Prof. Dipl.-Ing. Peter Pauli
German Armed Forces University Munich
Section: RF- and Microwaves, Radars

RF & Microwave Engineering
Alter Bahnhofplatz 26
D-83646 Bad Tölz
E-Mail: prof.peter.pauli@t-online.de

Expert Report

21st of June 2018

Ordered by: **Biologa GmbH**
Hauptstraße 27
72336 Balingen

Device under Test: Shielding knitware ***New Antiwave***

Subject: Shielding measurements against electromagnetic waves with frequencies from 20 MHz to 10 GHz

Regulations: ASTM D-4935-2010 and IEEE 299-2006

Date of the Measurements: 18th of June 2018

Contents: 5 pages of text and 9 measured diagrams in 5 appendices

Results: The measurements proved, that the shielding knitware ***New Antiwave*** presents a shielding efficiency between **20dB** and **36 dB** at mobile communication frequencies. These values were rather independent of the kind of polarization of the incident electromagnetic waves.
A stretching of the product increased the shielding values by 1dB to 2dB. The table below presents a first overlook of the shielding values at some important communication frequencies:

Frequency	450 MHz TETRA	900 MHz GSM900	1800 MHz GSM1800	2450 MHz W-LAN	5800MHz W-LAN new	10 GHz
ASTM 360⁰	**29 dB**	**26 dB**	**22 dB**	**20 dB**		
IEEE vert. pol.	**33 dB**	**31 dB**	**23 dB**	**21 dB**	**15 dB**	**10 dB**
IEEE hor.pol.	**31 dB**	**28 dB**	**23 dB**	**20 dB**	**15 dB**	**11 dB**
WG vert.polar.		**35/37 dB**	**25/26 dB**			
WG hor.polar.		**34/35 dB**	**25/26 dB**			

Table 1: Shielding values at some interesting frequencies

The measurements were performed according to different standards with omnidirectional polarization and with linear vertical and horizontal polarization. This is the reason of slightly different shielding values gained at the different methods and frequencies.
The two lines at the bottom present the results measured in a rectangular L-band-wave-guide (WG) with unstretched and stretched knitware.
The description of the methods and further results are presented on the next pages and in the appendix.

1 Introduction

To explain the measured diagrams, it is helpful to use this table. You can easily find the relation between shielding in „dB" and the 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 describes, 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	31,60	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

Table 2: Conversion of SE-values, given in dB, to percent values of transmitted power

2. Methods and Standards of shielding measurements

2.1 Shielding measurements according to ASTM D-4935-2010, 20 MHz – 4 GHz

For this measurement two coaxial TEM-adapters were connected to a Vector Network Analyzer (VNWA), used as transmitting and receiving antennas. During a calibration for measuring the S_{21}-parameter (= transmission), the distance between the two adapters was substituted by an neutral distance holder. Now the calibration was set to "0 dB". Then the shielding knitware ***New Antiwave*** was positioned between the adapters. The reduction of transmitted power was measured and documented in the diagrams in the appendix.

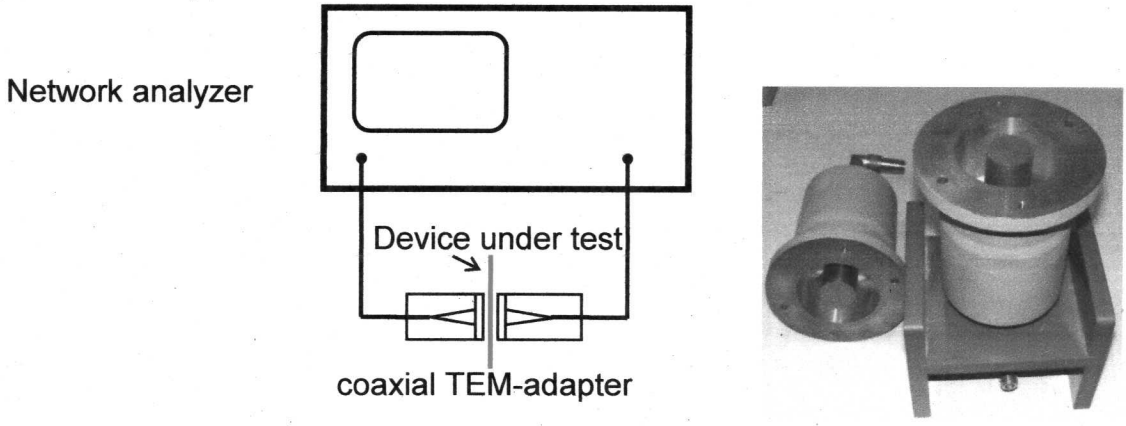

Fig. 1 Test setup to measure the shielding effectiveness of the ***New Antiwave***

