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EXPERT REPORT

31th of May 2019

Ordered by: **GEOVITAL**
Akademie für Geobiologie und Strahlenschutz
Unterwolfbühl 430
A-6934 Sulzberg

Device under Test: Shielding paint ***T98,*** two specimen on a 3mm wooden panel single coated (8 sqm/1 liter),
double-coated (4 sqm/1 Liter),
triple-coated (2,7 sqm/1 Liter)

Subject: Measuring the shielding efficiency against electromagnetic waves from 100 MHz to 40 GHz

Regulations: ASTM D-4935-10 (ASTM = American Society of Testing and Materials)and IEEE 299-2006 and MILSTD 285

Date of Measurements: 28th of May 2019

Content: 6 pages of text and 3 appendices

Results: The shielding paint ***T98*** has been tested with electromagnetic waves showing polarizations in all directions. The results of the shielding efficiency are valid as well for vertically as also for horizontally polarized waves. Table 1 presents the values of shielding efficiency (SE), measured at some interesting frequencies:

Shielding paint T 98	Shielding efficiency in dB		
Communication system:	Single	Double	Triple coated
C-Net, TETRA, 450 MHz	**40 dB**	**49**	**51 dB**
D-Net, GSM900, 900 MHz,	**40 dB**	**49**	**52 dB**
E-Net, GSM1800, 1800 MHz	**41 dB**	**52**	**56 dB**
Blue-Tooth, WLAN 2450 MHz	**42 dB**	**54**	**58 dB**
5G (Sub 6GHz-Band) 3,4 – 3,8GHz	**41 dB**	**53**	**60 dB**
W-LAN new generation 5,8 GHz	**42 dB**	**52**	**66 dB**

Table 1: Shielding efficiency at different frequencies

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1. Introduction

To analyse the measured diagram, it is helpful to use this table. You can easily find the relation between shielding in „dB“ and transmitted power in „%“.
To calculate the dB-value from the incident power P_1 respectively field strength E_1 and the transmitted power P_2 or field strength E_2, one has to use the following

equation: $$a_{Shield} = 10 \cdot log \frac{P_2}{P_1} = 20 \cdot log \frac{E_2}{E_1} \quad in\ decibel\ (dB)$$

The network analyzer presents the results of the shielding measurements in „Decibel“ (dB). The mode of measurement is a typical transmission measurement (S_{21}-measurement).
This dB value indicates, how much the level of an incident power or power flux density has decreased, passing the device under test.

It describes values of field-strengths as well. But the calculation of the percent-values in the table at the right refers to the **power-relationships**.
So it tells - for example - that 20 dB shielding reduces the penetrating power down to 1%.

Conversion of Decibel to Percent of transmitted Power			
dB	**Power Transmission in %**	**dB**	**Power Transmission in %**
0	100.00		
1	81.00	21	0.78
2	62.80	22	0.63
3	50.00	23	0.50
4	40.00	24	0.39
5	31.00	25	0.31
6	25.00	26	0.25
7	20.00	27	0.20
8	16.00	28	0.18
9	12.50	29	0.12
10	10,00	30	0.10
11	7.90	31	0.08
12	6.25	32	0.06
13	5.00	33	0.05
14	4,00	34	0.04
15	3.13	35	0.03
16	2.50	36	0.02
17	2.00	37	0.02
18	1.56	38	0.02
19	1.20	39	0.02
20	1.00	40	0.01
		50	0.001
		60	0.0001

Table 2: Conversion of shielding-efficiency-values, given in dB, to %-values of transmitted power

2. Measurement Setup according to ASTM D 4935-10 from 100 MHz to 8 GHz

This standard was published by the American Society of Testing and Materials (ASTM).

The DUT (**D**evice **U**nder **T**est) was installed between two coaxial TEM-adapters. The test signal was emitted from port 1 of the network analyzer. The transmitted signal was received by port 2 of the NWA. During a S_{21}-calibration without DUT but with a neutral distance holder of the same thickness as the DUT, the transmission value was set to “0” dB.

