

Contents

Part I Basics

1	Introduction	3
1.1	EMC Act Standardization	4
2	Volume Materials	5
2.1	Introduction	5
2.2	Microscopic and Macroscopic Properties of Spinel Ferrites	8
2.3	Models of Classical Field Theory (Maxwell) Compared to Landau–Lifschitz Theory	14
2.3.1	Classical Field Theory According to Maxwell	14
2.4	Considerations on RF Losses in Ferrite Compounds and Ferrite Layers	16
2.4.1	Ferromagnetic Resonance (FMR) Inversion Ratio in Ferrite Volume Materials	16
2.4.2	Discussion of Errors	21
2.5	Dielectric Measurements on Magnetic Materials	24
2.5.1	Selection of the Measuring Method	24
2.5.2	Resonator Measurement Method	24
2.5.3	Description of the Measuring Station	24
2.5.4	Performing the Measurement	26
2.6	Relaxation in Ferrite Volume Materials	27
2.6.1	Spinel Also Have Relaxation Mechanisms	27
2.6.2	Experimental Considerations	29
2.7	Texture in Ferrite Volume Materials	30
2.7.1	Creation of a Texture	32
2.7.2	Theoretical Considerations on the Relationship Between Texture and RF Loss	33
2.8	Degree of Filling of Ferrite in Volume Material	33
2.9	Field Adjustment of the Volume Material	35

2.9.1	Schelkunov Formula	37
2.9.2	Error Consideration of the Measuring Arrangement	38
2.9.3	Summary	39
2.10	The NiZn-ferrite Spinel System	40
2.10.1	Material Analyses of Ferrite Compounds	42
2.10.2	Grain Size Distribution, Change of Grain Size	42
2.10.3	Modelling Objective of the Layer Synthesis	44
2.10.4	Type of Spin Wave Modes as a Function of Layer Thickness	44
2.10.5	Summary	47
3	Nanomaterials	49
3.1	Layer Analysis, Anisotropy Constant and Grain Size of Ferrimagnetic Layers	49
3.2	Spin Wave Losses in Ferrite Layers	50
3.2.1	Spin Wave Excitation	54
3.3	Influence of the Anisotropy Constants on the RF Loss of the NiZn Ferrite Layer	55
3.3.1	Theoretical Considerations on Spin Wave Loss	55
3.3.2	Experimental Considerations on Spin Wave Loss	58
3.4	Special layer Analysis, Anisotropy Constant and Grain Size of Ferrimagnetic Layers	58
3.4.1	Absorption Loss of the Ferritic Layer	58
3.5	Eddy Current Effects in Metallic Magnetic Films: Snoek's Limit for layer Systems/Single Layer	60
3.5.1	Schelkunoff Equation	64
3.6	Maximum Frequency Attenuation Tests, RF Material Evaluation	65
3.7	Relaxation Effects of Magnetic Materials in the kHz Range	68
3.7.1	Bloch-Wall Relaxations	68
3.7.2	Bloch-Wall Eddy Current Relaxations: kHz Effects	68
3.8	LF Losses	70
3.8.1	Material Analysis	70
3.9	Deposition of Ultra-Thin Hematite Layers	71
3.10	Magnetic Spectroscopic Analysis	72
3.10.1	Analysis of the Sample Layers	73
3.10.2	Spin Wave Spectrum Characterisation Definitions	75
3.11	Waveguide Measuring Station	75
3.11.1	Results	77
3.12	X-Ray diffraction Analysis	77
3.13	RF Analysis by 20,000 MHz	78
3.14	Ratio of the Granule Size to the Layer Thickness of an Fe-Nanolayer	79

3.15	Multilayer Systems	84
3.16	Kittel Frequency	84
3.17	Wolmann Frequency	86
3.18	Snoek Frequency	87
3.19	Radar Effects	88
3.20	Magnetic Nanoparticles	89
3.20.1	Theoretical Considerations	90
3.20.2	Experimental Considerations	93

Part II Practical Examples

4	Shielding Using Nanomaterials	97
4.1	Measurement of the Complex Permeability of Nanolayers with One Permeameter	97
4.1.1	Permeability Measurements	100
5	LF Shielding	101
6	Double Shielding	105
6.1	Double Shielding	106
7	Polymer Housings	107
7.1	Previous Material Results	110
7.2	Housing Results	110
7.3	Summary	111
8	Shielding Example: Inner Lining of a 2.4 GHz Low-Noise Amplifier Housing to Suppress Higher Modes	115
9	Metal Housing with Magnetic Materials	119
9.1	Attenuation of Cavity Resonances by Means of Absorbing Magnetic Laminates	124
9.2	Cavity Resonances	124
9.3	Coated Housing	125
9.4	Absorbent Material as Insert	125
9.5	Ferrite-Containing Thick Films for New EMC Metal Housings	128
9.5.1	Slurry Layers	129
9.5.2	Slurry Layers with Conductive Coating	130
9.5.3	Layers of Ferrite Filler	130
9.6	Ferrite Volume Housing	131
9.6.1	Ferrite Volume Housings for New EMC-Resistant Automotive Sensor Housings	132
9.6.2	Principle of Comparative Shielding Effectiveness Measurement	137
9.7	Results of the Shielding Effectiveness Measurements	137

10	PCB Shielding	149
10.1	Technical Setup of the Test Structures/New EMC PCBs	149
10.2	Electromagnetic Interference Emission (EMC) with Old and New PCB	149
10.3	Evaluation	157
10.4	Summary	157
10.4.1	Experimental Results and Applications	163
11	Shielding Effectiveness on Layers for Cables	165
11.1	Measurement with Stripline	165
11.2	Application: Ribbon Cable	167
11.3	Summary	167
12	Textile Shielding Material	171
12.1	Summary/Outlook	171
13	Shielding Effectiveness of a Wire Mesh	175
 Part III Novel Future Ferrites: Hexagonal Volume Materials		
14	Basic Problem of Today's EMC Ferrite Interference Suppression Materials	179
14.1	Introduction	180
14.2	Theoretical Considerations	181
14.3	Experimental Investigation	184
14.4	Summary: Novel Hexaferrites of the Future	186
15	Appendix: Shielding Formulas	187
15.1	Basic Law of Electromagnetic Shielding According to Schelkunov	188
15.2	Shielding against Magnetostatic Fields	189
15.3	Shielding Against Electrostatic Fields	189
15.4	Shielding Against Quasi-Static Magnetic Fields	189
15.5	Shielding Against Alternating Magnetic Fields (Skin Effect)	190
15.6	Extended Shielding Law According to Schwab	191
15.7	Absorption Loss	191
15.8	Multiple Reflection Attenuation	192
15.9	Shielding Effectiveness as a Function of Surface Conductivity	192
15.10	Extended Shielding Effectiveness Law According to Perumalraj and Dasaradan [58] Considering Real Apertures of Wire Constructions of Real Shields with Holes	192
15.11	Shielding of Holes and Apertures	193
15.12	Near-Field Reflection Loss R on a Plane Plate	194

15.13	Law of Shielding Effectiveness Considering the Waveguide Effect and Apertures According to Tee Tang [61], Near Fields, Far Fields	195
15.14	Cut-off Frequency of Length and Depth of Rectangular Structures (Waveguide Like)	197
15.15	Corner Effect	198
15.16	Transient Shielding Effectiveness	198
15.17	Shielding Rules	198
References		201
FurtherReading		203
Index		205