Measurement equipment:
Vector Network Analyzer, type ZVRE (30 kHz – 8 GHz), Rohde & Schwarz
Coaxial TEM-Adapter, (1 MHz – 4 GHz), Wandel & Goltermann
Documentation: OfficeJet 500, Hewlett & Packard

During this test, the test signal presents a 360°-polarisation, which means, the electrical field lines of the test signal hit the DUT in all radial directions. If the shielding material presents an excellent shielding performance during this test, the shielding for linear vertically and horizontally polarizes signals will be as excellent.
So the results of these measurements are very close to the reality.
The measurement results are presented in appendix #1.
To measure the shielding of the knitware without and with stretching, the two coaxial adapters were substituted by two rectangular L-band-waveguides. According to the limited frequency range of the L-band-waveguides, the measurements were performed between 1GHz and 2GHz.
Comments to the polarization: On one side of the knitware you can recognize small dark triangles like arrows. If measurements were performed with "vertical polarization", the lines of the E-field were applied to the knitware parallel to the arrows. At "horizontal polarization", the E-field-lines hit the knitware perpendicular to the arrows.

2.2 Shielding measurements according to IEEE 299-2006, 200MHz to 10GHz

The measurements were performed according to IEEE 299 on 18th of JUNE 2018 at the EMC-test site of the Radar Laboratories at the German Armed Forces University Munich in Neubiberg at frequencies from 200 MHz to 10GHz. Linear polarization was radiated and received by double ridged exponential horn antennas as well as from two Logper Antennas. The device under test was attached to a specific aperture (height 40 cm, width 40 cm as shown in the picture below) in a metallic shelter wall with the front dimensions of 210cm x 200cm.
During the measurements neither interferences from external signals nor any creeping waves between DUT and cabin wall could be detected.

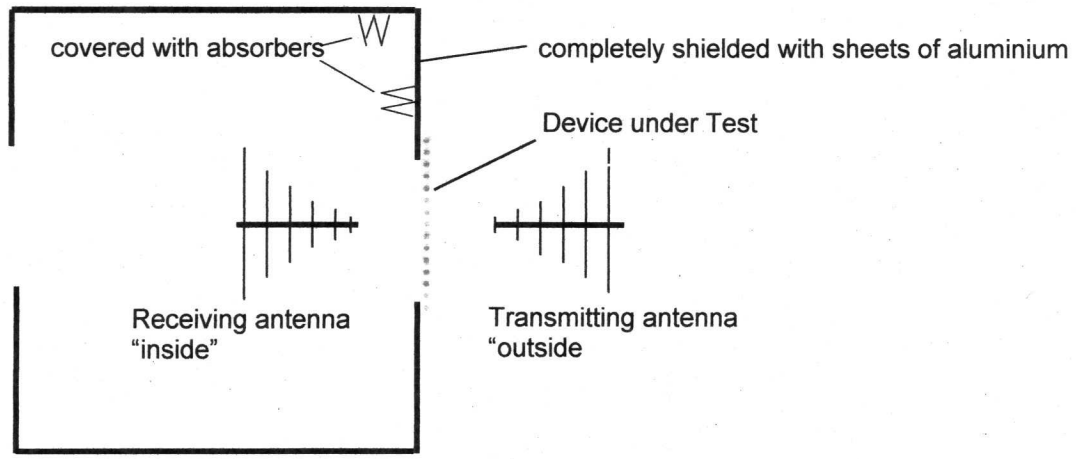

Fig. 2 Setup for Shielding Measurements according to IEEE299 (schematically)

The test range was calibrated without any object between the two antennas, to adjust the zero-dB-transmission-value. The horn- and the Logper-antennas were positioned at a distance of 60cm in front of the DUT and 30cm behind it.