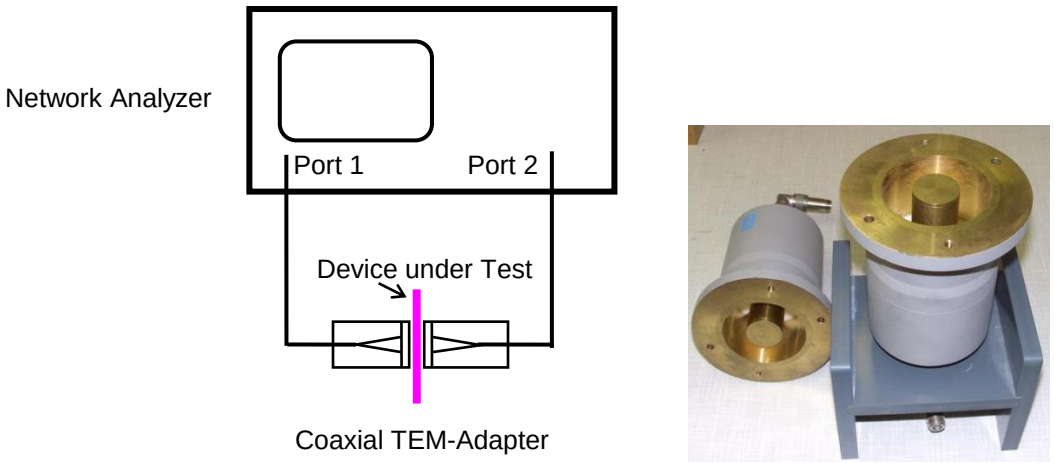

Fig. 1: Set-up to measure the shielding efficiency by means of TEM-adapters

Test equipment:

Vector Network Analyzer, type ZVRE, 30 kHz – 8 GHz, Rohde & Schwarz
A pair of coaxial TEM-Adapters, (100 kHz – 8 GHz) Wandel + Goltermann
Documentation: OfficeJet 500, H & P

Due to the coaxial structure of the adapters they transmit a TEM-wave. Thus the DUT was hit by **E-field vectors in all transverse directions**.
The consequence is: If the measured shielding efficiency is very good, you can assume, that the DUT will shield as well against vertically as also against horizontally polarized waves in the same good quality.
The results correspond closely to the reality, where the polarization of the incident waves normally cannot be predicted.

2.1 Shielding measurements according to IEEE 299-2006 from 6 GHz to 40 GHz

The measurements were performed according to IEEE 299 on 28th of May 2019 at the EMC-test site of the Radar Laboratories at the German Armed Forces University Munich in Neubiberg at frequencies from 20 GHz to 40 GHz. Linear polarization was radiated by the exponential horn antennas. Normally, the device under test is attached to a specific aperture (height 40 cm, width 40 cm) as shown in the picture below in a metallic shelter wall.

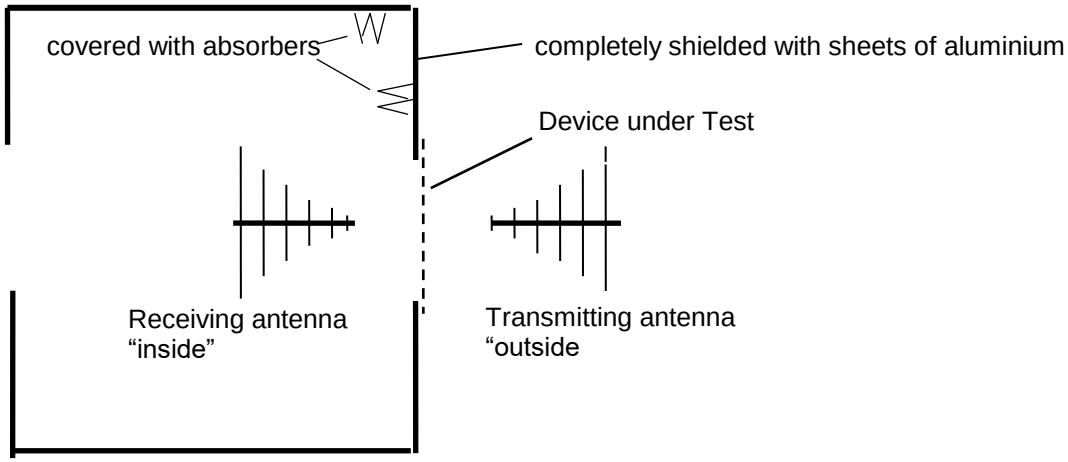

Fig. 1 Setup for Shielding Measurements (schematically)

The test range was calibrated without any object between the two antennas, to adjust the zero-dB-transmission-value.

