The Core of Automotive EMC Testing

Cory Bradshaw

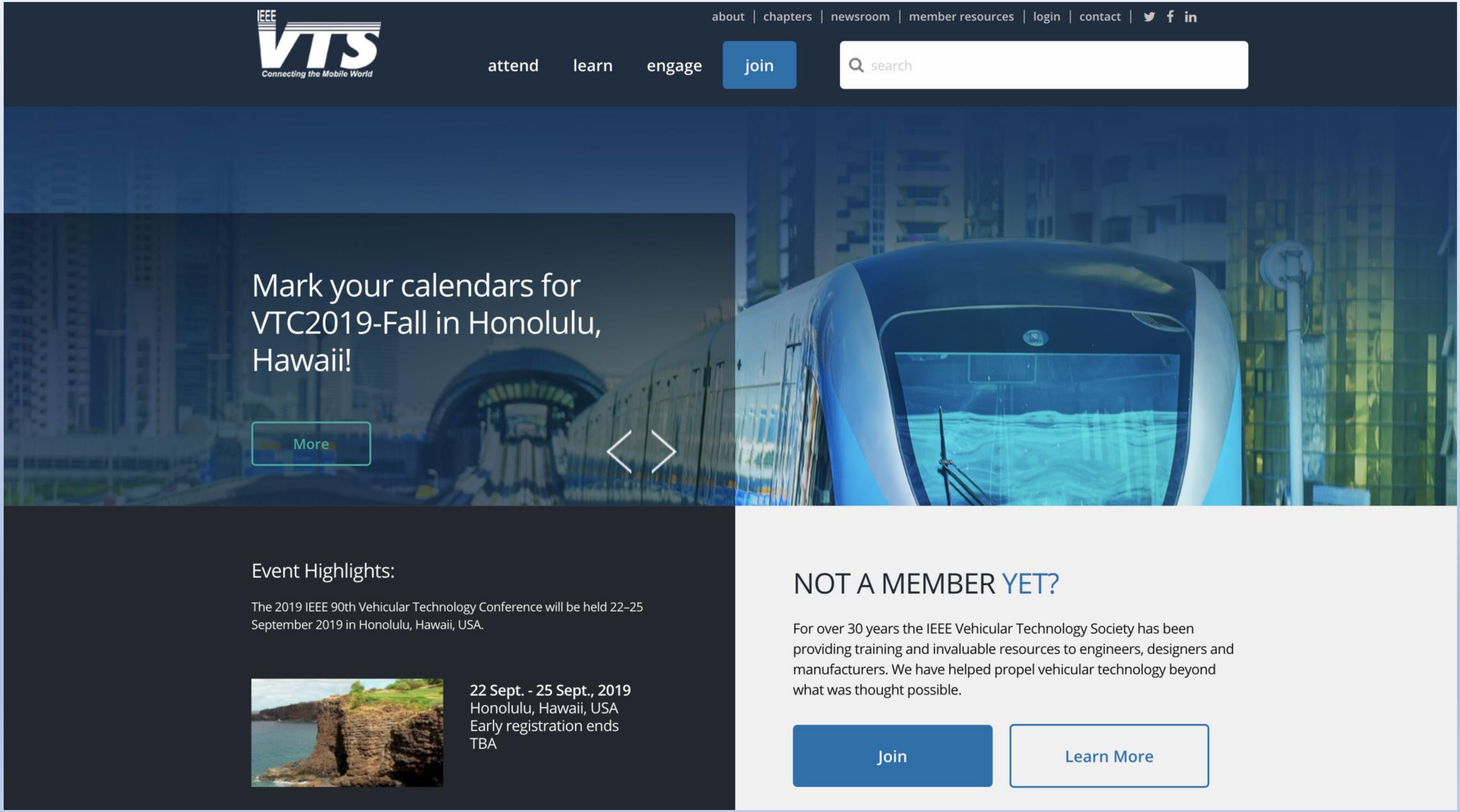
IEEE Vehicular Technology Society Chicago Chapter

IEEE EMC Society Chicago Chapter

DLS Electronics Systems

June 27, 2019

IEEE VEHICULAR TECHNOLOGY SOCIETY (HTTPS://VTSOCIETY.ORG)



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Vehicular Technology Society, Chicago Chapter

Welcome to the IEEE Vehicular Technology Society, Chicago Chapter! We are a group of passionate researchers, engineers, practitioners, industry professionals, and academics who are interested in all things about technology in the vehicle to create connected vehicles and autonomous vehicles. We hold meetings of our chapter around 4 times a year in the Chicagoland area and invite speakers to talk about topics like blockchain for vehicles, cloud and big data for connected vehicles, autonomous vehicles, and shared mobility, just to name a few. You can check out our previous meetings that we had below.

The Chair for the IEEE Vehicular Technology Society, Chicago Chapter is Dr. Alvin Chin, who is a Senior Researcher at BMW TechnologyCorporation in Chicago. The IEEE Vehicular Technology Society, Chicago Chapter is part of the IEEE Vehicular Technology Society (https://vtsociety.org) and the VTS holds their flagship conference IEEE Vehicular Technology Conference twice a year. Last year, the fall edition of the conference was held in Chicago.

Please follow this page to learn about our past and upcoming events and if you have any questions or suggestions, please feel free to email me atalvin.chin@bmwna.com. Also, we are looking for others to volunteer with our chapter, and open positions that are available include Vice-Chair and Treasurer.

Many thanks and I look forward to seeing you at one of the VTS Chicago meetings.

Yours sincerely,

Alvin Chin

Chair, IEEE VTS Chicago

Planned Events

VTS Chicago chapter meeting

IEEE VTS CHICAGO CHAPTER

- http://ieeechicago.org/vt/
- Chair: Alvin Chin, BMW Technology Corporation, alvin.chin@bmwna.com, http://www.alvinychin.com
- Vice-Chair: Kevin Stutenberg, Argonne National Laboratory, kstutenberg@anl.gov
- IEEE Young Professionals VTS Student Chair: Ziru Chen, IIT, zchen71@hawk.iit.edu
- Mission: Create a community of academics and professionals who are interested in all things about technology and engineering in the vehicle, to create connected vehicles and autonomous vehicles.
- Chicago chapter of the IEEE VTS, local VTS activities, and other activities with SAE Chicago
- Have meetings at least 3 times a year
- Venue: BMW Technology office and other offices
- Topics: VANETs, 5G, ACE vehicles, vehicular network, vehicular cloud, connected vehicle platform, smart cities, power, charging, etc.

PREVIOUS IEEE VTS CHICAGO CHAPTER MEETINGS AND JOINT MEETINGS

- *Joint meeting with IEEE Chicago, EMC and SAE Chicago on Wireless Power Transfer – Travis Thul, Minnesota State College Southeast (March 15, 2018*
- *THE ULTIMATE SMART DRIVING MACHINE: POWERING THE CONNECTED CAR WITH MACHINE LEARNING – Dr. Alvin Chin, BMW (April 25, 2018)*
- *CREATING A MARKETPLACE FOR DIGITAL MOBILITY AND TRANSPORTATION IN THE AUTOMOTIVE INDUSTRY– Joe Renz, New Mobility Lab (July 26, 2018)*
- *PERSPECTIVE TO 2040: AUTONOMOUS VEHICLES & MOBILITY-AS-A-SERVICE– Dr. Egil Juliusse, IHS Markit (Nov 28, 2018) – joint with SAE Chicago*
- *Joint meeting with IEEE Chicago, EMC and SAE Chicago on LiveWire Electric Motorcycle, Jim Rader and Zachariah Varney, Harley Davidson (March 13, 2019)*
- *MOBILITY AND THE CONTINUED IMPORTANCE OF EFFICIENCY – Kevin Stutenberg, Argonne National Lab (April 23, 2019) – joint with SAE Chicago*
- *THE ORIGINS OF SILICON VALLEY – Paul Wesling, IEEE Life Member, UIC (May 15, 2019) – joint with SAE Chicago, IEEE CS Chicago, ACM Chicago, Stanford Historical Society, IEEE APS/MTT-S*