Test equipment:

Vector Network Analyzer type ZVRE, (30 kHz – 8 GHz), Rohde & Schwarz
Signal generator type SMB100A, (9kHz – 22GHz), Rohde & Schwarz
2 Double-ridged exponential horn antennas type HF 906, (1 – 18 GHz), R & S
2 Logper-Antennas type CBL 6112A, (30 MHz – 2 GHz), Chase Inc.
Printer: Kyocera Ecosys, FS – 1020D

3. Summary

This table presents the results of all measurements, listed for some important mobile communication and radar frequencies:

Frequency	450 MHz TETRA	900 MHz GSM900	1800 MHz GSM1800	2450MHz W-LAN	5800MHz new W-LAN	10 GHz
ASTM 360⁰	**29 dB**	**26 dB**	**22 dB**	**20 dB**		
IEEE vert. pol.	**33 dB**	**31 dB**	**23 dB**	**21 dB**	**15 dB**	**10 dB**
IEEE hor.pol.	**31 dB**	**28 dB**	**23 dB**	**20 dB**	**15 dB**	**11 dB**
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WG hor.polar.		**34/35 dB**	**25/26 dB**			

Table 3: Shielding values of ***New Antiwave*** at different frequencies

In the last two lines of the table, shielding values are presented, measured with vertical and horizontal polarization in the rectangular waveguides. The values before the slash were measured at the **unexpanded** knitware. The values behind the slash show the shielding of the **stretched** knitware. This confirms an even better shielding of the **New Antiwave** knitware in a moderate stretched application.

At a shielding efficiency of **33 dB** only **0,5 parts per thousand** of the incident power flux density are penetrating the knitware. **99,95%** of the power is removed by shielding.
At **20 dB** shielding efficiency **99%** of the power is removed by shielding.
Only 1 % of the incident power can penetrate the knitware with the product name ***„New Antiwave“*** .

Bad Tölz, 21st of June 2018

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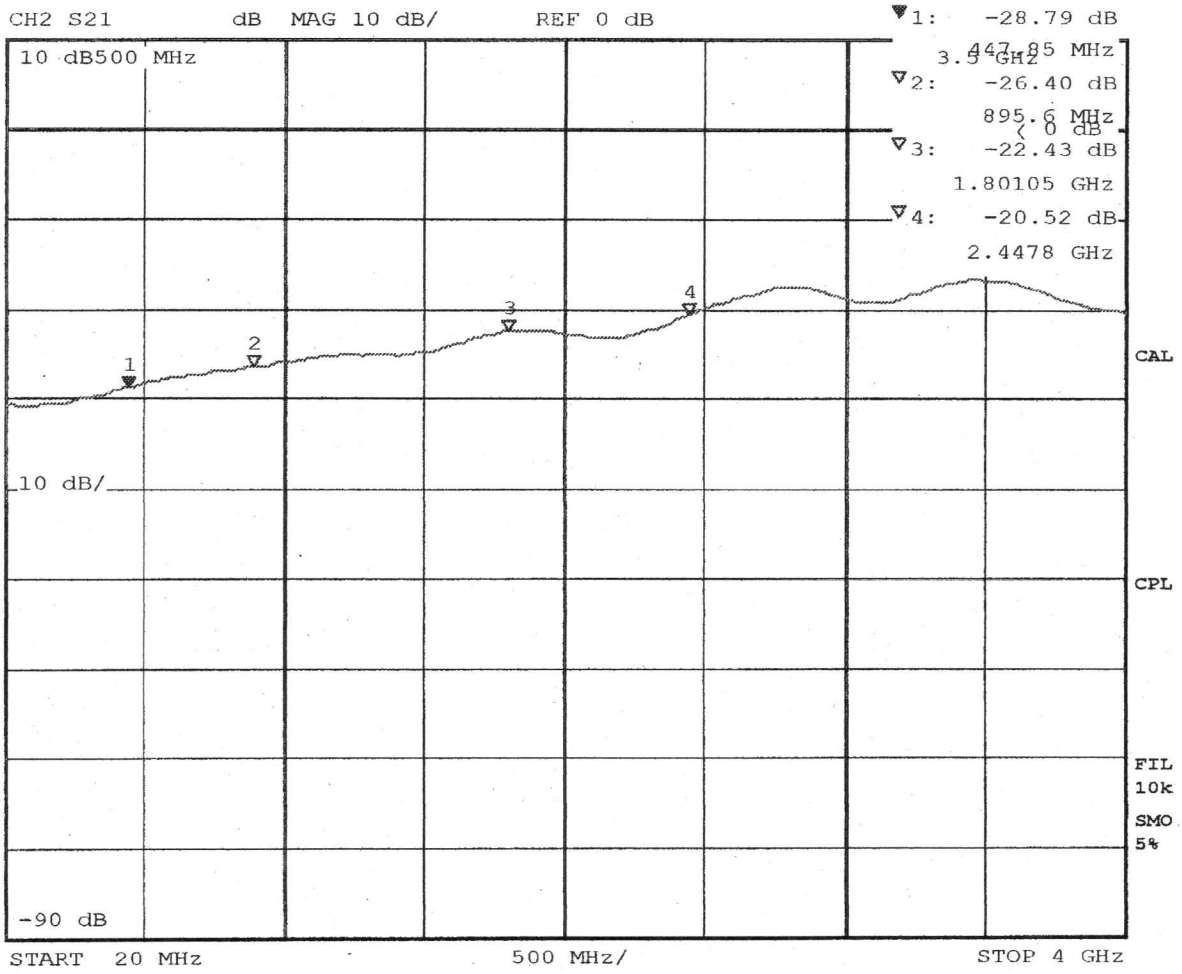
Test report appendix #1, 21st of June 2018
ASTM-measurement with 360°-Polarization