To prevent signals passing the DUT uncontrolled, the samples were positioned directly between the two exponential horn antennas.

Test equipment:

Scalar Networkanalyzer type 562+6669B (10 MHz – 40 GHz) Wiltron
2 Double horn antennas (20 GHz – 40 GHz) HF 906 (1 GHz – 18 GHz) R&S

Scalar Networkanalyzer type 562+6669B (10 MHz – 40 GHz) Wiltron
2 K-Band exponential horn antennas (20 GHz – 40 GHz) NARDA

3. Results of the Measurements

The diagram in the appendix presents the measured transmission values i.e. shielding efficiency of the shielding paint ***T98*** in decibels as a function of frequency. At the right of the diagram, some dB-values are printed for some typical frequencies of mobile services.

Shielding paint T 98	Shielding efficiency in dB		
Communication system:	Single	Double	Triple coated
C-Net, TETRA, 450 MHz	**40 dB**	**49**	**51 dB**
D-Net, GSM900, 900 MHz,	**40 dB**	**49**	**52 dB**
E-Net, GSM1800, 1800 MHz	**41 dB**	**52**	**56 dB**
Blue-Tooth, WLAN 2450 MHz	**42 dB**	**54**	**58 dB**
5G (Sub 6GHz-Band) 3,4 – 3,8GHz	**41 dB**	**53**	**60 dB**
W-LAN new generation 5,8 GHz	**42 dB**	**52**	**66 dB**

Table 3: Shielding efficiency at different frequencies

Device under Test: Shielding paint ***T98,*** two specimen on a 3mm wooden panel double-coated (4 sqm/1 liter) and triple coated (2,7 sqm/1 Liter)

Subject: Measuring the shielding efficiency against electromagnetic waves from **20 GHz to 40 GHz**

Regulations: According to IEEE 299-2006 and MILSTD 285
Scalar Networkanalyzer type 562+6669B (10 MHz – 40 GHz) Wiltron
2 K-Band exponential horn antennas (20 GHz – 40 GHz) NARDA

Date of Measurements: 28th of May 2019

Results:

Frequency	20 GHz	25 GHz	30 GHz	35 GHz	38 GHz	40 GHz
Geovital T98 4 qm/Liter	**50 dB**	**49 dB**	**47 dB**	**40 dB**	**40 dB**	**38 dB**
2,7 qm/Liter	**55 dB**	**50 dB**	**47 dB**	**44 dB**	**42 dB**	**41 dB**

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4. Final conclusions

In the most interesting frequency range of **GSM 900 (at 900MHz)** the shielding paint ***T98*** presents single coated a shielding effectiveness of **40 dB.** After this shielding only **0.01%** of the incident power will appear behind the single layered fabric. Double layered coating shields nearly 5**0 dB**. Now only **0.006%** of the power will penetrate.

Even at the new **5G-Cellphone-Services** between **3.4GHz and 3.8GHz**, the shielding of the ***T98*** is single layered **41dB,** double **53 dB** and triple layered **60 dB**. Less than **0.01%** respectively less than **0.0001%** of the incident power can be measured behind the coated specimen.

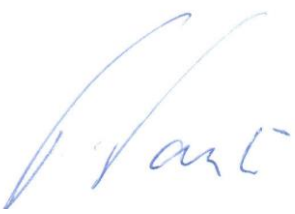
In practice, these values guarantee a very good to excellent shielding effectiveness, to protect sensitive areas or persons from electromagnetic radiation.

At **20 GHz** (λ = 1.5 cm) the shielding paint ***T98*** presents at the double layered measurement a shielding efficiency of **50 dB**. In this case, **0.001%** of the incident power is penetrating the fabric, 99.999% of it is removed by reflection.
The triple layered paint shields with **55 dB**. Now only **0.0003%** of the incident power can be measured. 99.9997 % are reflected.

The frequencies around **38 GHz** (λ = 0.79 cm) will be used in **future 5G services**. Here, the screen attenuation by the shielding paint is just over **40dB**, less than 0.01% of the incoming power is allowed through. 99.99% of the performance is prevented from penetrating the paint.

At **40 GHz** (λ = 0.75 cm) the shielding of the double layer is **38 dB** and of the triple layer is **41 dB**. At **40dB**, **0.01%** of the power penetrates the paint and 99.99 **%** are prevented to penetrate the painted panel.

