**Prof. Dipl.-Ing. Peter Pauli**
**Engineering office for high frequency**
**microwave and radar technology**

D-83646 Bad Tölz, 28.08.2019
Alter Bahnhofplatz 26
<prof.peter.pauli@t-online.de>


[ –Translation of the German original expert opinion (certificate) into the English language– ]

# Expert opinion (certificate)

**from 28.08.2019**

| | |
|---|---|
| **Client :** | **EMF-Protect**<br>**Kanalstraße 18½**<br>**D-83052 Bruckmühl** |
| **Measurement object:** | **Shielding-Paint EMF-Turtal,** 10µ – 250µ- particles applied on 2 primed 5mm poplar wood panels<br>**Sample 1: 5 m²/Liter, Sample 2: 2,5 m²/Liter** |
| **Order:** | Determination of the shielding effectiveness against electromagnetic waves in the frequency range of<br>**500MHz – 40GHz** |
| **Basis for examination:** | ASTM D – 4935-10 und IEEE 299-06 |
| **Date measurements:** | August 28, 2019 |
| **Scope:** | 4 pages of text, 2 measurement protocols as attachment |

**Results:** The test samples with the shielding colour EMF-Turtal were tested in the frequency range of 500MHz - 8GHz with electromagnetic waves with polarisation in all directions during the measurement according to ASTM. The measurement results are also valid for linear vertical and horizontal polarization. From 10GHz to 40GHz the measurements were performed according to IEEE 299 with linear vertical polarization. Due to the homogeneity of the color application, the results are equally valid for waves with horizontal or arbitrarily oblique polarization.

For sample 1, where 1 litre of paint was distributed over 5m2, the shield attenuation values - depending on the measuring frequency - were between 27dB at 500MHz and 57dB at 40GHz.

Sample 2: With a yield of 2.5m2 per 1 liter (i.e. twice as thick paint application), the shield attenuation values increased to 32dB at 500 MHz and grow to 64dB at 40GHz.

The detailed values can be taken from the enclosed measurement curves and from the table on page 4.

**1. preliminary remarks**

When measuring the attenuation of electromagnetic waves through a shielding material, the test object is usually irradiated with high-frequency energy of a certain power flux density S1 or with a certain power P1. Behind the shielding material, the power flux density S2 or power P2 passing through is measured. The logarithmic quotient according to the following equations gives the shield attenuation value in decibels (dB):

$$a_{Schirm} = 10 \cdot \log \frac{S_2}{S_1} = 10 \cdot \log \frac{P_2}{P_1} \quad in\ Dezibel \quad (dB)$$

To interpret the measured curves and their measured values, it is helpful to use the adjacent conversion table.

This table allows the logarithmic dB values to be converted into percentage values. As a rule - as in this table - the power or power flux density passing through the shielding is used to evaluate the shielding effectiveness.

| **Conversion of the attenuation from dB to %.** | | | |
|---|---|---|---|
| **dB** | **Power transmission in %** | **dB** | **Power trans-mission 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 | 31,60 | 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 1: Conversion of dB values into percentage values

## 2. Test setups for shielding attenuation measurement
## 2.1 according to ASTM D 4935-2010 from 500 MHz - 8 GHz

For these measurements 2 coaxial TEM measuring vessels were connected to the network analyzer quasi like a transmitting and receiving antenna. In an S21 calibration, the arrangement was calibrated to "0 dB" for the transmittance measurement without the DUT but with a non-shielding replacement object of the same thickness between the measuring heads.

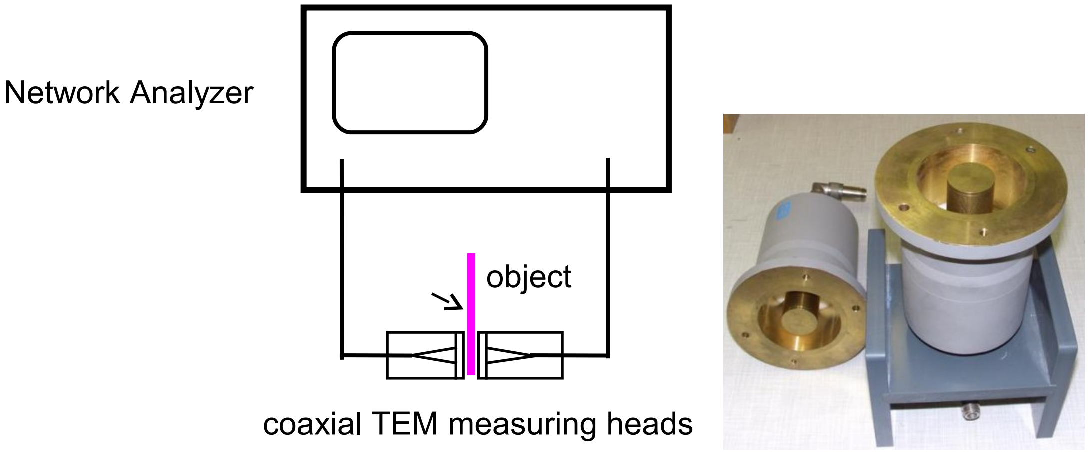



Figure 1
Measuring arrangement for determining the shielding effectiveness with TEM measuring heads