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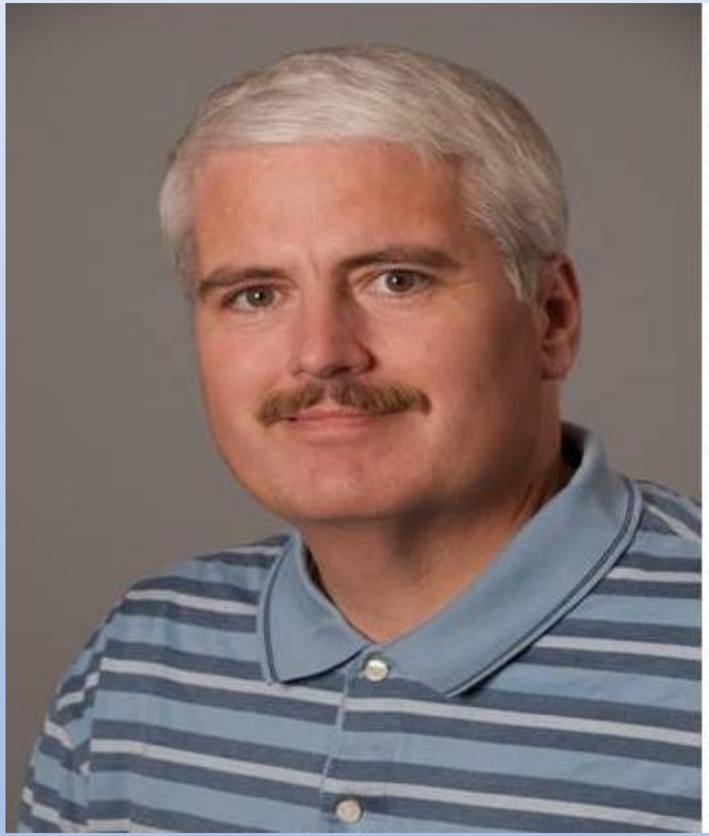
THANKS

Roger A Swanberg

IEEE EMC Chicago Chapter

- Roger A Swanberg
- 1940-2019
- Vice Chair – 33 Years
- IEEE Section Member of the Year
- EMC Society Man of the Year
- EMC Education Recognition
- EMC Society Lifetime Achievement Award

Steven R Sherman



- Steven R Sherman
- 1959-2019
- IEEE EMC Society Member
- IEEE Antennas and Propagation Society Member

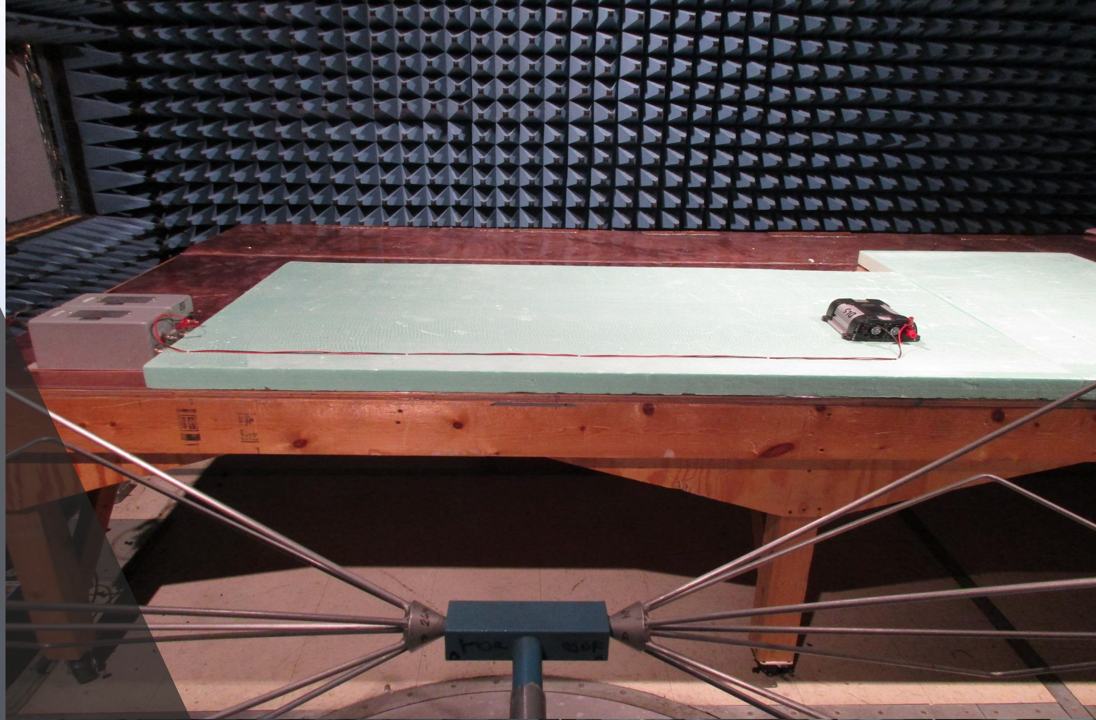
OUR SPEAKER: CORY BRADSHAW

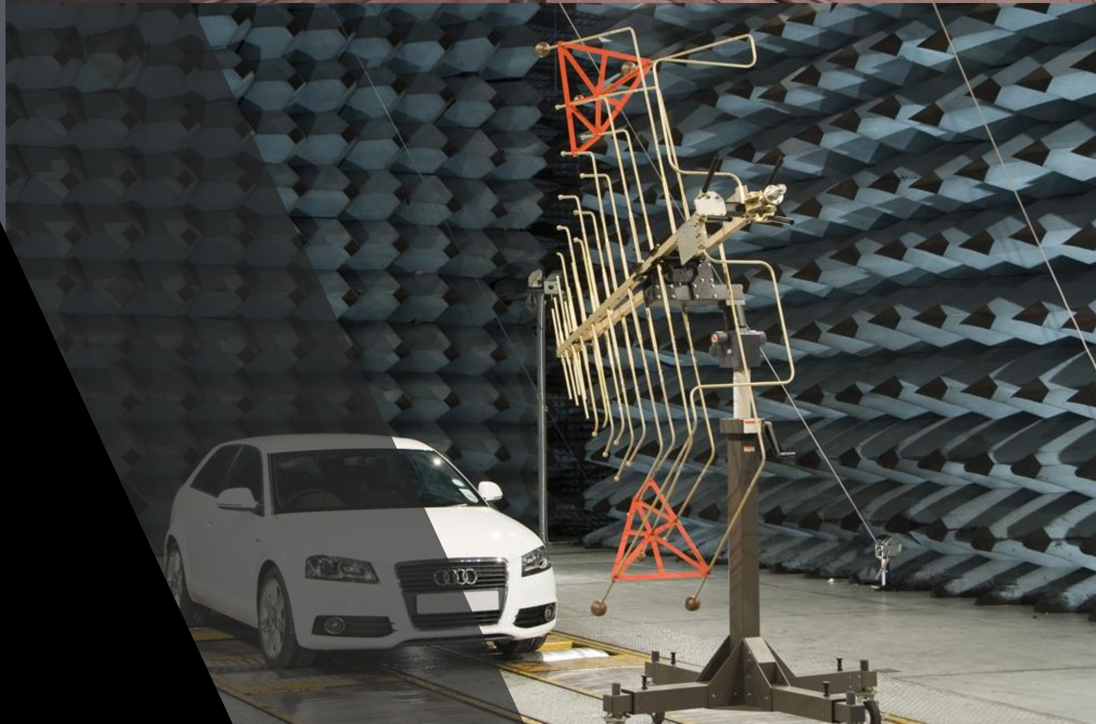
- *Cory Bradshaw is an iNARTE certified EMC test engineer with over 8 years experience in the field of Electromagnetic Compatibility testing.*

