CISPR/TR 16-3

Edition 3.0 2010-08

TECHNICAL REPORT

colour
inside

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 3: CISPR technical reports

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XH

ICS 33.100.10; 33.100.20

ISBN 978-2-88912-147-2

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 14

1 Scope 16

2 Normative references 16

3 Terms, definitions and abbreviations 17

- 3.1 Terms and definitions 17
- 3.2 Abbreviations 20

4 Technical reports 20

- 4.1 Correlation between measurements made with apparatus having characteristics differing from CISPR characteristics and measurements made with CISPR apparatus 20
  - 4.1.1 General 20
  - 4.1.2 Critical interference-measuring instrument parameters 21
  - 4.1.3 Impulse interference – correlation factors 23
  - 4.1.4 Random noise 25
  - 4.1.5 The root mean square (rms) detector 25
  - 4.1.6 Discussion 25
  - 4.1.7 Application to typical noise sources 25
  - 4.1.8 Conclusions 26
- 4.2 Interference simulators 27
  - 4.2.1 General 27
  - 4.2.2 Types of interference signals 27
  - 4.2.3 Circuits for simulating broadband interference 28
- 4.3 Relationship between limits for open-area test site and the reverberation chamber 32
  - 4.3.1 General 32
  - 4.3.2 Correlation between measurement results of the reverberation chamber and OATS 32
  - 4.3.3 Limits for use with the reverberation chamber method 33
  - 4.3.4 Procedure for the determination of the reverberation chamber limit 33
- 4.4 Characterization and classification of the asymmetrical disturbance source induced in telephone subscriber lines by AM broadcasting transmitters in the LW, MW and SW bands 34
  - 4.4.1 General 34
  - 4.4.2 Experimental characterization 34
  - 4.4.3 Prediction models and classification 44
  - 4.4.4 Characterization of the immunity-test disturbance source 47
- 4.5 Predictability of radiation in vertical directions at frequencies above 30 MHz 55
  - 4.5.1 Summary 55
  - 4.5.2 Range of application 56
  - 4.5.3 General 56
  - 4.5.4 Method used to calculate field patterns in the vertical plane 58
  - 4.5.5 Limitations of predictability of radiation at elevated angles 59
  - 4.5.6 Differences between the fields over a real ground and the fields over a perfect conductor 87
  - 4.5.7 Uncertainty ranges 93
  - 4.5.8 Conclusions 96

4.6 The predictability of radiation in vertical directions at frequencies up to 30 MHz 97
  4.6.1 Range of application 97
  4.6.2 General 97
  4.6.3 Method of calculation of the vertical radiation patterns 98
  4.6.4 The source models 99
  4.6.5 Electrical constants of the ground 100
  4.6.6 Predictability of radiation in vertical directions 101
  4.6.7 Conclusions 109
  4.6.8 Figures associated with predictability of radiation in vertical directions 110
4.7 Correlation between amplitude probability distribution (APD) characteristics of disturbance and performance of digital communication systems 139
  4.7.1 General 139
  4.7.2 Influence on a wireless LAN system 139
  4.7.3 Influence on a Bluetooth system 142
  4.7.4 Influence on a W-CDMA system 146
  4.7.5 Influence on Personal Handy Phone System (PHS) 149
  4.7.6 Quantitative correlation between noise parameters and system performance 153
  4.7.7 Quantitative correlation between noise parameters of repetition pulse and system performance of PHS and W-CDMA (BER) 157
4.8 Background material on the definition of the rms-average weighting detector for measuring receivers 160
  4.8.1 General – purpose of weighted measurement of disturbance 160
  4.8.2 General principle of weighting – the CISPR quasi-peak detector 160
  4.8.3 Other detectors defined in CISPR 16-1-1 161
  4.8.4 Procedures for measuring pulse weighting characteristics of digital radiocommunications services 162
  4.8.5 Theoretical studies 165
  4.8.6 Experimental results 167
  4.8.7 Effects of spread-spectrum clock interference on wideband radiocommunication signal reception 185
  4.8.8 Analysis of the various weighting characteristics and proposal of a weighting detector 186
  4.8.9 Properties of the rms-average weighting detector 189
4.9 Common mode absorption devices (CMAD) 191
  4.9.1 General 191
  4.9.2 CMAD as a two-port device 193
  4.9.3 Measurement of CMAD 197
4.10 Background on the definition of the FFT-based receiver 207
  4.10.1 General 207
  4.10.2 Tuned selective voltmeters and spectrum analyzers 208
  4.10.3 General principle of a tuned selective voltmeter 208
  4.10.4 FFT-based receivers – digital signal processing 210
  4.10.5 Measurement errors specific to FFT processing 213
  4.10.6 FFT-based receivers – examples 215
5 Background and history of CISPR 228
5.1 The history of CISPR 228
  5.1.1 The early years: 1934-1984 228