Device under Test: Shielding knitware „*New Antiwave*“
Frequency range: 20 MHz – 4 GHz



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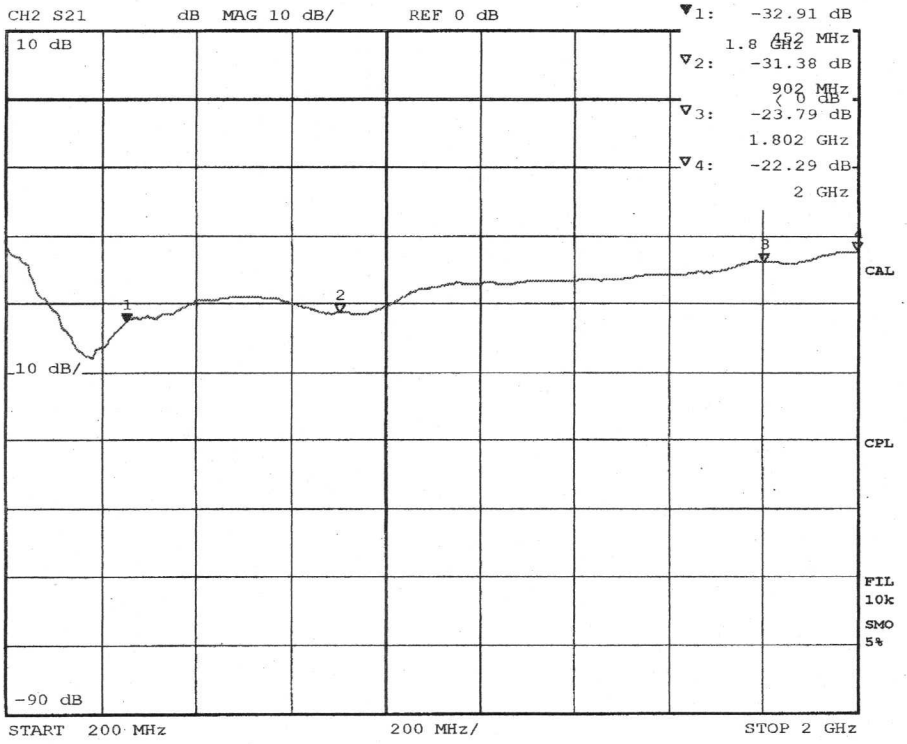
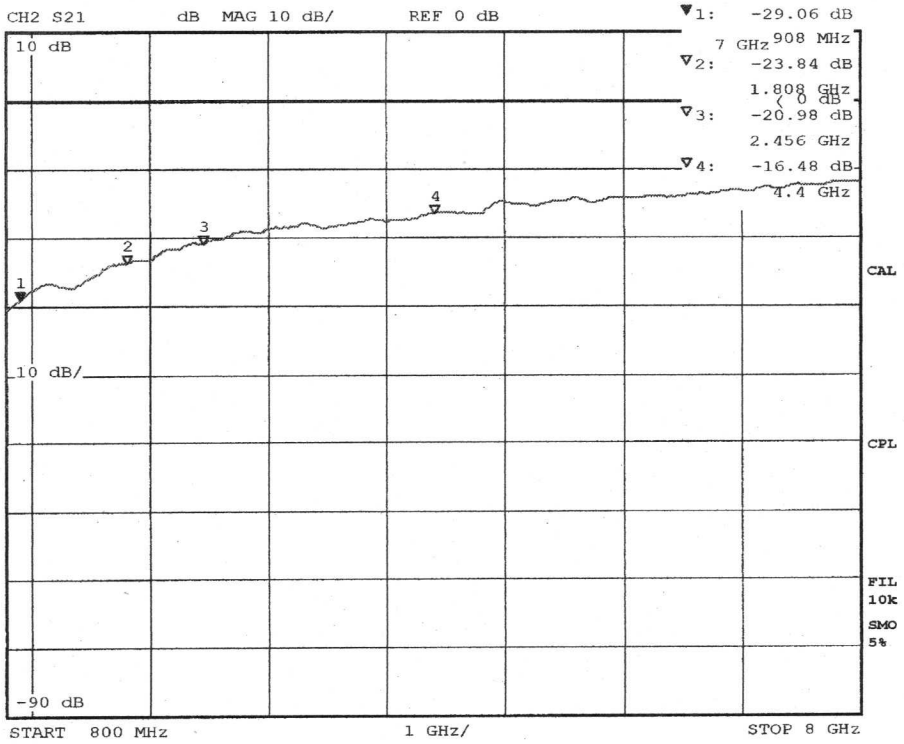
Test report appendix #2, 21st of June 2018
IEEE-measurement with **vertical** polarization

Device under Test: Shielding knitware „*New Antiwave*“

Upper trace: 200MHz – 2GHz, lower trace: 800MHz – 8GHz. Extra result at 10 GHz: **10dB**