- *He holds a bachelor's degree in Technical Management and an Associate's degree in Electrical Engineering, both from DeVry University.*

- *Cory works for DLS Electronic Systems as a test engineer covering all aspects of EMC with a concentration in the automotive electronics area*
- *Email: CBradshaw@dlsemc.com*

THE CORE OF AUTOMOTIVE EMC





Common Automotive EMC Standards

Product Specific

- ISO16750 Earth Moving Machinery
- ISO14982 Agricultural and Forestry
- EN13309 Construction Machinery
- EN 50498 Aftermarket electronic equipment in vehicles
- 204.104.EC Directive relating to Interference in Vehicles

Manufacturer Specific

- BMW - GS 95002
- Harley Davidson - EG 812-22614
- Ford - FMC 1278
- GMC - GMW3091
- Caterpillar - EC-42
- Volkswagen - TL 81000
- John Deere - JDQ 53.3

The Core Automotive EMC Tests for ESA’s

Emissions

- CISPR 25
  - Radiated Emissions
    - 150kHz-2500MHz
  - Conducted Emissions
    - 150kHz-108MHz

Immunity

- ISO 11452-2 Radiated Immunity
- ISO 11452-4 Bulk Current Injection
- ISO 10605 Electrostatic Discharge

CISPR 25 Emissions

- Intended to provide protection for components installed in a vehicle from disturbances produced by other components in the same vehicle.
- Contains provisions for the measurement of disturbances in the frequency range of 150kHz to 2500MHz.
- Defines the test methods used by manufacturers to ensure controlled levels of on-board radio frequency emissions
- This standard is used by vehicle OEMs as an engineering standard for vehicle performance.
- Vehicle OEMs can decide which frequency bands should be protected based upon region and economics.

CISPR 25 Radiated Emissions Measurements

3 Methods of Measurement

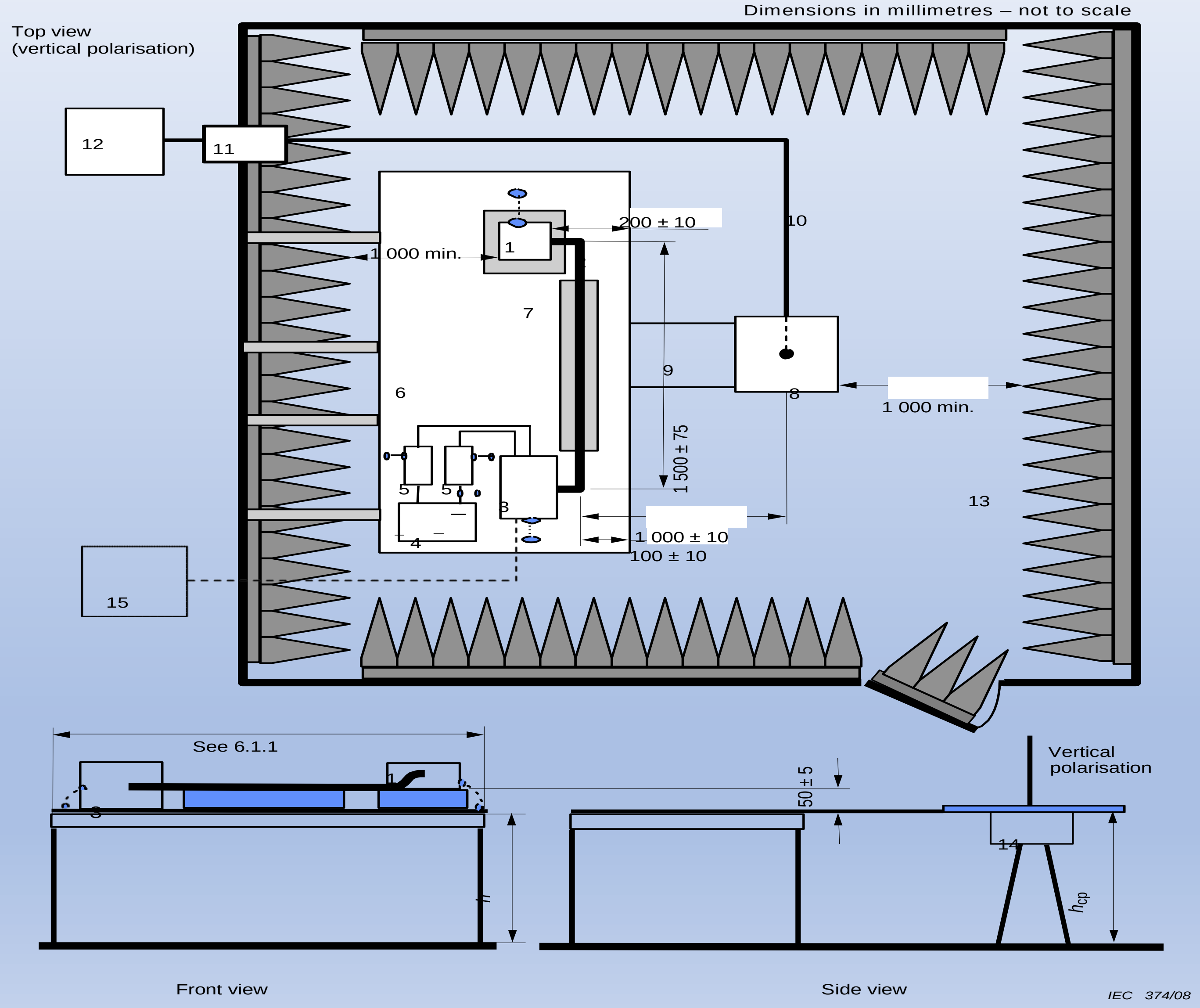
- ALSE (Absorber Lined Shielded Enclosure)
- TEM Cell Method
- Strip-line Method