5.1.2 The division of work 230
5.1.3 The computer years: 1984 to 1998 230
5.1.4 The people in CISPR 231
5.2 Historical background to the method of measurement of the interference power produced by electrical household and similar appliances in the VHF range 231
5.2.1 Historical detail 231
5.2.2 Development of the method 232
Annex A (informative) Derivation of the formula 234
Annex B (informative) The field-strength distribution 238
Annex C (informative) The induced asymmetrical open-circuit voltage distribution 242
Annex D (informative) The outlet-voltage distribution 245
Annex E (informative) Some mathematical relations 247
Annex F (informative) Harmonic fields radiated at elevated angles from 27 MHz ISM equipment over real ground 249
Bibliography 255

Figure 1 – Relative response of various detectors to impulse interference 22
Figure 2 – Pulse rectification coefficient $P(\alpha)$ 23
Figure 3 – Pulse repetition frequency 24
Figure 4 – Block diagram and waveforms of a simulator generating noise bursts 30
Figure 5 – Block diagram of a simulator generating noise bursts according to the pulse principle 31
Figure 6 – Details of a typical output stage 32
Figure 7 – Scatter plot of the measured outdoor magnetic field strength H_o (dBμA/m) versus the calculated outdoor magnetic field strength H_c dB(μA/m) 36
Figure 8 – Measured outdoor magnetic versus distance, and probability of the building-effect parameter 37
Figure 9 – Normal probability plot of the building-effect parameter A_b dB 38
Figure 10 – Scatter plot of the outdoor antenna factor G_o dB(Ωm) versus the indoor antenna factor G_i 39
Figure 11 – Normal probability plots of the antenna factors 40
Figure 12 – Normal probability plot of the equivalent asymmetrical resistance R_a dB(Ω) 43
Figure 13 – Examples of the frequency dependence of some parameters 44
Figure 14 – Example of the frequency histogram $\Delta N(E_\mathrm{o},\Delta E_\mathrm{o})$ 49
Figure 15 – Example of $n_\mathrm{m}(E_\mathrm{o})$, i.e. the distribution of the outlets experiencing a maximum field strength E_o resulting from a given number of transmitters in (or near) the respective geographical region 50
Figure 16 – Example of the number of outlets with an induced asymmetrical open-circuit voltage $U_\mathrm{L} \leq U_\mathrm{h} \leq U_\mathrm{max}$ = 79 V (see Table 10) 52
Figure 17 – Examples of number (left-hand scale) and relative number (right-hand scale) of outlets with $U_\mathrm{L} \leq U_\mathrm{h} \leq U_\mathrm{max}$ 53
Figure 18 – Vertical polar patterns of horizontally polarized E_x field strengths emitted around small vertical loop (horizontal magnetic dipole) over three different types of real ground 61
Figure 19 – Height scan patterns of vertically oriented E_z field strengths emitted from small vertical loop (horizontal magnetic dipole) over three different types of real ground 61

Figure 20 – Vertical polar patterns of horizontally polarized E_x field strengths emitted around small vertical loop (horizontal magnetic dipole), over three different types of real ground 63

Figure 21 – Vertical polar patterns of vertically oriented E_z field strengths emitted around small vertical loop (horizontal magnetic dipole) over three different types of real ground 63

Figure 22 – Height scan patterns of vertically oriented E_z field strengths emitted at 1 000 MHz from the small vertical loop (horizontal magnetic dipole), at horizontal distance of 10 m, 30 m and 300 m in the Z-X plane over three different types of real ground 64