The following measuring instruments were used:

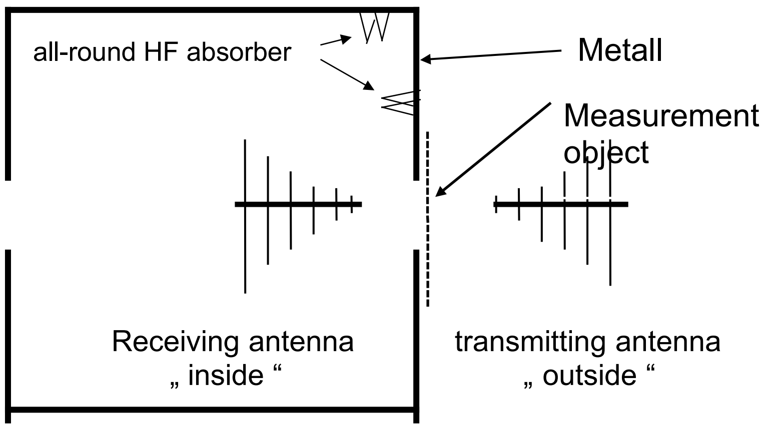
Vector network analyzer type ZVRC (30 kHz – 8 GHz) Rohde & Schwarz
Coaxial TEM measurement probes, (1 MHz – 8 GHz), Wandel & Goltermann
(see photo)

Documentation: OfficeJet 500, Hewlett & Packard

In this measurement, the electric field strengths in the TEM arrangement hit the test object in all polarization directions - as is usual with coaxial lines. This means that no discrete statement can be made about the behavior of the measurement object with respect to a specific linear polarization. On the other hand, it provides important information about how the measured object will behave with respect to polarizations from any direction. **This usually happens in practice, so that the measurement results are very close to reality.**

## 2. 2 Shield attenuation measurement according to IEEE 299-2006 from 10 GHz to 40 GHz

These measurements were performed in accordance with the IEEE standard 299-2006 in a measurement room of the radar hall of the UniBw Munich in Neubiberg on 28.8.2019 in the frequency range from 10 GHz to 40 GHz with linearly polarized waves. For this purpose, the test samples were placed in front of the 40 cm x 40 cm opening of a metal wall (area 210cm x 200cm) as shown in the picture below.




Picture 2
Measuring arrangement according to IEEE 299-2006

After the calibration of the test section (without test sample to determine the 0 dB transmission value) the shielding effectiveness of the test samples was measured.
In order to avoid overradiation of the test signals on the sides of the test samples, it was mounted directly between the two test antennas.

The following measuring instruments and antennas were used:

Microwave signal generator type SMB100A, (9 kHz - 20 GHz), Rohde & Schwarz

Programmable Sweep Generator Type 6668B (10 MHz - 40 GHz), Wiltron

Spectrum analyzer type FSP 30 (9 kHz - 30 GHz), Rohde & Schwarz

EPM Series Power Meter, Type 4418B with power sensor 4487D (50MHz - 50GHz)
HP measuring antennas: 2 double-bar horn antennas (1 GHz - 18 GHz)
Rohde & Schwarz
2 HL-Standard Gain Horn Radiators, 12 GHz - 22 GHz, Narda
2 HL horn radiators 22.5 GHz - 40 GHz, Qpar Angus Ltd

Documentation: Laser printer Ecosys FS-1020D, Kyocera

### 3. Summary of the results

In the appendices are measurement curves for the shielding attenuation values between 500MHz and 8GHz. There the shield attenuation values for some important frequencies are printed in decibels at the top right-hand edge.
Measurements between 10 GHz and 40 GHz were performed punctual every 2.5 GHz. All results are summarized in the table below:

| | Shielding effectiveness in dB | |
|---|---|---|
| Radio service/frequency | ***EMF-Turtal***, 5m²/Liter * | ***EMF-Turtal***, 2,5m²/l ** |
| C-Netz, TETRA, 450 MHz | **27 dB** | **32 dB** |
| D-Netz, GSM900, 900 MHz | **27 dB** | **32 dB** |
| 1 GHz | **27 dB** | **32 dB** |
| E-Netz, GSM1800, 1800 MHz | **27 dB** | **32 dB** |
| Blue-Tooth, WLAN 2450 MHz | **28 dB** | **33 dB** |
| 5G (Sub 6GHz-Range) 3,4–3,8GHz | **30 dB** | **36 dB** |
| W-LAN New generation 5,8 GHz | **30 dB** | **38 dB** |
| 7,5 GHz | **31 dB** | **38 dB** |
| 10,0 GHz | **31 dB** | **44 dB** |
| 12,5 GHz | **32 dB** | **44 dB** |
| 15,0 GHz | **32 dB** | **44 dB** |
| 17,5 GHz | **37 dB** | **44 dB** |
| 20,0 GHz | **39 dB** | **49 dB** |
| 22,5 GHz | **40 dB** | **53 dB** |
| 25,0 GHz | **45 dB** | **57 dB** |
| 27,5 GHz | **47 dB** | **59 dB** |
| 30,0 GHz | **49 dB** | **61 dB** |
| 32,5 GHz | **50 dB** | **62 dB** |
| 35,0 GHz | **52 dB** | **63 dB** |
| 37,5 GHz | **56 dB** | **64 dB** |
| 40,0 GHz | **57 dB** | **64 dB** |

