{Nenner} \end{bmatrix}$$

S_{21}

Quelle: Heuermann Hochfrequenztechnik, S. 295

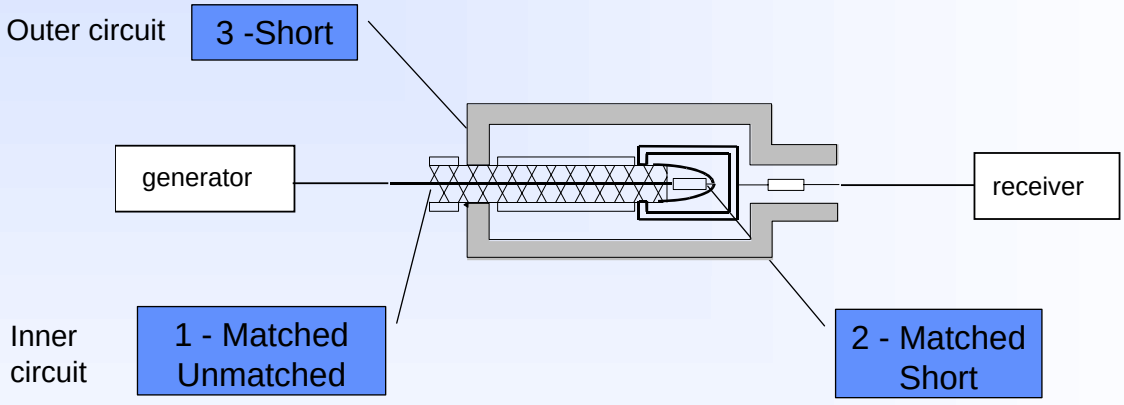
$$S21 = 2 \cdot \frac{\sqrt{ZL1} \cdot Z3 \cdot \sqrt{ZL2}}{Z1 \cdot Z2 + Z1 \cdot Z3 + Z1 \cdot ZL2 + Z3 \cdot Z2 + Z3 \cdot ZL2 + ZL1 \cdot Z2 + ZL1 \cdot Z3 + ZL1 \cdot ZL2}$$

$$Z3(Z1, Z2, ZL1, ZL2, S21) := S21 \cdot \frac{Z1 \cdot (Z2 + ZL2) + ZL1 \cdot (Z2 + ZL2)}{(-S21) \cdot (Z1 + Z2 + ZL2 + ZL1) + 2 \cdot \sqrt{ZL1 \cdot ZL2}}$$

($Z3 = Z_T$)

valid for low frequencies and for any load

Matching conditions

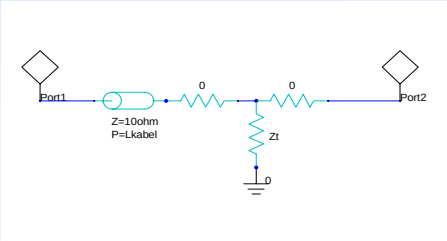


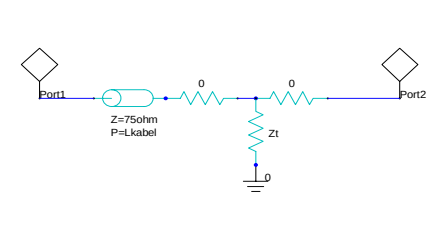
Unmatched-Short-Short
Matched-Short-Short
Unmatched-Matched-Short
Matched-Matched-Short

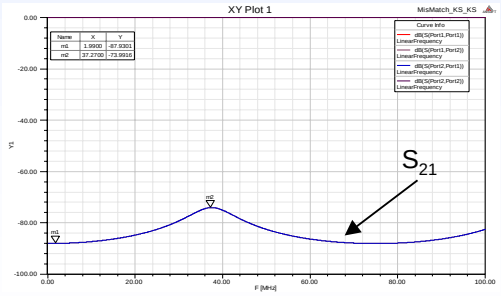
1 = Generator- DUT, (with matching device)
2 = Prüfling – matching resistor (far end of the generator)
3 = outer conductor of DUT - Tube (short circuit)