Figure 23 – Vertical polar patterns of horizontally polarized E_x and vertically oriented E_z field strengths emitted around small horizontal electric dipole, in Y-Z and Z-X planes respectively 66

Figure 24 – Height scan patterns of horizontally polarized E_x field strengths emitted from small horizontal electric dipole 66

Figure 25 – Vertical polar patterns of horizontally polarized E_x and vertically oriented E_z field strengths emitted around small horizontal electric dipole in Y-Z and Z-X planes respectively 69

Figure 26 – Height scan patterns of horizontally polarized E_x field strengths emitted small horizontal electric dipole 69

Figure 27 – Vertical polar patterns of horizontally polarized E_x and vertically oriented E_z field strengths emitted around small vertical loop (horizontal magnetic dipole) in Y-Z and Z-X planes respectively 70

Figure 28 – Height scan patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted from small vertical loop (horizontal magnetic dipole) 70

Figure 29 – Vertical polar patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted around small vertical electric dipole 73

Figure 30 – Height scan patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted from small vertical electric dipole 73

Figure 31 – Vertical polar patterns of horizontally polarized E_x and vertically oriented E_z field strengths emitted around small vertical loop (horizontal magnetic dipole) in Y-Z and Z-X planes respectively 74

Figure 32 – Height scan patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted from small vertical loop (horizontal magnetic dipole) 74

Figure 33 – Vertical polar patterns of horizontally polarized E-field strength emitted around small horizontal loop (vertical magnetic dipole) 75

Figure 34 – Height scan patterns of horizontally polarized E-field strength emitted from small horizontal loop (vertical magnetic dipole) 75

Figure 35 – Vertical polar patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted around small vertical electric dipole 78

Figure 36 – Height scan patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted from the small vertical electric dipole 78

Figure 37 – Vertical polar patterns of horizontally polarized E_x and vertically oriented E_z field strengths emitted around small vertical loop (horizontal magnetic dipole) in Y-Z and Z-X planes respectively 79

Figure 38 – Height scan patterns of vertically oriented E_z and horizontally oriented E_x field strengths emitted from small vertical loop (horizontal magnetic dipole) 79

Figure 39 – Vertical polar patterns of horizontally polarized E-field strength emitted around small horizontal loop (vertical magnetic dipole) 80

Figure 40 – Height scan patterns of horizontally polarized E-field strength emitted from small horizontal loop (vertical magnetic dipole) 80

Figure 41 – Vertical polar patterns of horizontally polarized *E*-field strength emitted around the small horizontal loop (vertical magnetic dipole) 83

Figure 42 – Height scan patterns of horizontally polarized *E*-field strength emitted from small horizontal loop (vertical magnetic dipole) 83

Figure 43 – Height scan patterns of horizontally polarized *E*-field strength emitted from small horizontal loop (vertical magnetic dipole) 87

Figure 44 – Height scan patterns of the vertical component of the *E*-fields emitted from a small vertical electric dipole 90

Figure 45 – Height scan patterns of the vertical component of the *E*-fields emitted from a small vertical electric dipole 90

Figure 46 – Height scan patterns of the horizontally polarized *E*-fields emitted in the vertical plane normal to the axis of a small horizontal electric dipole 92

Figure 47 – Height scan patterns of the horizontally polarized *E*-fields emitted in the vertical plane normal to the axis of a small horizontal electric dipole 92

Figure 48 – Ranges of uncertainties in the predictability of radiation in vertical directions from electrically small sources located at a height of 1 m or 2 m above ground 94

Figure 49 – Ranges of uncertainties in the predictability of radiation in vertical directions from electrically small sources located at a height of 1 m or 2 m above ground 95

Figure 50 – Ranges of uncertainties in the predictability of radiation in vertical directions from electrically small sources located at a height of 1 m or 2 m above ground 96

Figure 51 – Geometry of the small vertical electric dipole model 100

Figure 52 – Geometry of the small horizontal electrical dipole model 100

Figure 53 – Geometry of the small horizontal magnetic dipole model (small vertical loop) 100

Figure 54 – Geometry of the small vertical magnetic dipole model (small horizontal loop) 100

Figure 55 – Ranges of errors in the predictability of radiation in vertical directions from electrically small sources located close to the ground, based on measurements of the horizontally oriented *H*-field near ground at a distance of 30 m from the sources 108