CISPR 25 Radiated Emissions - ALSE

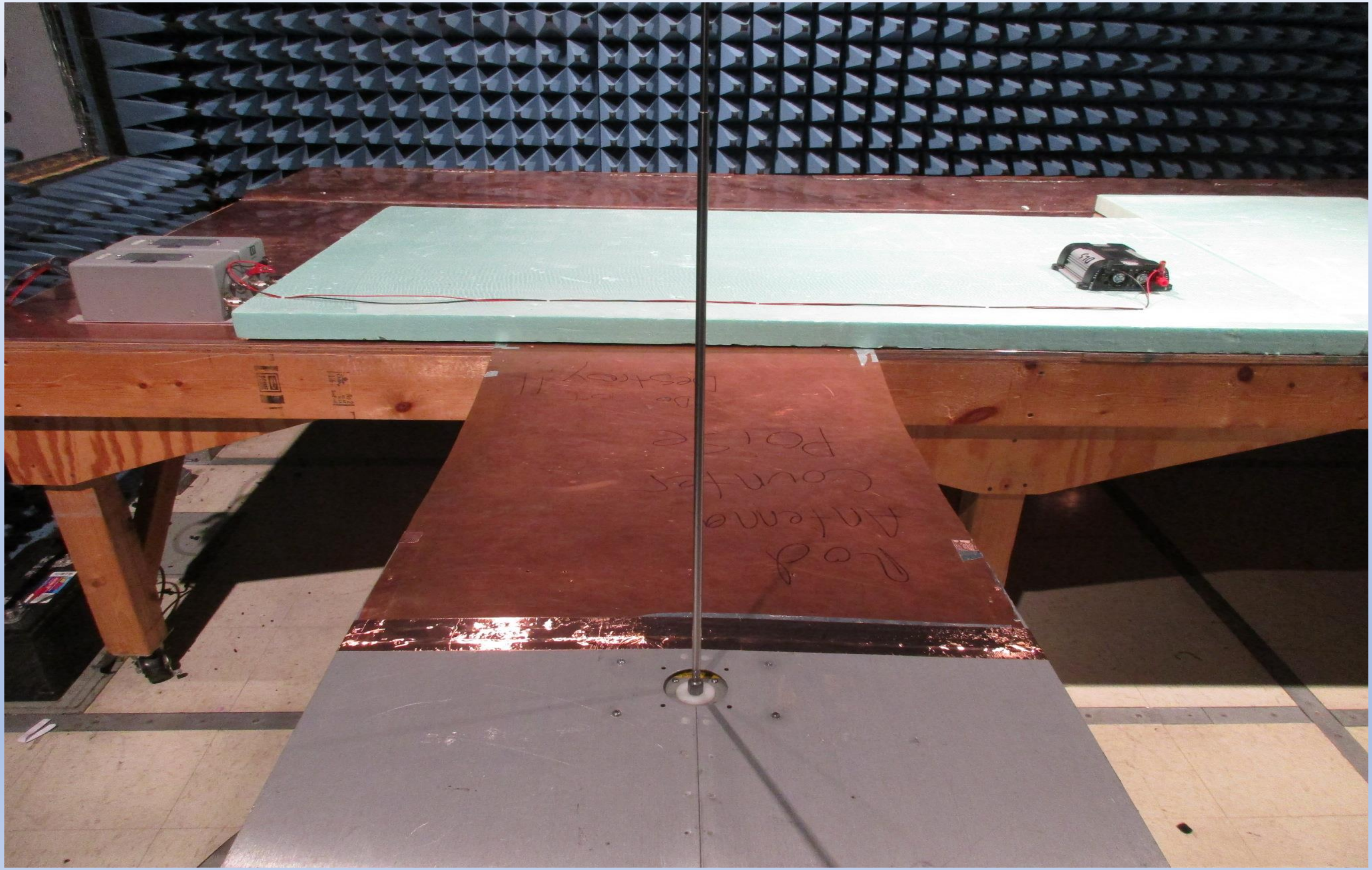
Antenna vs Frequency Range

Rod Antenna	**Biconical Antenna**	**Log Periodic Antenna**	**Horn Antenna**
150kHz – 30MHz	30MHz – 300MHz	200-1000MHz	1000MHz – 2500MHz
Vertical Polarization Only	Horizontal & Vertical Polarization	Horizontal & Vertical Polarization	Horizontal & Vertical Polarization

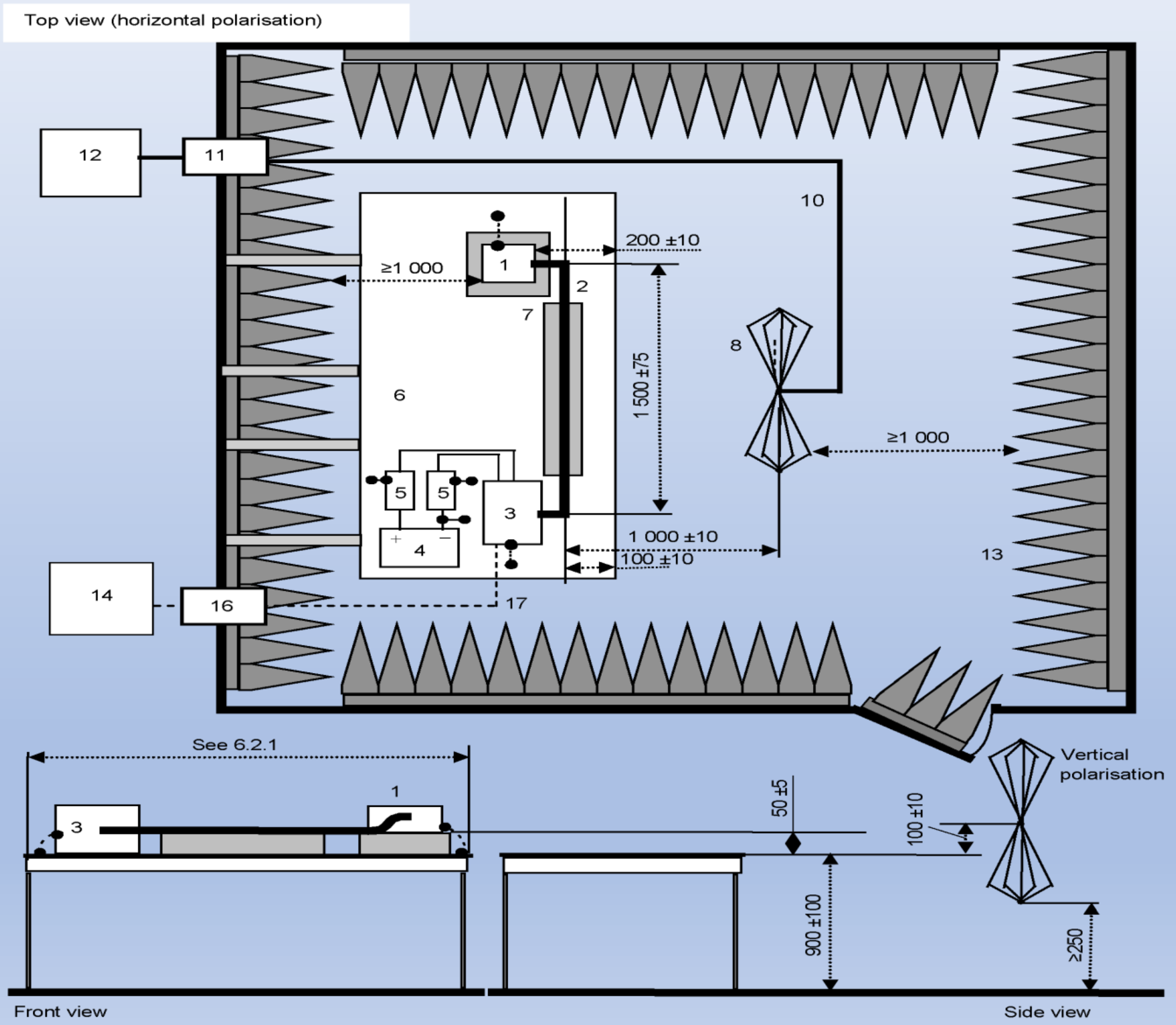
CISPR 25 Radiated Emissions – ALSE 150kHz - 30MHz