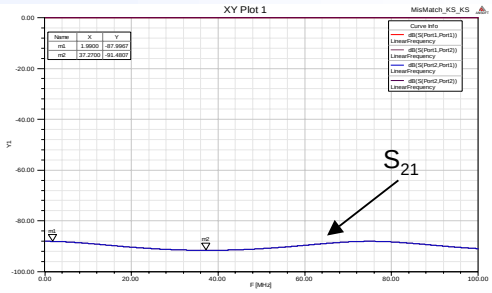
Unmatched-Short-Short (with network simulator)

- Impedances of cables: 10 Ohm vs 75 Ohm
- L_{cable}= 2m, Z_T = 1mOhm





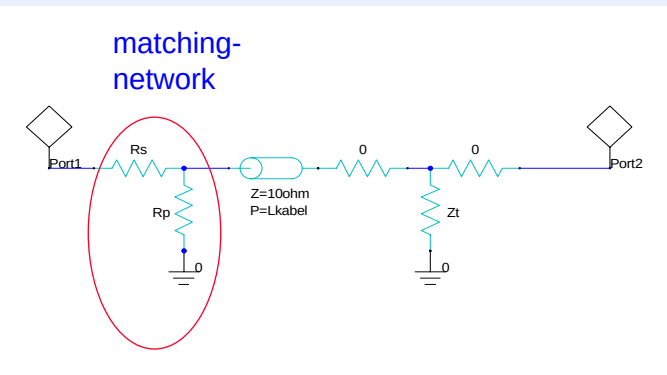


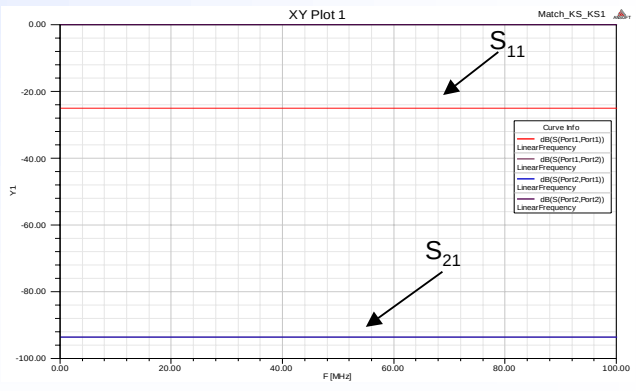


Matched-Short-Short (with network simulator)

- L_{cable} = 2m, Z_T = 1mOhm
- Char. Impedance of cable: 10 Ohm
- Matching network, R_s = 44.7 and R_p =11.2 Ohm