Figure 56 – Ranges of errors in the predictability of radiation in vertical directions from electrically small sources located close to the ground, based on measurements of the horizontally oriented *H*-field at the ground supplemented with measurements of the vertically oriented *H*-field in a height scan up to 6 m at a distance of 30 m from the sources 109

Figure 57 – Vertical radiation patterns of horizontally oriented *H*-fields emitted by a small vertical electric dipole located close to the ground 111

Figure 58 – Vertical radiation patterns of horizontally oriented *H*-fields emitted by a small vertical electric dipole located close to the ground 111

Figure 59 – Vertical radiation patterns of *E*-fields emitted by a small vertical electric dipole located close to the ground 112

Figure 60 – Vertical radiation patterns of the *E*-fields emitted by a small vertical electric dipole located close to the ground 112

Figure 61 – Vertical radiation patterns of the *H*-fields emitted by a small horizontal electric dipole located close to the ground 113

Figure 62 – Influence of a wide range of values of the electrical constants of the ground on the vertical radiation patterns of the horizontally oriented *H*-fields emitted by a small horizontal electric dipole located close to the ground 113

Figure 63 – Vertical radiation patterns of the horizontally oriented *H*-fields emitted by a small horizontal electric dipole located close to the ground 114

Figure 64 – Vertical radiation patterns of the E-fields emitted by a small horizontal electric dipole located close to the ground 114

Figure 65 – Vertical radiation patterns of the E-fields emitted by a small horizontal electric dipole located close to the ground 115

Figure 66 – Vertical radiation patterns of H-fields emitted by small horizontal magnetic dipole (vertical loop) located close to ground 115

Figure 67 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 116

Figure 68 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 116

Figure 69 – Vertical radiation patterns of the E-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 117

Figure 70 – Vertical radiation patterns of the E-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 117

Figure 71 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 118

Figure 72 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 118

Figure 73 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 119

Figure 74 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 119

Figure 75 – Vertical radiation pattern of the E-field emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 120

Figure 76 – Vertical radiation patterns of the E-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 120

Figure 77 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small vertical electric dipole located close to the ground 121

Figure 78 – Vertical radiation patterns of the E-fields emitted by a small vertical electric dipole located close to the ground 121

Figure 79 – Vertical radiation patterns of the E-fields emitted by a small vertical electric dipole located close to the ground 122

Figure 80 – Vertical radiation patterns of the H-fields emitted by a small horizontal electric dipole located close to the ground 122

Figure 81 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal electric dipole located close to the ground 123

Figure 82 – Vertical radiation patterns of the E-fields emitted by a small horizontal electric dipole located close to the ground 123

Figure 83 – Vertical radiation patterns of the E-fields emitted by a small horizontal electric dipole located close to the ground 124

Figure 84 – Vertical radiation patterns of the H-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 124

Figure 85 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 125

Figure 86 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 125

Figure 87 – Vertical radiation patterns of the E-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 126

Figure 88 – Vertical radiation patterns of the E-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 126

Figure 89 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 127

Figure 90 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 127

Figure 91 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 128

Figure 92 – Vertical radiation patterns of the E-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 128

Figure 93 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small vertical electric dipole located close to the ground 129

Figure 94 – Vertical radiation patterns of the E-fields emitted by a small vertical electric dipole located close to the ground 129

Figure 95 – Vertical radiation patterns of the E-fields emitted by a small vertical electric dipole located close to the ground 130

Figure 96 – Vertical radiation patterns of the H-fields emitted by a small horizontal electric dipole located close to the ground 130

Figure 97 – Vertical radiation patterns of the E-fields emitted by a small horizontal electric dipole located close to the ground 131

Figure 98 – Vertical radiation patterns of the E-fields emitted by a small horizontal electric dipole located close to the ground 131

Figure 99 – Vertical radiation patterns of the H-field emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 132

Figure 100 – Vertical radiation patterns of the vertically polarized E-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 132

Figure 101 – Vertical radiation patterns of the H-field emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 133

Figure 102 – Vertical radiation patterns of the E-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 133

Figure 103 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small vertical electric dipole located close to the ground 134