This is an excellent value at these high GHz-frequencies!



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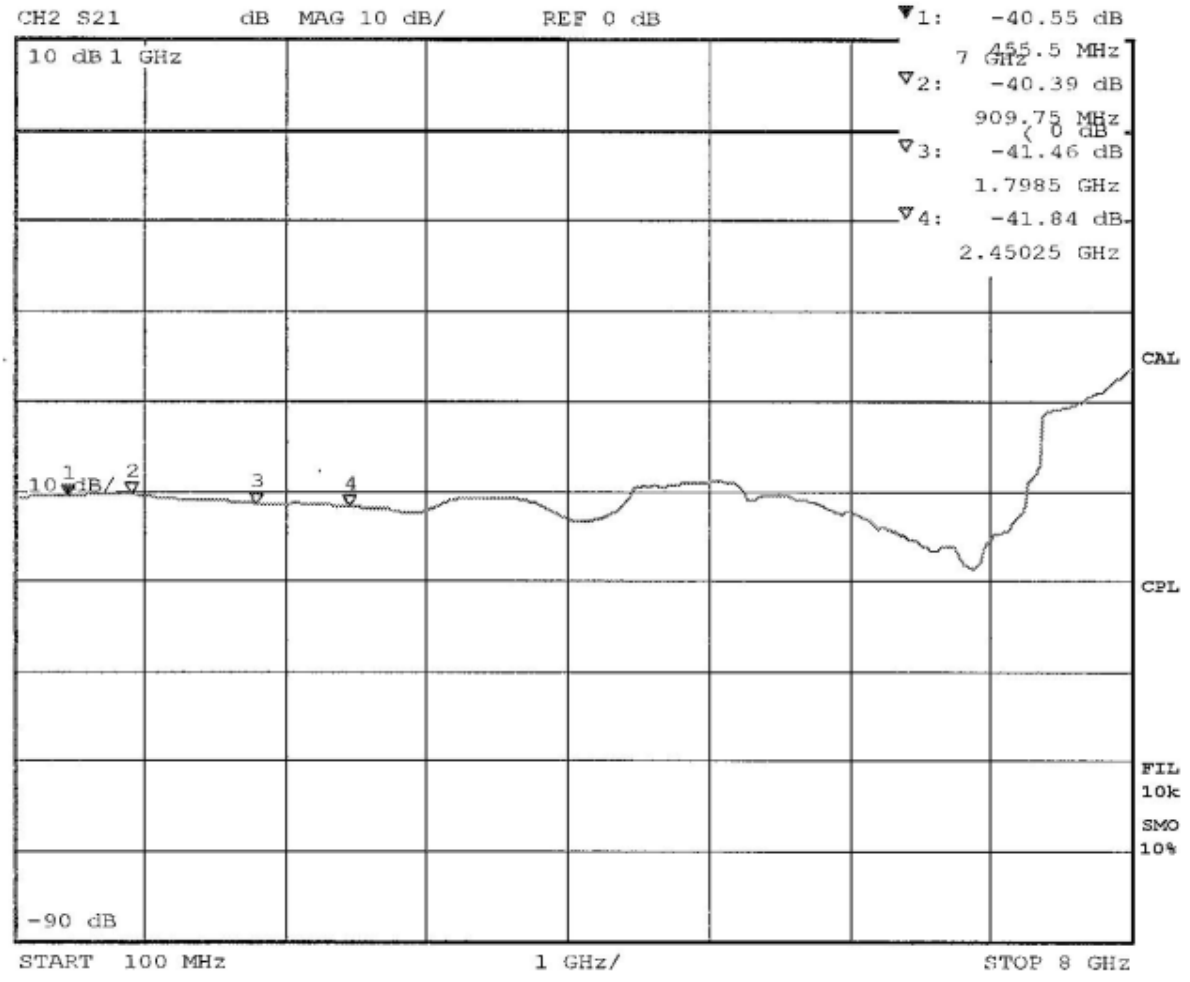
Appendix 1
of the Test Report from 28st of May 2019
measured according to ASTM D-4935
with omnidirectional polarization

Device under test: Shielding paint ***T98,*** single layered
Frequency Range: 100 MHz to 8 GHz