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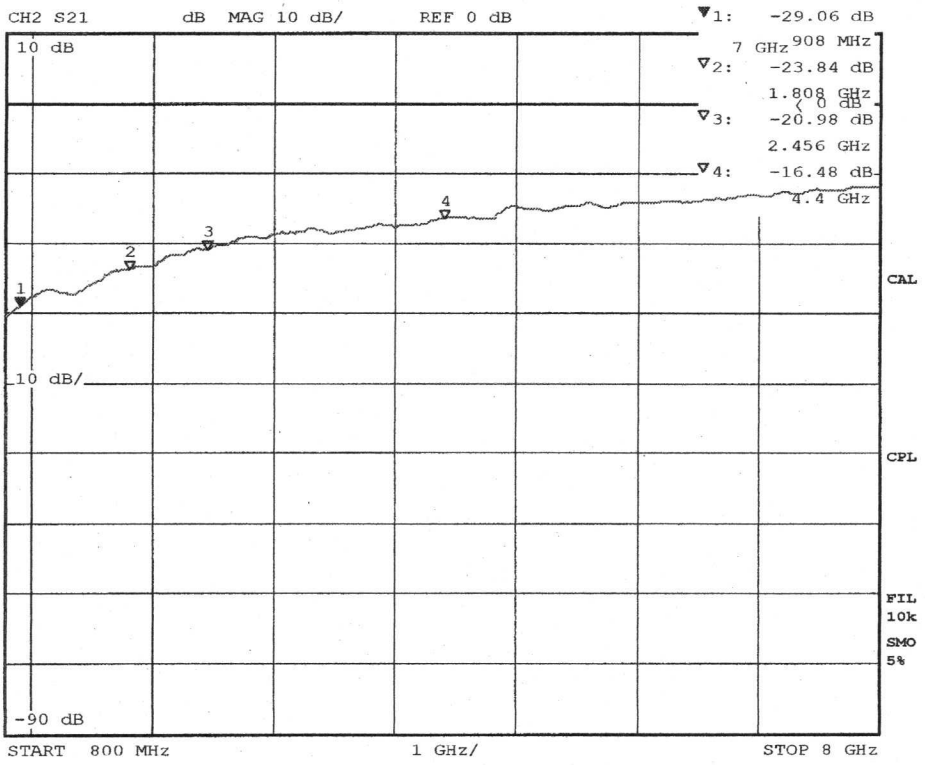
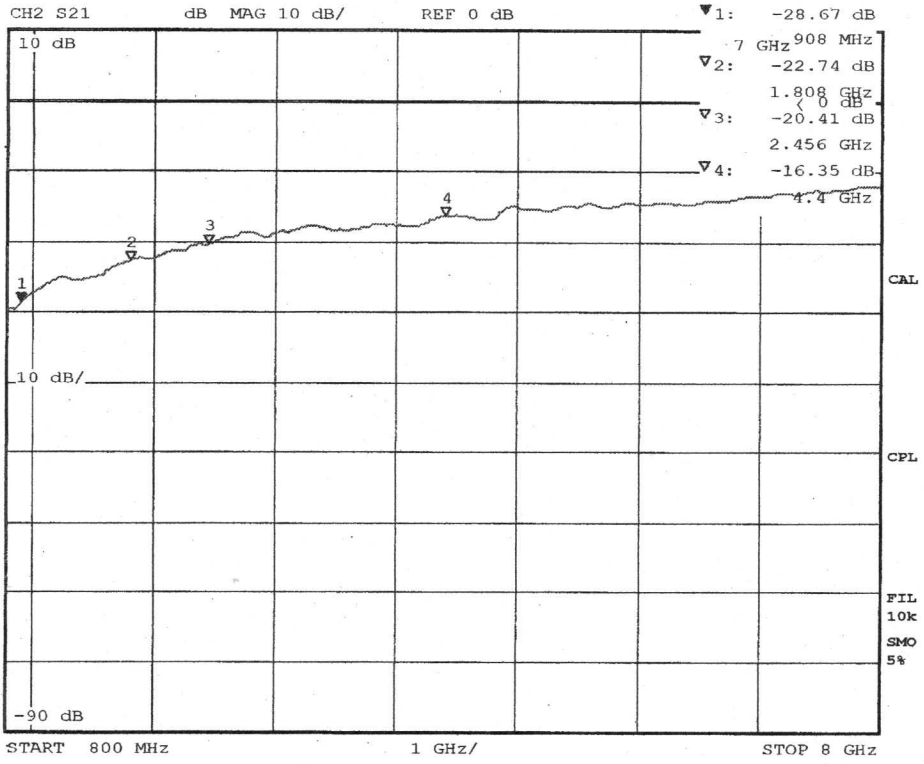
Test report appendix #3, 21st of June 2018
IEEE-measurement with **horizontal** polarization