Figure 104 – Vertical radiation patterns of the vertically polarized E-fields emitted by a small vertical electric dipole located close to the ground 134

Figure 105 – Vertical radiation patterns of the H-fields emitted by a small horizontal electric dipole located close to the ground 135

Figure 106 – Vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal electric dipole located close to the ground 135

Figure 107 – Influence of a wide range of values of the electrical constants of the ground on the vertical radiation patterns of the horizontally oriented H-fields emitted by a small horizontal electric dipole located close to the ground 136

Figure 108 – Vertical radiation patterns of the vertically polarized E-fields emitted by a small horizontal electric dipole located close to the ground 136

Figure 109 – Vertical radiation patterns of the H-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 137

Figure 110 – Vertical radiation patterns of the vertically polarized E-fields emitted by a small horizontal magnetic dipole (vertical loop) located close to the ground 137

Figure 111 – Vertical radiation patterns of the H-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 138

Figure 112 – Vertical radiation patterns of the E-fields emitted by a small vertical magnetic dipole (horizontal loop) located close to the ground 138

Figure 113 – Set-up for measuring communication quality degradation of a wireless LAN 139

Figure 114 – APD characteristics of disturbance 141
Figure 115 – Wireless LAN throughput influenced by noise 142
Figure 116 – Set-up for measuring the communication quality degradation of Bluetooth 143
Figure 117 – APD of disturbance of actual MWO (2 441MHz) 143
Figure 118 – APD characteristics of disturbance (2 460 MHz) 144
Figure 119 – Throughput of Bluetooth influenced by noise 146
Figure 120 – Set-up for measuring the BER of W-CDMA 147
Figure 121 – APD characteristics of disturbance 148
Figure 122 – BER of W-CDMA caused by radiation noise 149
Figure 123 – Set-up for measuring the PHS throughput 150
Figure 124 – Set-up for measuring the BER of PHS 150
Figure 125 – APD characteristics of disturbance 151
Figure 126 – PHS throughput caused by radiation 152
Figure 127 – BER of PHS caused by radiation noise 153
Figure 128 – Correlation of the disturbance voltages with the system performance (C/N_0) 154
Figure 129 – Correlation of the disturbance voltages with the system performance 155
Figure 130 – Correlation of the disturbance voltages with the system performance 155
Figure 131 – Correlation of the disturbance voltages with the system performance (C/N_0) 156
Figure 132 – Correlation of the disturbance voltages with the system performance (C/N_0) 156
Figure 133 – Experimental set-up for measuring communication quality degradation of a PHS or W-CDMA 157
Figure 134 – Simulation set-up for estimating communication quality degradation of a PHS or W-CDMA 157
Figure 135 – APD of pulse disturbance 158
Figure 136 – BER degradation of PHS and W-CDMA caused by repetition pulse (Carrier power, –35 dBm) 158
Figure 137 – Evaluation method of the correlation between BER and APD 159
Figure 138 – Correlation between measured ΔL_{BER} and ΔL_{APD} 159
Figure 139 – Correlation between measured p_{BER} and p_{APD} 160
Figure 140 – Weighting curves of quasi-peak measuring receivers for the different frequency ranges as defined in CISPR 16-1-1 161
Figure 141 – Weighting curves for peak, quasi-peak, rms and linear average detectors for CISPR bands C and D 162
Figure 142 – Test setup for the measurement of the pulse weighting characteristics of a digital radiocommunication system 163
Figure 143 – Example of an interference spectrum: pulse modulated carrier with a pulse duration of 0,2 µs and a PRF < 10 kHz 164
Figure 144 – The rms and peak levels for constant BEP for three K = 3, convolutional codes of different rate 166
Figure 145 – The rms and peak levels for constant BEP for two rate ½, convolutional code 167
Figure 146 – Test setup for the measurement of weighting curves for Digital Radio Mondiale (DRM) 169

Figure 147 – Weighting characteristics for DRM signals for various pulse widths of the pulse-modulated carrier 170

Figure 148 – Weighting characteristics for DRM protection level 0: average of results for two receivers 171

Figure 149 – Weighting characteristics for DRM protection level 1: average of results for two receivers 171

Figure 150 – Weighting characteristics for DVB-T with 64 QAM 2k, *CR* 3/4 (as used in France and UK) 173

