Development of Flexible Materials suitable for Shielding of Electromagnetic Waves over a wide Range of high Frequencies

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1. Introduction

For high frequencies HF and electromagnetic shielding EMC technologies the requirements are rising higher and higher: The electronic devices use higher frequencies, this in consequence rises the demands for:

- higher shielding properties over a wider frequency range
- materials with particular high or low loss magnetic hysteresis properties at such frequencies
- special magnetic permeability properties µ
- special electric permittivity properties eps
- special reflectance and/or absorbance properties

Particularly for shielding there is an abundance of materials and technologies in use:

- chemical metallisation and plating processes are used especially for smaller and more complex shaped plastic housings.
- direct stationary physical vapour deposition (PVD) of plastic housings: This allows for simple shaped housing direct application of metal layers
- special metal housings, where particular attention has to be payed for being dense at feed throughs
- more complex housings that are put together from various pieces necessitate the use of gaskets made of metallic yarn or metallized woven or nonwoven. The metallization can be made either by chemical metallization and subsequent plating or by physical vapour deposition of flexible materials.
- shielding of larger areas for example in buildings is usually done by using chemical or PVD metallized wovens or non wovens.

The present paper shall introduce new developments in the area of flexible PVD coated materials for EMC applications. The goal was, to improve the shielding properties for substrates coated by PVD, the advantage of this process on flexible substrates is its low cost, that is considerably lower when compared to the other processes mentioned above: The natural limitations are set by the layer thickness that can be achieved by this method without excessive heat introduction: This is a process immanent problem: The layer thickness is controlled by the evaporation rate and the speed with which the substrate is moved over the evaporation source: Slower speed yields a higher layer thickness but exposes the (polymer) substrate to a higher heat load, the main fraction of which is due to thermal radiation from the evaporation source. The goal was to improve the properties of materials coated by this technology taking into account the limitations just stated.

2. Shielding Mechanisms according to Schelkunow

For electromagnetic shielding the basic principles were established by Schelkunow in the 40ties and hence a model was established. The following sketch shows the principles of the diminuation of the intensity of an electromagnetic wave by passing through a material:

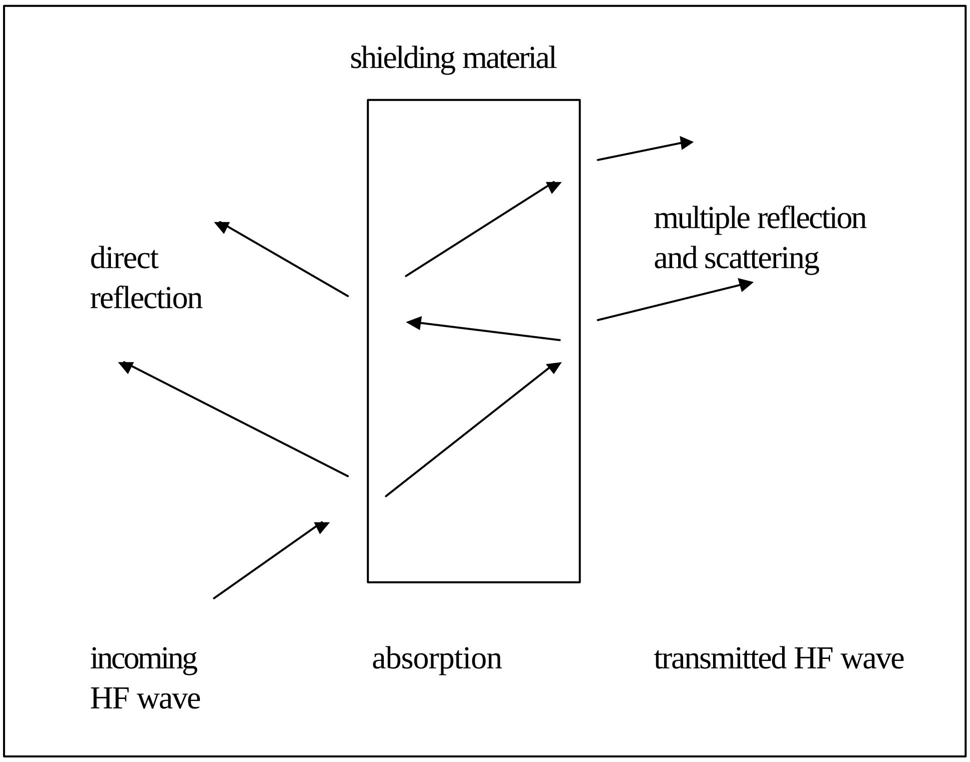

Figure 1: Model of the shielded HF wave: This may be the wall of a housing of an electromagnetic device, that needs to be shielded / 1 /

For further explanation of this model the following equation is to be used:

$S = -\lg (T/I_o)$, with $T = I_o - (A + R + B)$ yields:

$$S = -\lg (1-(A+R+B)/I_o) \qquad (1)$$

The definition of the shielding efficiency is given by this equation 1:

The shielding factor S may be defined as the negative log of transmited to incoming intensity of the HF wave (in correspondence to laws of optics). The transmission T is the sum of absorption A in the material that forms the housing, the direct reflection R at the same material and the multiple reflection B inside this material (wall).

3. Improvement of the shielding efficiency using multiple layers

The priciples of shielding by Schelkunow can be improved by using

a) a more complex model by not just using ideal plane and continuous material surfaces: Instead a porous nonflat material is used. This introduces the effect of wave scattering.
b) Several layers consisting of different metal materials rise the effect of the multiple reflection and absorbance inside the material because the number of interfaces is increased.

This rises the efficiency of the shielding considerably. This is demonstrated by figure 2:

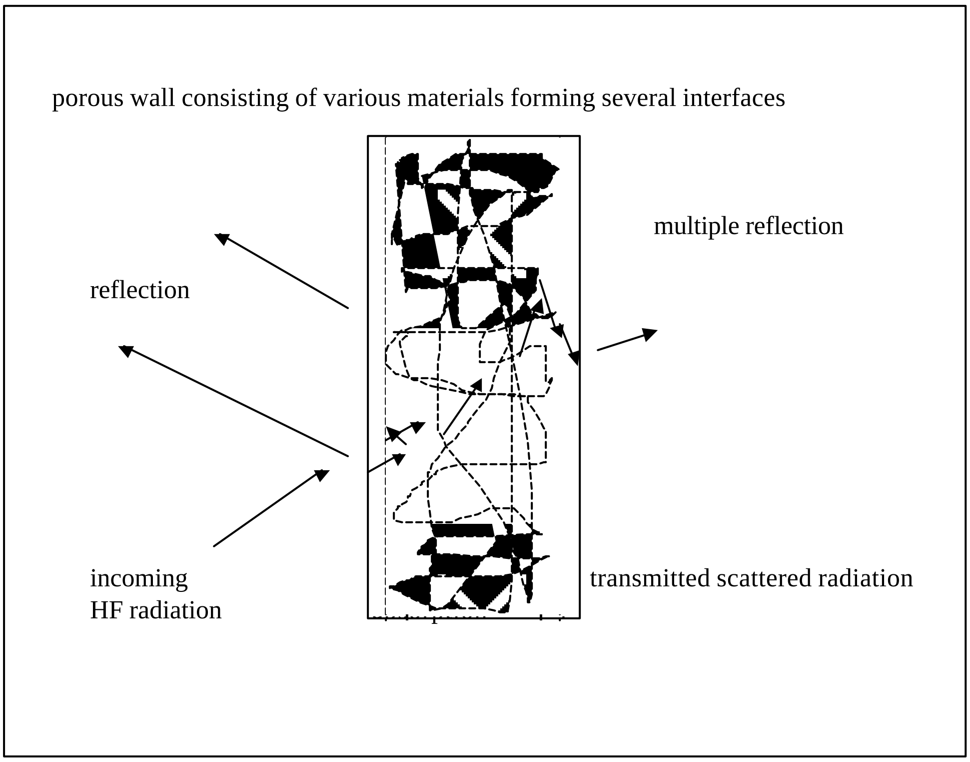

Bild 2: Schematic structure of the shielding material

In equation 2 the Shieding equation by Schelkunoff is used expanded by a fraction for losses by additional multiple reflectance and by scattering:

$$\mathbf{S = -\lg T/Io = -\lg(1-(AB + R + BB + C)/Io)} \qquad \mathbf{(2)}$$

With the new definition the shielding is formed by:

Here the transmission T is diminuished additionally by the multiple absorption AB caused by the wall, the multiplereflectance BB at the inner interfaces formed by the sequence of various metal layers and finally the multiple scattering C caused by the roughness and porosity of the substrate material.

The comparison of equation 1 with 2 shows the introduction of new scources of shielding, that should improve the shielding efficiency. In the table below this is done by comparison to film metallised in the same manner.

4. Fabrication and Structure of the new HF Shielding Material

The material according to the model introduced above is formed by a triple metal layer on either side of a nonwoven with 65 g/m2 areal weight. The single layers are subsequently produced by PVD of Cu, Al and Cu. They each form semicontinuous layers on both sides of the substrate. A metric thickness cannot be measured due to the roughness (that for the substrate used is not even on both sides of the substrate: It has a flat and a rough side) and porosity but may be characterised by measuring the electric resistance of the layers after each PVD process step:

Substrate	designation	layer sequence	process step#	4 point probe resist.	eddy current resistance	ϕ shielding dB
			even numbers: flat side, uneven numbers: rough side	Ω/ð	Ω/ð (integral over both sides)	near N far range F
35 um Cu metal foil		reference material		<< 0.1	<< 0.1	N: 20 F: 20
Kapton 50 μm		Cu	1	0,22	0.1	N: 35
			2	0,12		F: 25
nonwoven	MV83/93	Cu	1	1,70	0,99	N: 35
65 g/m2			2	1,72		F: 25
nonwoven	MV28/11/98	Cu	1	3,17	0,36	
65 g/m2			2	10,1		N: 35
		Al-Cu	3	1,42	0,99	F: 25
			4	3,62		
		Cu-Al-Cu	5	1,06	0,64	
			6	2,03		
nonwoven	MV28/11/98	Al	1	2,54	0,55	N: 40 F: 25
65 g/m2			2	6,29		
		Cu-Al	3	1,71	1,1	
			4	2,97		
		Al-Cu-Al	5	1,34	0,76	
			6	2,06		

The measurements were always performed on both sides of the substrate. The results emphasise the effect of using a rough and porous substrate by comparison to metallised Kapton film and even a copper metal foil of much higher thickness: Yet the efficiency of the shielding in the frequency range considered is far better by the PVD layer and further improved by the triple layer on either substrate side.

The following scanning electron microscope image reveals the porous structure of the material:

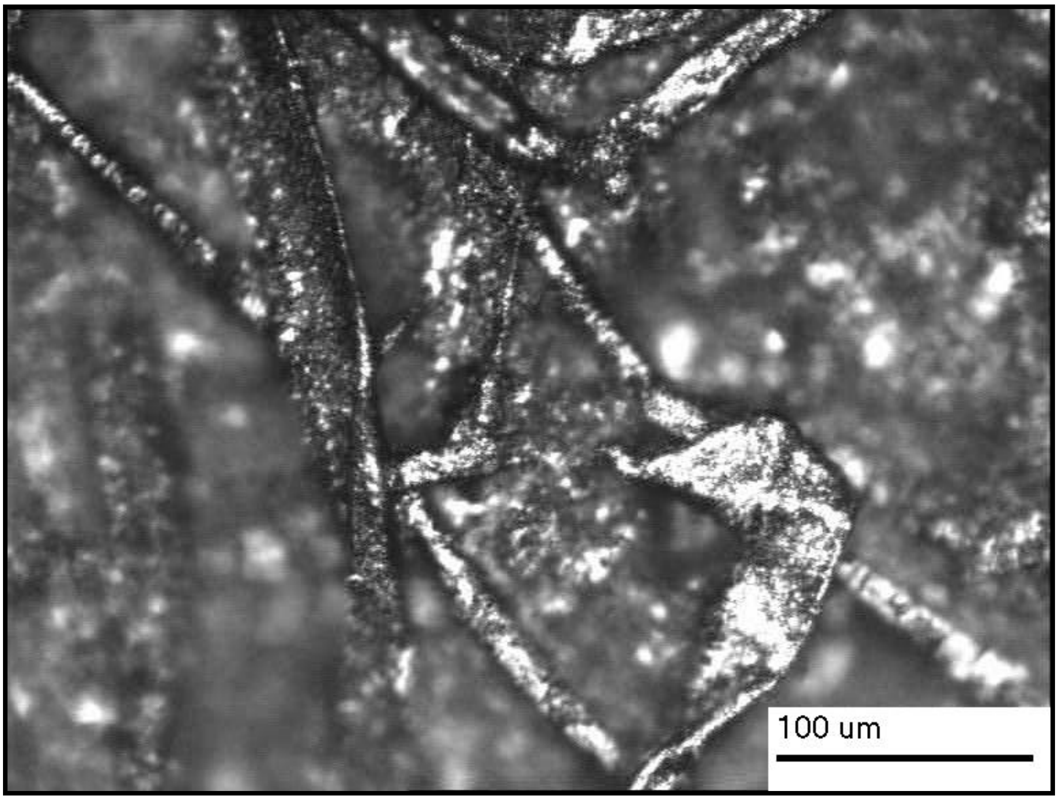

Figure 3 Scanning microscope image of the shielding material

5. Discussion of the shielding measurements

The shielding measurements were carried out in an absorbing chamber according to VG 95373 T 15. Figure 4 shows the shielding of the nonwoven with a triplet metal layer on either substrate side:

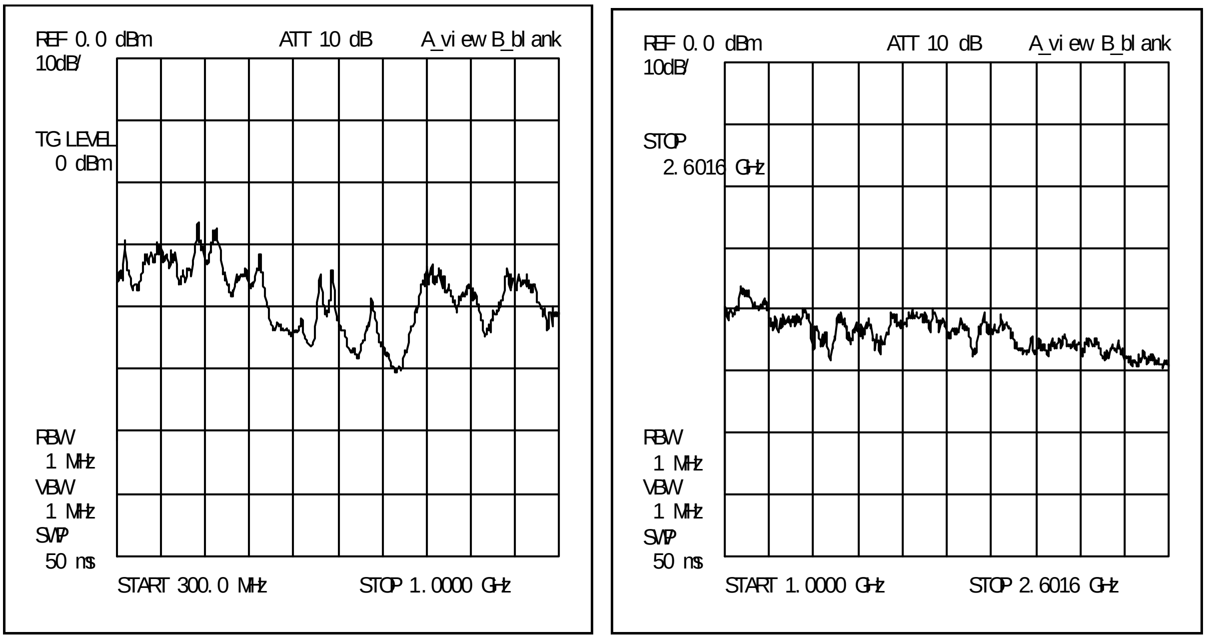

Figure 4 Shielding of a nonwoven with a triplet PVD metal layer Cu-Al-Cu on either side for a) f= 300 MHZ - 1 GHZ b) f= 1 GHZ - 2,6 GHZ