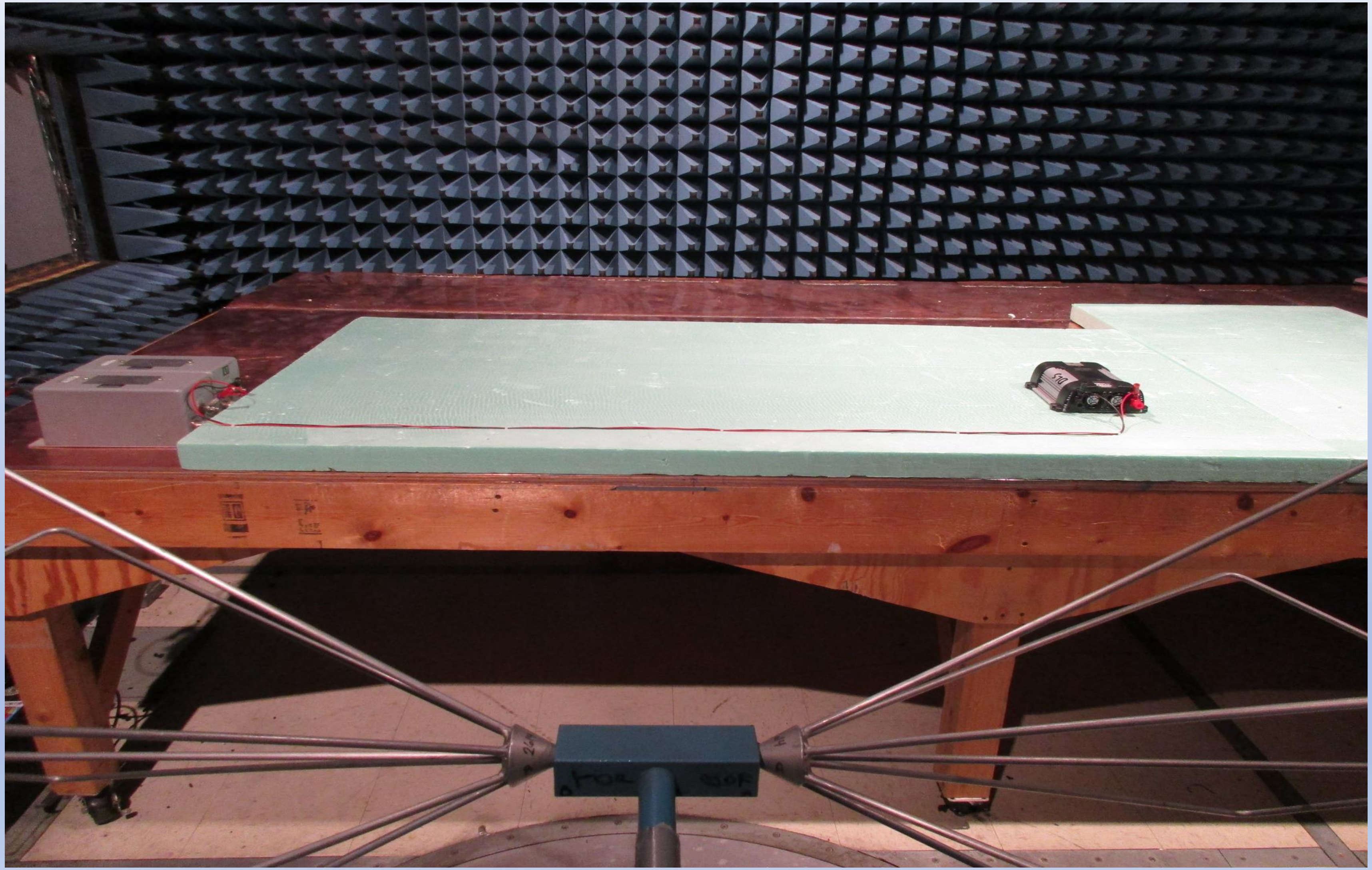
CISPR 25 Radiated Emissions – ALSE
150kHz – 30MHz



CISPR 25 Radiated Emissions – ALSE 30 – 1000MHz



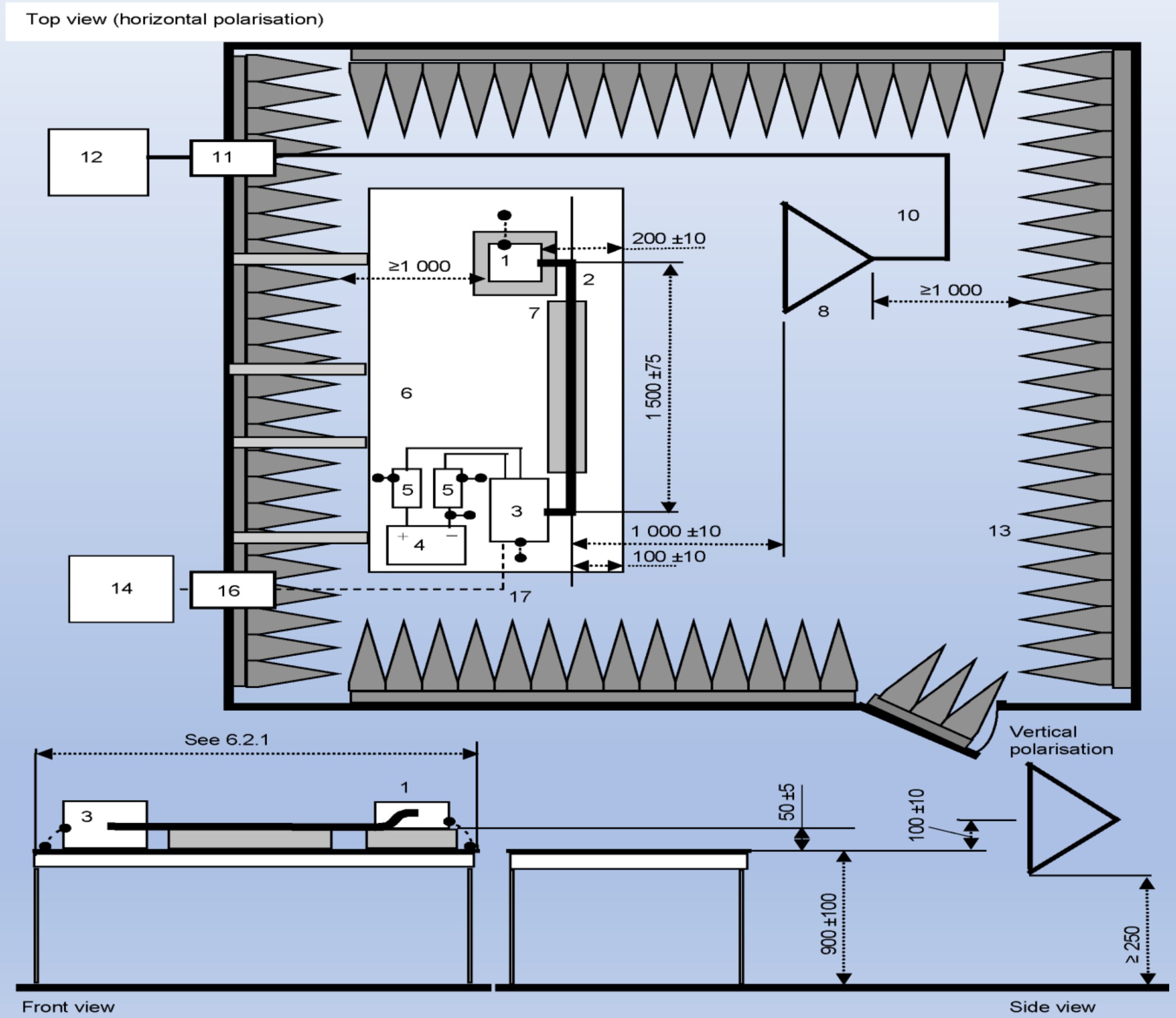
CISPR 25 Radiated Emissions – ALSE
30 – 300MHz