Table 2: Shield attenuation values at different frequencies

* [***EMF-Turtal***, 5 m²/Liter correspond to 1.32086 US-American liquid gallons ]
** [***EMF-Turtal***, 2,5 m²/Liter correspond to 0,66043 US-American liquid gallons ]

Neubiberg/Bad Tölz, 28.08.2019 Prof. Dipl.-Ing. P. Pauli

Prof. Dipl.-Ing. P. Pauli
Turtal

standard

polarization

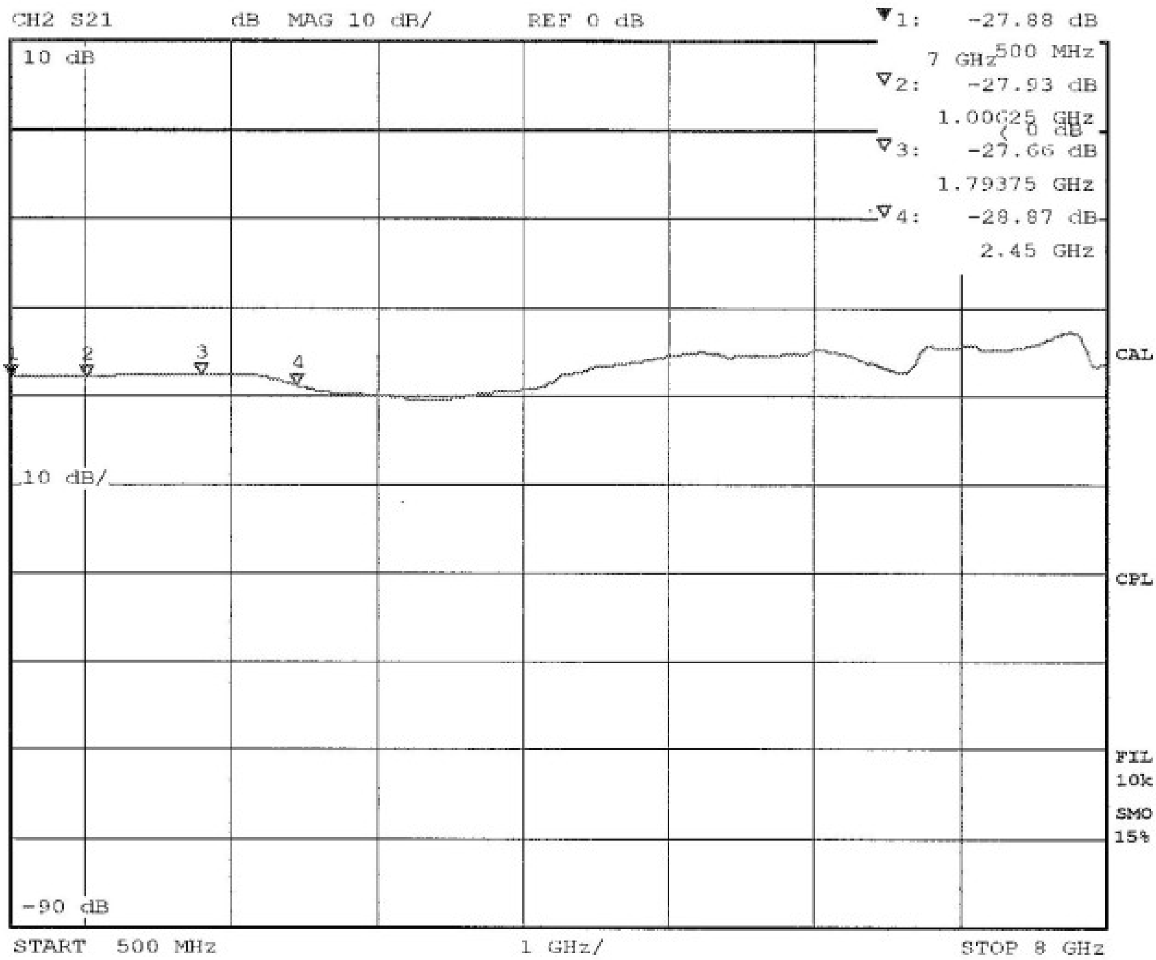
Measurement object: Shielding color EMF-

Measurement according to ASTM

D- 4935-2010 with non-directional

**Measurement object: Shielding paint EMF-Turtal,** applied in one layer with **5m²/Liter**

Frequency range: 500 MHz - 8 GHz



**Measurement object: Shielding paint EMF-Turtal,** applied in two layers with **2,5m²/Liter**

Frequency range: 500 MHz – 8 GHz