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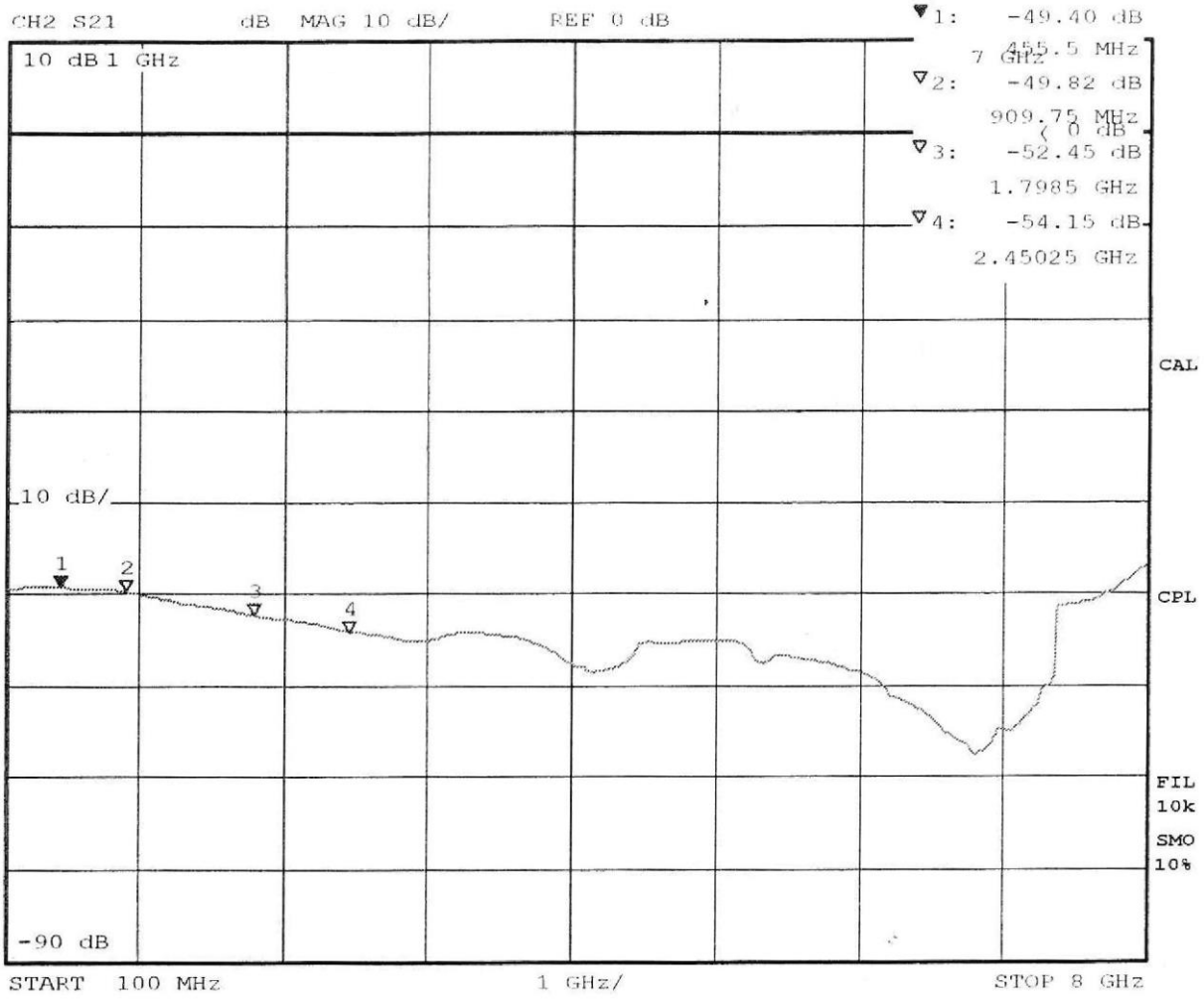
Appendix 2
of the Test Report from 28st of May 2019
measured according to ASTM D-4935
with omnidirectional polarization

Device under test: Shielding paint ***T98,*** double layered
Frequency Range: 100 MHz to 8 GHz



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Appendix 3
of the Test Report from 28st of May 2019
measured according to ASTM D-4935
with omnidirectional polarization

Device under test: Shielding paint ***T98,*** triple layered
Frequency Range: 100 MHz to 8 GHz