CISPR 25 Radiated Emissions – ALSE
200MHz – 1GHz

DLS

CISPR 25 Radiated Emissions – ALSE Above 1GHz



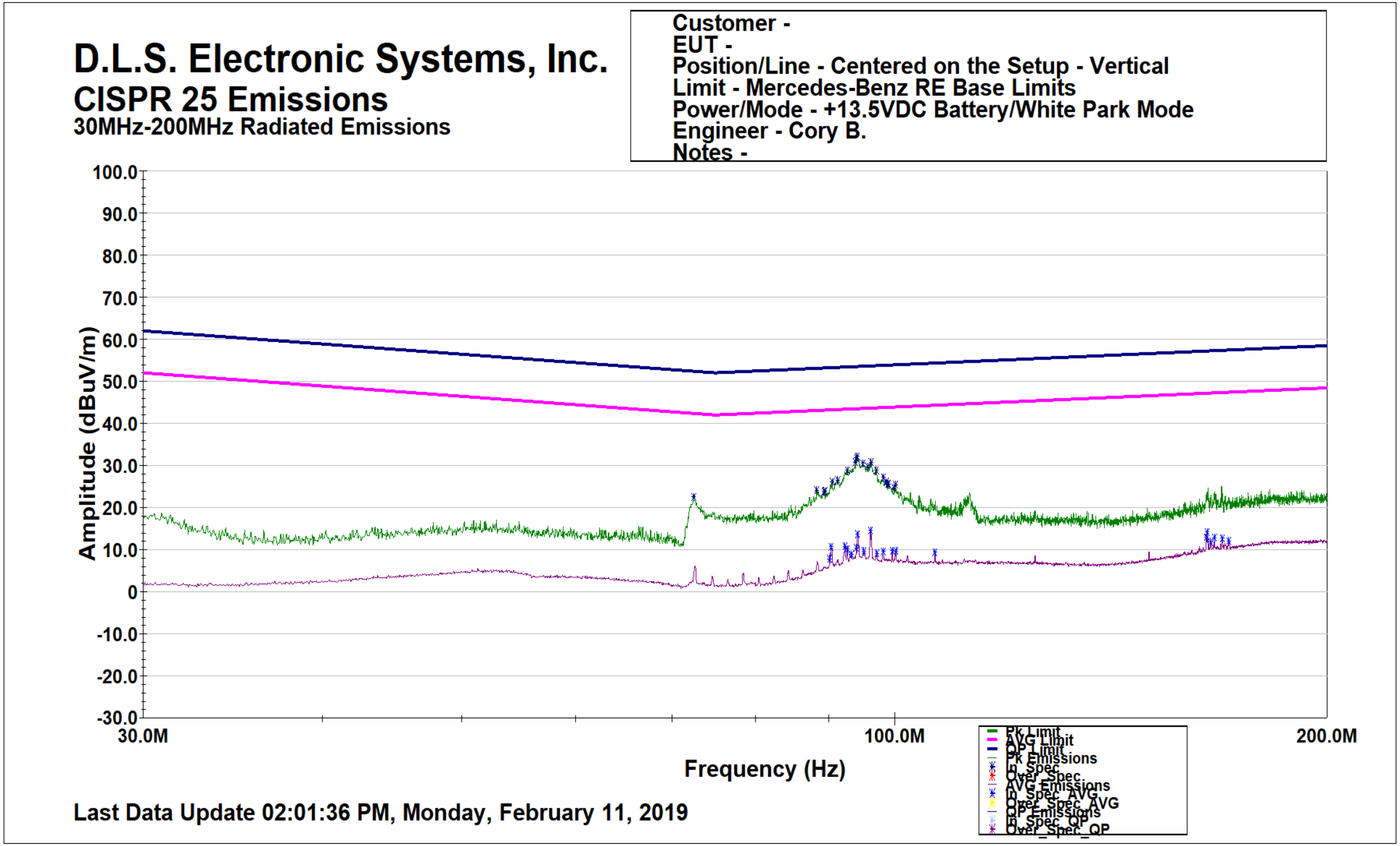
CISPR 25 Radiated Emissions – ALSE Above 1GHz

Radiated Emissons Limits

Service / Band	Frequency MHz	Levels in dB(μV/m)									
		Class 1		Class 2		Class 3		Class 4		Class 5	
		Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak
BROADCAST											
LW	0,15 - 0,30	86	73	76	63	66	53	56	43	46	33
MW	0,53 - 1,8	72	59	64	51	56	43	48	35	40	27
SW	5,9 - 6,2	64	51	58	45	52	39	46	33	40	27
FM	76 - 108	62	49	56	43	50	37	44	31	38	25
TV Band I	41 - 88	52	-	46	-	40	-	34	-	28	-
TV Band III	174 - 230	56	-	50	-	44	-	38	-	32	-
DAB III	171 - 245	50	-	44	-	38	-	32	-	26	-
TV Band IV/	468 - 944	65	-	59	-	53	-	47	-	41	-
DTTV	470 - 770	69	-	63	-	57	-	51	-	45	-
DAB L band	1447 - 1494	52	-	46	-	40	-	34	-	28	-
SDARS	2320 - 2345	58	-	52	-	46	-	40	-	34	-

Service / Band	Frequency MHz	Levels in dB(μV/m)				
		Class 1	Class 2	Class 3	Class 4	Class 5
		AVG	AVG	AVG	AVG	AVG
BROADCAST						
LW	0,15 - 0,30	66	56	46	36	26
MW	0,53 - 1,8	52	44	36	28	20
SW	5,9 - 6,2	44	38	32	26	20
FM	76 - 108	42	36	30	24	18
TV Band I	41 - 88	42	36	30	24	18
TV Band III	174 - 230	46	40	34	28	22
DAB III	171 - 245	40	34	28	22	16
TV Band IV/V	468 - 944	55	49	43	37	31
DTTV	470 - 770	59	53	47	41	35
DAB L band	1447 - 1494	42	36	30	24	18
SDARS	2320 - 2345	48	42	36	30	24

Radiated Emissions Data Analysis



Radiated Emissions Data Analysis

Peak/Average Data Evaluation
Negative = dB of margin; Positive = dB over Limit
Margins of up to 20 highest peaks

02:01:36 PM, Monday, February 11, 2019

Customer:

Frequency (MHz)	Complying Emissions (dB)	Excessive Emissions (dB)	Highest Emissions (dBuV/m)	Complying Emissions AVG (dB)	Excessive Emissions AVG (dB)	Highest Emissions AVG (dBuV/m)
72.50 MHz	-29.802		22.568			
88.27 MHz	-28.934		24.136			
89.32 MHz	-29.290		23.858			
89.47 MHz	-29.248		23.911			
90.12 MHz				-35.386		7.820
90.32 MHz				-32.594		10.627
90.52 MHz	-27.104		26.132			
91.32 MHz	-26.837		26.456			
92.37 MHz				-32.536		10.833
92.72 MHz	-24.572		28.822	-33.299		10.095
93.32 MHz				-34.594		8.842
93.92 MHz	-22.727		30.751			
94.07 MHz	-21.657		31.831	-33.077		10.411
94.22 MHz	-21.372		32.127			
94.27 MHz				-29.790		13.713
95.07 MHz	-23.111		30.447			
95.22 MHz				-33.898		9.670
95.82 MHz	-23.965		29.644			
96.22 MHz				-29.092		14.545
96.32 MHz	-22.886		30.758			
97.12 MHz	-24.855		28.843			
97.22 MHz				-34.566		9.139
98.22 MHz	-26.601		27.171	-34.200		9.572
98.67 MHz	-27.674		26.128			
98.92 MHz	-28.213		25.606			
99.02 MHz	-28.212		25.614			
99.67 MHz				-34.115		9.753
99.92 MHz	-29.259		24.625			
100.17 MHz	-28.489		25.412			
100.22 MHz				-34.201		9.703
106.67 MHz				-34.942		9.373
164.78 MHz				-34.243		12.930
165.03 MHz				-33.011		14.171
165.93 MHz				-35.363		11.855
166.98 MHz				-34.462		12.798
169.08 MHz				-34.660		12.682
170.83 MHz				-35.364		12.046

Customer -
EUT -
Position/Line - Centered on the Setup - Vertical
Limit - Mercedes-Benz RE Base Limits
Power/Mode - +13.5VDC Battery/White Park Mode
Engineer - Cory B.
Notes -