Figure 151 – Weighting characteristics for DVB-T with 64 QAM 8k, *CR* 3/4 (as used in Spain) 174

Figure 152 – Weighting characteristics for DVB-T with 16 QAM 8k, *CR* 2/3 (as used in Germany) 174

Figure 153 – Average weighting characteristics of 6 receiver types for DVB-T with 16QAM 175

Figure 154 – Average weighting characteristics of 6 receiver types for DVB-T with 64QAM 176

Figure 155 – Weighting characteristics for DAB (signal level -71 dBm) with a flat response down to approximately 1 kHz 177

Figure 156 – Weighting characteristics for DAB: average of two different commercial receiver types 177

Figure 157 – Weighting characteristics for TETRA (signal level – 80 dBm) for a code rate of 1 178

Figure 158 – Weighting characteristics for RBER 1b of GSM (signal level –90 dBm) 179

Figure 159 – Weighting characteristics for RBER 2 of GSM 179

Figure 160 – Carrier-to-interference improvements with decreasing PRF in dB computed for GSM using COSSAP 180

Figure 161 – Rms and quasi-peak values of pulse level for constant effect on FM radio reception 180

Figure 162 – Weighting characteristics for RBER 1b of GSM (signal level –90 dBm) 181

Figure 163 – Weighting characteristics for DECT (signal level –83 dBm) 182

Figure 164 – Weighting characteristics for IS-95 (signal level -97 dBm) with comparatively high immunity to interference 183

Figure 165 – Weighting characteristics for J-STD 008 (signal level –97 dBm) 183

Figure 166 – Weighting characteristics for the Frame Error Ratio (FER) of CDMA2000 (measured at a receive signal level of –112 dBm) for a low data rate of 9,6 kb/s 184

Figure 167 – Weighting characteristics for the Frame Error Ratio (FER) of CDMA2000 (measured at a receive signal level of –106 dBm) for two different data rates (9,6 kb/s and 76,8 kb/s) 185

Figure 168 – The proposed rms-average detector for CISPR Bands C and D with a corner frequency of 100 Hz 188

Figure 169 – Rms-average detector function by using an rms detector followed by a linear average detector and peak reading 188

Figure 170 – Rms-average weighting functions for CISPR Bands A, B, C/D and E for the shortest pulse widths allowed by the measurement bandwidths 189

Figure 171 – Shift of the rms-average weighting function for CISPR band C/D by using a bandwidth of 1 MHz instead of 120 kHz, if the shortest possible pulse widths are applied 190

Figure 172 – Example of a simple EUT model 192

Figure 173 – Representation of a CMAD as a two-port device 194

Figure 174 – Conformal mapping between z-plane and f-plane 196

Figure 175 – Conversion from 50 Ω coaxial system to the geometry of the two-port device-under-test 198

Figure 176 – Basic model for the TRL calibration 199

Figure 177 – The four calibration configurations necessary for the TRL calibration 200

Figure 178 – Measurement of CMAD characteristics 204

Figure 179 – Preliminary measurements of the test set-up 206

Figure 180 – Position of the reference planes for the measurement with SOLT calibration and $ABCD$ transformation to Z_{ref} level 207

Figure 181 – Superheterodyne EMI receiver 209

Figure 182 – An example spectrogram $Z[m,k]$ 211

Figure 183 – Sidelobe effect due to the finite length of window 213

Figure 184 – Measurement error for a single pulse 214

Figure 185 – IF signal for different overlapping factors for the same sequence of pulses 215

Figure 186 – FFT-based baseband system 216

Figure 187 – Real-time FFT-based measuring instrument 217

Figure 188 – Digital down-converter 217

Figure 189 – Short time fast Fourier transform – An example of implementation 218

Figure 190 – Floating-point analogue-to-digital conversion 218

Figure 191 – Example of a 120 kHz Gaussian filter 219

Figure 192 – Essential parts of an FFT-based heterodyne receiver 220

Figure 193 – Dynamic range for broadband emission as measured with the peak detector 222