Device under Test: Shielding knitware „*New Antiwave*“

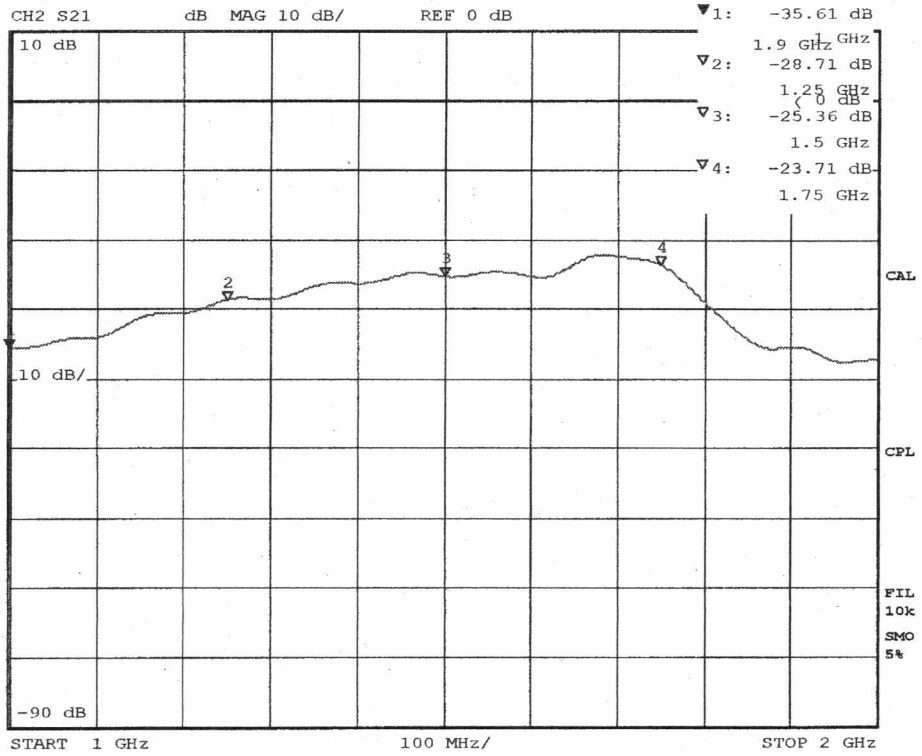
Upper trace: 200MHz – 2GHz, lower trace: 800MHz – 8GHz. Extra result at 10 GHz: **10dB**

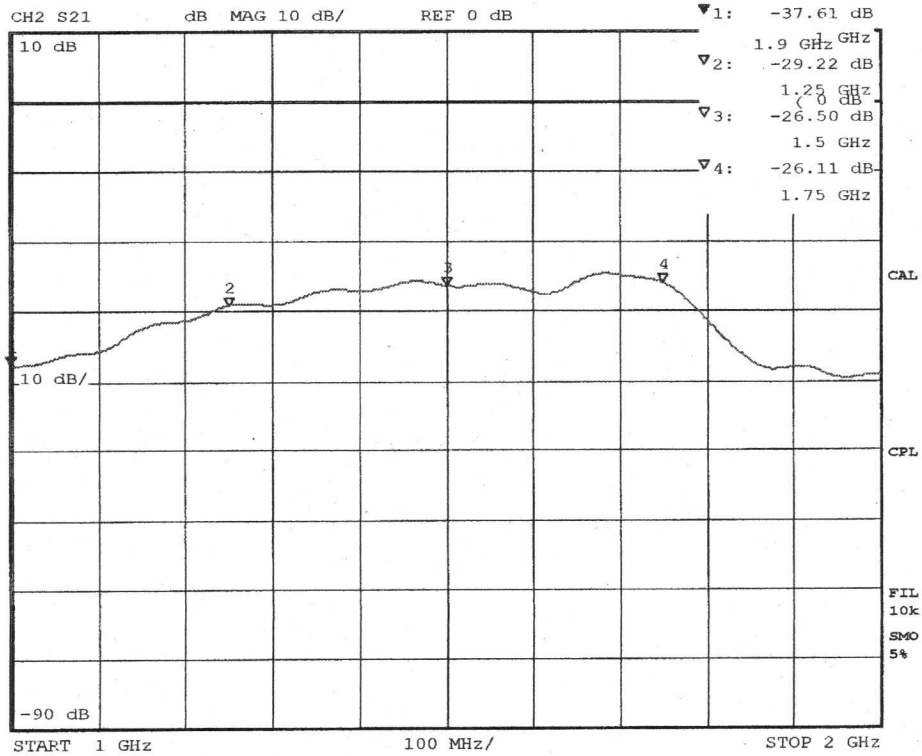




Device under Test: Shielding knitware „*New Antiwave*“

Frequency: 1GHz – 2 GHz; upper trace: knitware not stretched, lower trace: knitware stretched





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Test report appendix #5, 21st of June 2018
Waveguide-measurement with **horizontal** polarization

Device under Test: Shielding knitware „*New Antiwave*“

Frequency: 1GHz – 2 GHz; upper trace: knitware not stretched, lower trace: knitware stretched