Matching network
resp. matching pad required

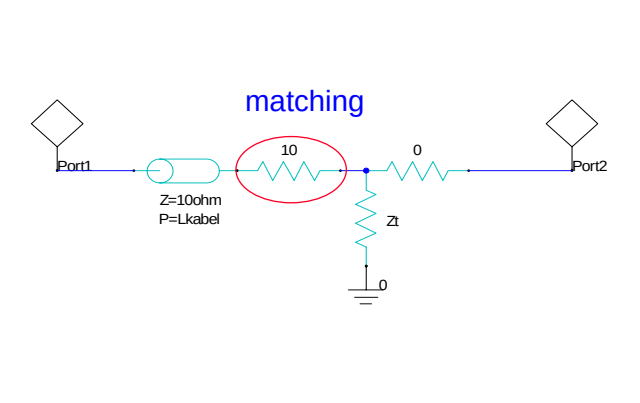


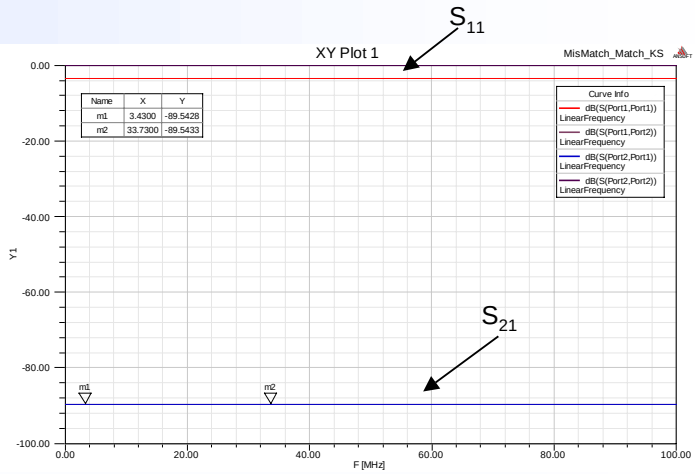


Unmatched-Matched-Short (with network simulator)

- L_{cable} = 2m, Z_T = 1mOhm
- Char. Impedance of cable: 10 Ohm
- R_1 = 10 Ohm

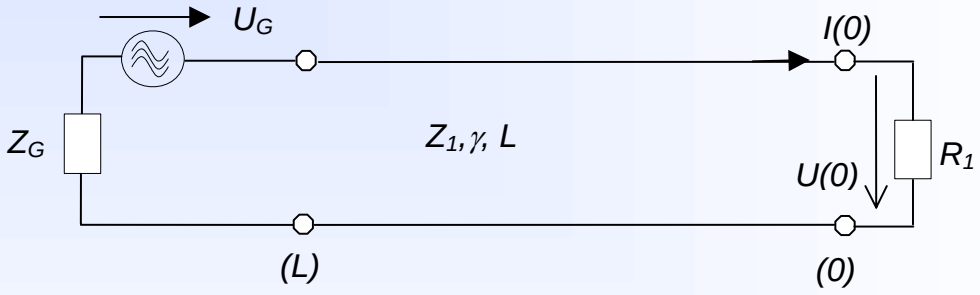
simply realizable
with commercial available resistor !





Current distribution on extended systems

Inner system with source- und load impedance



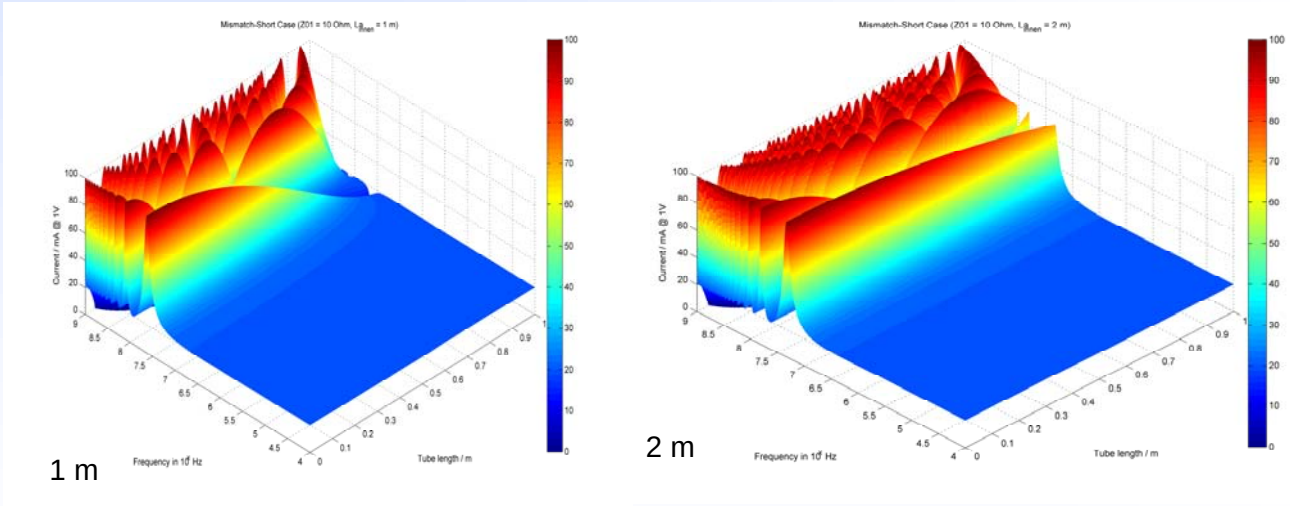
current I(0) at load:

$$I(0) = \frac{U_G}{R_1 \cdot [\cosh(\gamma L) + \frac{Z_G}{Z_1}\sinh(\gamma L)] + Z_1 \cdot [\sinh(\gamma L) + \frac{Z_G}{Z_1}\cosh(\gamma L)]}$$

current depending on length x

$$I(x) = I(0) \cdot \cosh(\gamma x) + U(0) / Z_1 \cdot \sinh(\gamma x)$$

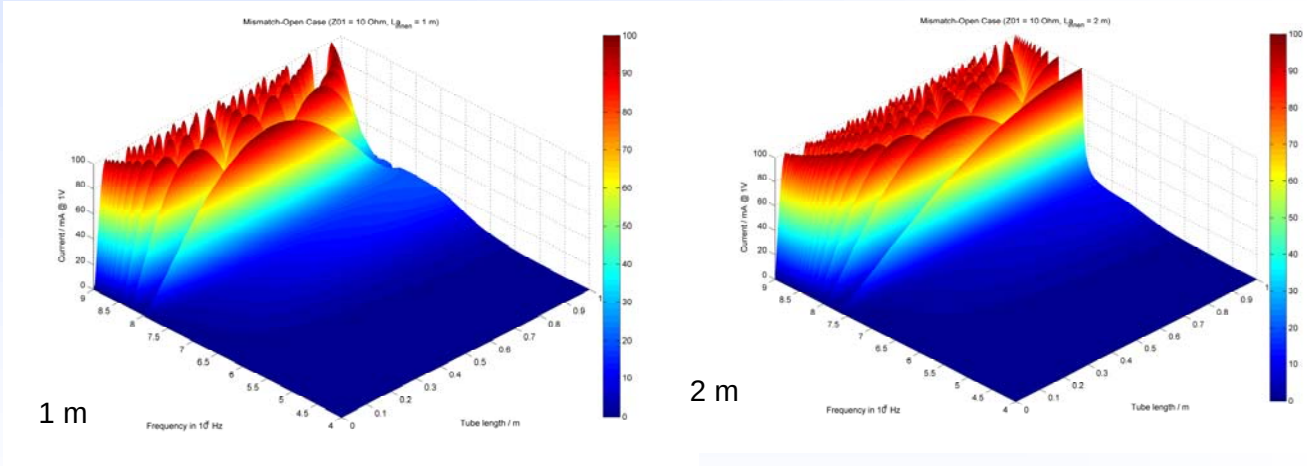
Distribution of current vs. length at short circuit, left side, 1m & 2m



1 m

2 m

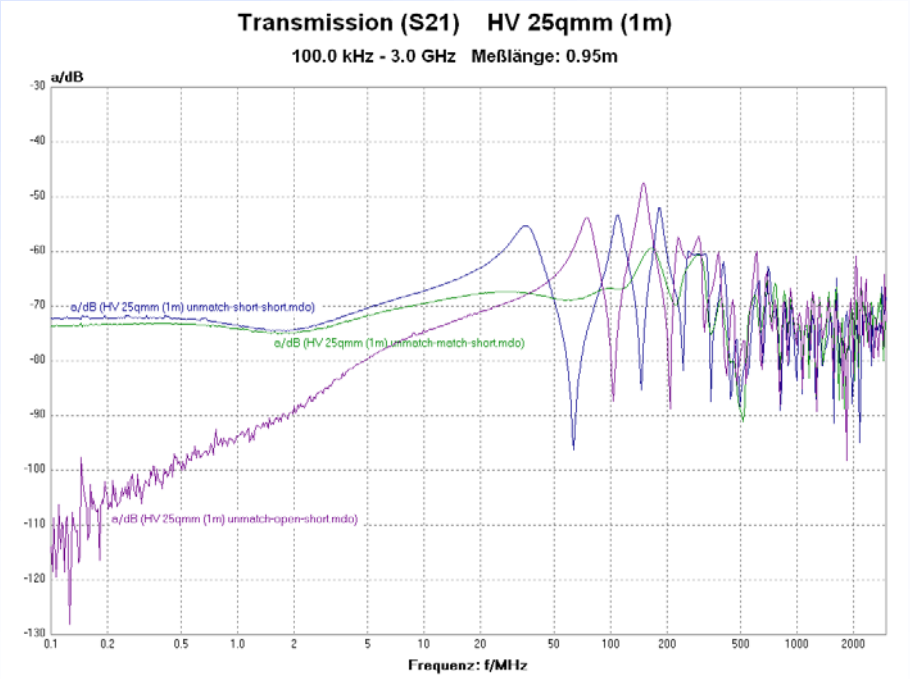
Distribution of current vs. length at open circuit, right side, 1m & 2m