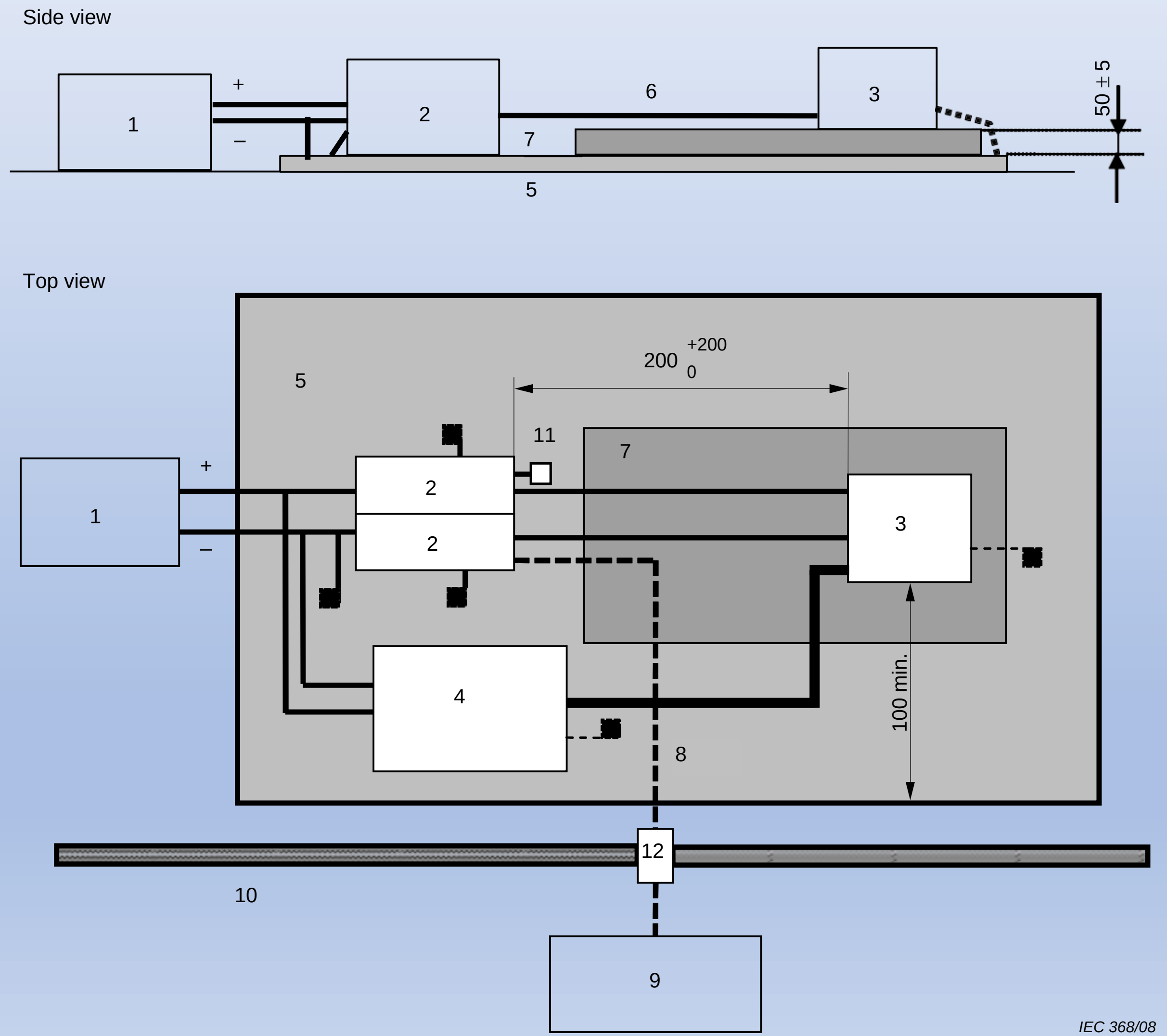
Questions about Radiated Emissions?