Figure 194 – Set-up of FFT-based system type 2 222

Figure 195 – FFT Software (“FFTemi”) screen shot 225

Figure 196 – Example of pulse generator measurement with antenna 226

Figure 197 – Radiated emission measurement of a motor – peak detector 227

Figure 198 – Angular characterization of a PC 227

Figure 199 – Example FFT IF analysis display 228

Figure A.1 – Example plot using the expression $P_{\mathrm{t}} + G = P_{\mathrm{q}} + 2$ 235

Figure A.2 – Examples of a number of microwaves measured for P_{q} and P_{t} 237

Figure B.1 – Definition of the ring-shaped area round the transmitter T 239

Figure C.1 – The permissible ranges of U_{h} and G are within the polygon $\{G_{\mathrm{L}},U_{\mathrm{a}}\}$, $\{G_{\mathrm{L}},U_{\mathrm{b}}\}$, $\{G_{\mathrm{U}},U_{\mathrm{d}}\}$, $\{G_{\mathrm{I}},U_{\mathrm{c}}\}$ and $\{G_{\mathrm{L}},U_{\mathrm{a}}\}$. For the given value U_{L} the double-shaded area represents $pr\{U_{\mathrm{h}} \geq U_{\mathrm{L}}\}$ 243

Figure F.1 – Vertical radiation patterns of horizontally polarized fields, 109 MHz, 300 m scan radius (adapted from [34]) 251

Figure F.2 – Vertical radiation patterns of horizontally polarized fields, 109 MHz, 300 m scan radius (adapted from [34]) 252

Figure F.3 – Vertical radiation patterns of horizontally polarized fields, 109 MHz, 300 m scan radius (adapted from [34]) 253

Figure F.4 – Vertical radiation patterns of horizontally polarized fields, 109 MHz, 300 m scan radius (adapted from [34]) 254

Table 1 – Comparative response of slideback peak, quasi-peak and average detectors to sine wave, periodic pulse and Gaussian waveform 22

Table 2 – Characteristics of gate generator and modulator to simulate various types of broadband interference 28

Table 3 – Summary results of building-effect, A_b, analysis 38

Table 4 – Summary of results of G-factor analysis 41

Table 5 – Summary of L_0 factors (far-field) 41

Table 6 – Summary of truncation parameters of $f(G)$ 42

Table 7 – Summary results of equivalent-resistance analysis 43

Table 8 – Example of field-strength classification 46

Table 9 – Example of voltage classification assuming for the outdoor field strength: E_{max} = 60 V/m and E_{min} = 0,01 V/m 47

Table 10 – Summary of the parameters used in the numerical examples presented in Figures 16 and 17 51

Table 11 – Frequencies of interest in ITU designated bands from Table 9 of CISPR 11:2009 58

Table 12 – Electrical constants for “medium dry ground” [31] (CCIR: medium dry ground; rocks; sand; medium sized towns[32]) 59

Table 13 – Electrical constants for “wet ground” [31] (CCIR: marshes (fresh water); cultivated land [24]) and “very dry ground” [31] (CCIR: very dry ground; granite mountains in cold regions; industrial areas [32]) 59

Table 14 – Estimates of the errors in prediction of radiation in vertical directions based on a measurement height scan from 1 m to 4 m at known distances, d; frequency = 75 MHz (adapted from [39]) 67

Table 15 – Estimates of the errors in prediction of radiation in vertical directions based on a measurement height scan from 1 m to 4 m at known distances, d; frequency = 110 MHz (adapted from [39]) 71

Table 16 – Estimates of the errors in prediction of radiation in vertical directions based on a measurement height scan from 1 m to 4 m at known distances, d; frequency = 243 MHz (adapted from [39]) 76

Table 17 – Estimates of the errors in prediction of radiation in vertical directions based on a measurement height scan from 1 m to 4 m at known distances, d; frequency = 330 MHz (adapted from [39]) 81

Table 18 – Estimates of the errors in prediction of radiation in vertical directions based on a measurement height scan from 1 m to 4 m at known distances, d; frequency = 1 000 MHz (adapted from [39]) 84

Table 19 – Predictability of radiation in vertical directions at 100 kHz, using ground-based measurements of horizontally oriented H-field at distances up to 3 km from the source (figures are located in 4.6.8) 101