1 m

2 m

Test results – open circuit, short circuit & matching



Conclusion 1

- The **Screening effectiveness** of Communication cables is described in the lower frequency range by the **Transfer impedance Z_T** and in the upper frequency range by the **Screening attenuation a_S**.
- For measurements of larger components, the Triaxial procedure may be extended by **"Triaxial Cells".**
- Depending on the size of the cell, higher modes occur at about **720 MHz** with the 1000er Cell and at about **870 MHz** with the 750er Cell,
- Measurements in the Cell up to the resonanz frequencies are identical, compared to the measurements in the tube.
- Measurements above the resonance frequencies in the **Triaxial Cell** are within the range of **< 3 dB**.
- With the **Coupling Transfer Function, (CTF),** Transfer impedance Z_T and Screening attenuation a_S may be depicted in one diagramm.
- Measurint the EMC of Cables and Cords with the **"Triaxial Cell"** is under consideration at IEC TC 46/WG5 as revision of **IEC 62153-4-7.**

Conclusion 2

- The Standard **IEC 62153-4-3** is in revision at IEC TC 46/WG 5 **(46/371/CD),**
- Different procedures are described:
  - Matched-Matched-Short,
  - Matched-Short-Short,
  - Unmatched-Matched-Short.
- HV-cables and cords for Electric vehicles have a Characteristic impedance of about **10 Ohm to 12 Ohm** and are not match to common Networkanalysers.
- At least one side of the DUT shall be matched, (far end).
- Unmatched-Matched-Short procedure is easy to use at 10 Ohm cords.
- The length out of the test set-up shall be as short as possible.
- The changes of **IEC 62153-4-3** are already included into the new **WinCoMeT** Software.
- The considerations above regarding the matching of the different test procedures are valid for both, **Tube** and **Triaxial Cell** procedure

International Standards for Triaxial test procedure

IEC TR 62153-4-1	Introduction to EMC measurements	2010-05
IEC 62153-4-3Ed2	Surface transfer impedance - Triaxial method	(46/371/CD)
IEC 62153-4-4	Shielded screening attenuation, test method for measuring of the screening attenuation "a_s" up to and above 3 GHz	2006-05
IEC 62153-4-7	Shielded screening attenuation, test method for measuring the Transfer impedance Z_T and the screening attenuation a_S of RF-Connectors up to and above 3 GHz; Tube in Tube method	2006-04
IEC 62153-4-9 IEC/PAS 62338 Ed1	Coupling attenuation, triaxial method	2008-03
IEC 62153-4-10	Shielded screening attenuation test method for measuring the Screening Effectiveness of Feedtroughs and Electromagnetic Gaskets	2009-05
EN 50289-1-6	Communication cables - Specifications for test methods Part 1-6: Electrical test methods -Electromagnetic performance (includes IEC 62153-4-3 and IEC 62153-4-4)	2002

Literatur

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[2] Bernhard Mund: EMV von Steckverbindern und Verbindungskabeln, 4. Anwenderkongress Steckverbinder 2010, Vogel Verlag, Würzburg,

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