For comparison the same substrate is shown in figure 5 with a single metal layer (designated MV83/98 in the table above:

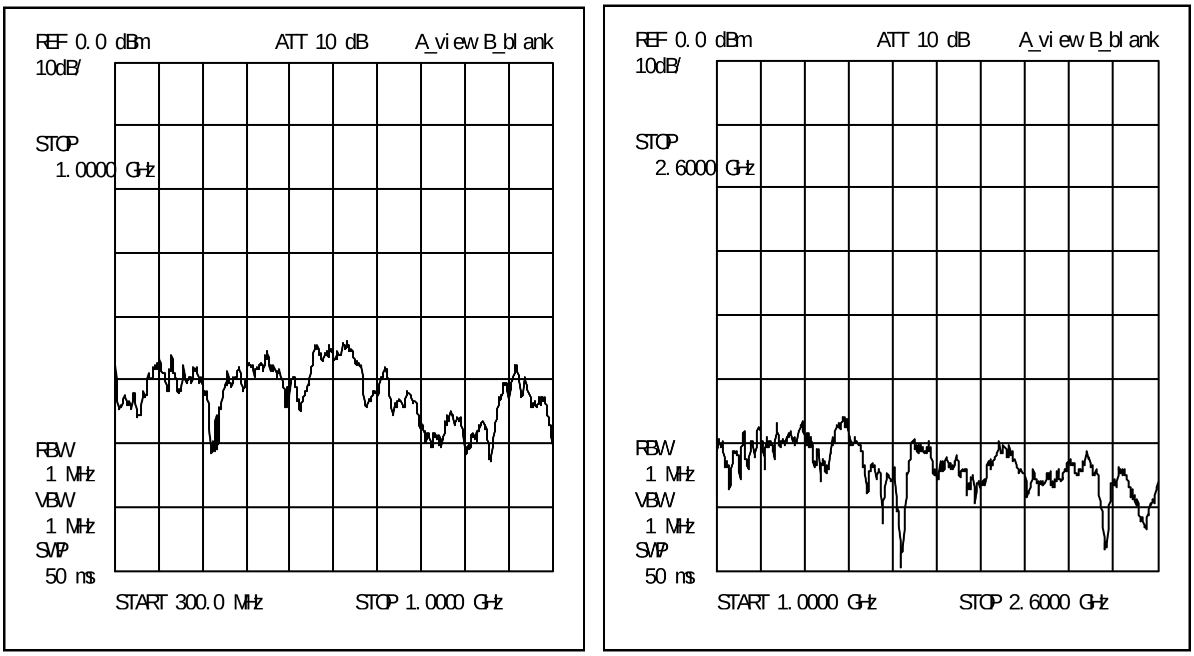

Figure 5 Shielding of a nonwoven with a single PVD metal layer Cu on either side for a) f= 300 MHZ - 1 GHZ b) f= 1 GHZ - 2,6 GHZ

6 Conclusions

The concept for rising the shielding efficiency was the introduction of additional factors using porous noneven substrate surface and multiple metallic layers. These introduce multiple scattering and multiple inner reflection adding to the shielding efficiency: The substrate used is a nonwoven with a triple PVD metal layer on either side, which improved the damping by 10-15 dB over a frequency range from 0.3 - 2-6 GHz. This brings the shielding values into a range where direct application can be envisaged for:

- Shielding carpets or wall papers in safety rooms for data security
- EMC housings for larger simple shaped housings
- EMC gaskets
- EMC cable shielding

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7. Literatur

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