Table 20 – Predictability of radiation in vertical directions at 1 MHz, using ground-based measurements of horizontally oriented H-field at distances up to 300 m from the source (figures are located in 4.6.8) 103

Table 21 – Predictability of radiation in vertical directions at 10 MHz, using ground-based measurements of horizontally oriented H-field at distances up to 300 m from the source (figures are located in 4.6.8) 104

Table 22 – Predictability of radiation in vertical directions at 30 MHz, using ground-based measurements of horizontally oriented H-field at distances up to 300 m from the source (figures are located in 4.6.8) 105

Table 23 – Conditions for measuring communication quality degradation 140

Table 24 – Average and rms values of noise level normalized by N_0 141

Table 25 – Conditions for measuring communication quality degradation of Bluetooth 143

Table 26 – Average and rms values of noise level normalized by N_0 144
Table 27 – Average and rms values of noise level normalized by N_0 145
Table 28 – Conditions for measuring communication quality degradation of W-CDMA......... 147
Table 29 – Average and rms values of noise level normalized by N_0 148
Table 30 – Conditions for measuring the PHS throughput 150
Table 31 – Conditions for measuring the BER of PHS 150
Table 32 – Average and rms values of noise level normalized by N_0 151
Table 33 – Overview of types of interference used in the experimental study of weighting characteristics 164
Table 34 – DRM radio stations received for the measurement of the weighting characteristics 168
Table 35 – Comparison of BER values for the same interference level 172
Table 36 – Transmission parameters of DVB-T systems used in various countries 173
Table 37 – Example of measurement results in dB(μV) of unmodulated and FM modulated carriers for various detectors (bandwidth 120 kHz) 186
Table 38 – Survey of the corner frequencies found in the various measurement results 187
Table 39 – Measurement results for broadband disturbance sources (measurements with rms-average and quasi-peak detectors are normalized to average detector values)..... 191
Table 40 – Expected deviations between different laboratories for small EUTs due to variations of the impedance Z_{apparent} at point B 192
Table 41 – Calibration measurement results format 201
Table 42 – Scan times 219
Table 43 – Sampling rates for different B_{WIF} 223
Table 44 – Scan times for a scan 30 MHz to 1 GHz 224

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 3: CISPR technical reports

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art."

CISPR 16-3, which is a technical report, has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods.

This third edition of CISPR 16-3 cancels and replaces the second edition published in 2003, and its Amendments 1 (2005) and 2 (2006). It is a technical revision.

The main technical change with respect to the previous edition consist of the addition of a new clause to provide background information on FFT instrumentation.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
CISPR/A/888/DTR	CISPR/A/899/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

A list of all parts of the CISPR 16 series can be found, under the general title *Specification for radio disturbance and immunity measuring apparatus and methods*, on the IEC website.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 3: CISPR technical reports

1 Scope

This part of CISPR 16 is a collection of technical reports (Clause 4) that serve as background and supporting information for the various other standards and technical reports in CISPR 16 series. In addition, background information is provided on the history of CISPR, as well as a historical reference on the measurement of interference power from household and similar appliances in the VHF range (Clause 5).

Over the years, CISPR prepared a number of recommendations and reports that have significant technical merit but were not generally available. Reports and recommendations were for some time published in CISPR 7 and CISPR 8.

At its meeting in Campinas, Brazil, in 1988, CISPR subcommittee A agreed on the table of contents of Part 3, and to publish the reports for posterity by giving the reports a permanent place in Part 3.

With the reorganization of CISPR 16 in 2003, the significance of CISPR limits material was moved to CISPR 16-4-3, whereas recommendations on statistics of disturbance complaints and on the report on the determination of limits were moved to CISPR 16-4-4. The contents of Amendment 1 (2002) of CISPR 16-3 were moved to CISPR 16-4-1.

NOTE As a consolidated collection of independent technical reports, this document may contain symbols that have differing meanings from one clause to the next. Attempts have been made to minimize this to the extent possible at the time of editing.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CISPR 11:2009, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 60050-300:2001, *International Electrotechnical Vocabulary (IEV) – Electrical and electronic measurements and measuring instruments – Part 311: General terms relating to measurements – Part 312: General terms relating to electrical measurements – Part 313: Types of electrical measuring instruments – Part 314: Specific terms according to the type of instrument*

ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*