CISPR 25 Conducted Emissions Measurements

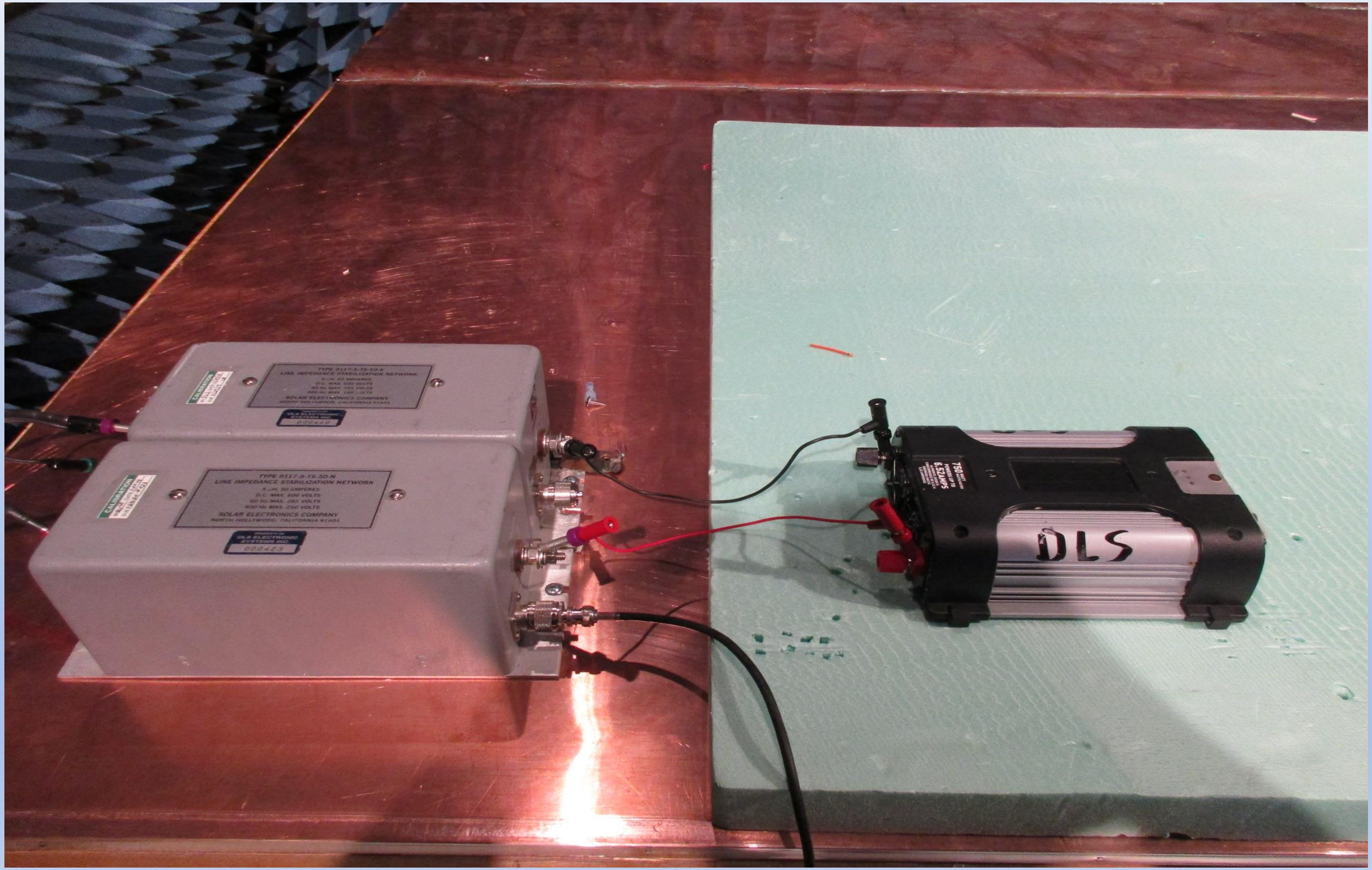
2 Methods of Measurement

- Voltage Method – Power Lines
- Current Probe Method – I/O Lines

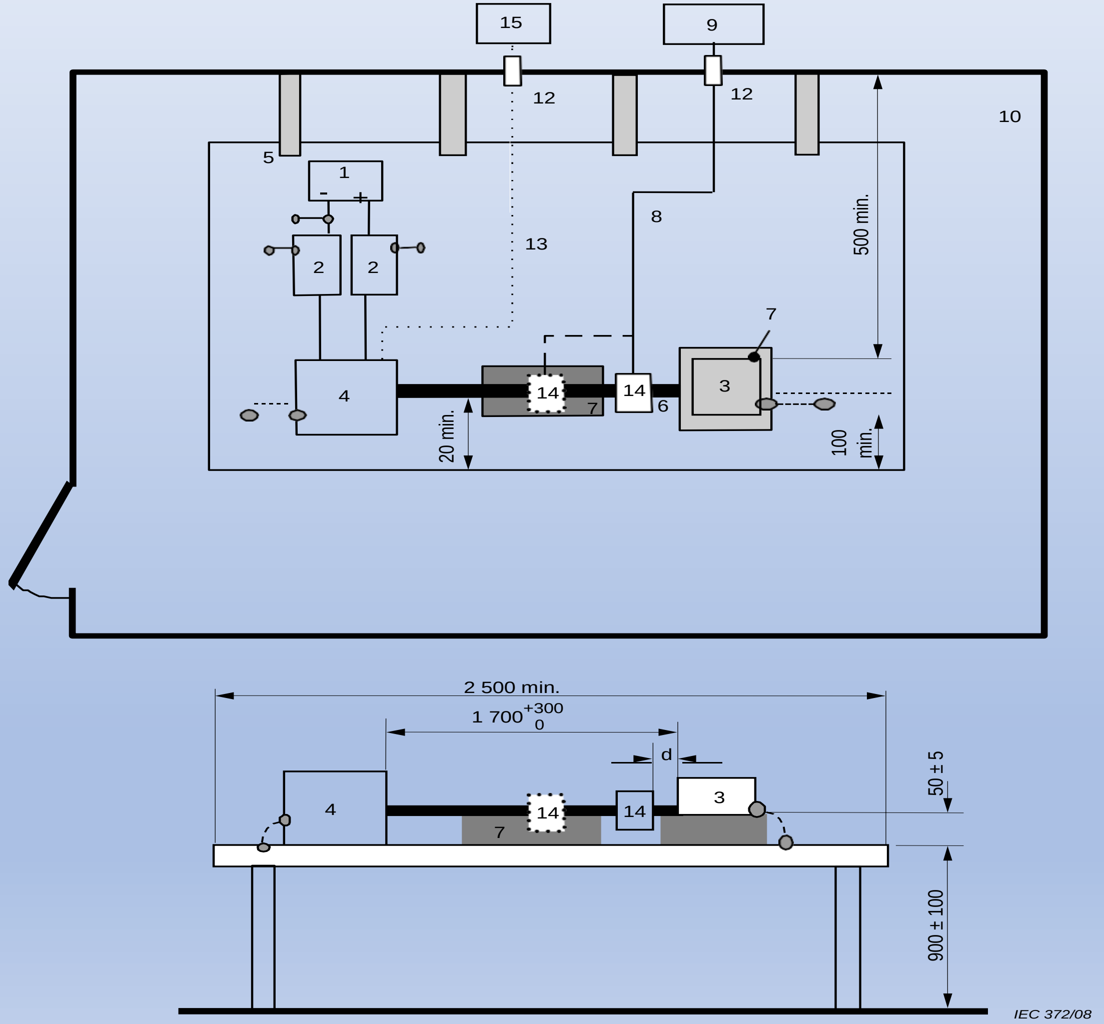
CISPR 25 Conducted Emissions – Voltage Method 150kHz - 108MHz



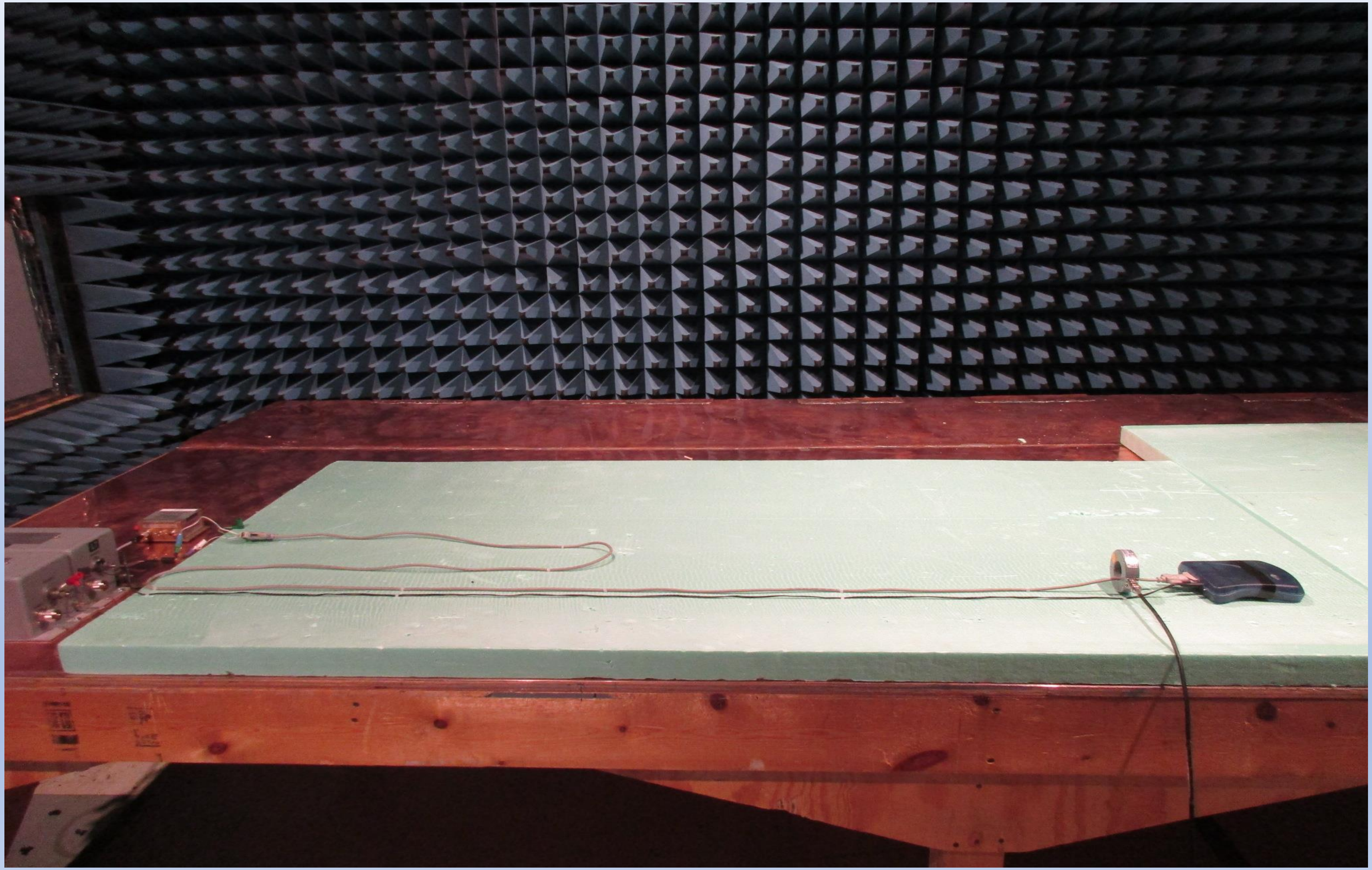
CISPR 25 Conducted Emissions – Voltage Method 150kHz - 108MHz



CISPR 25 Conducted Emissions – Current Probe Method 150kHz - 108MHz



CISPR 25 Conducted Emissions – Current Probe Method 150kHz - 108MHz

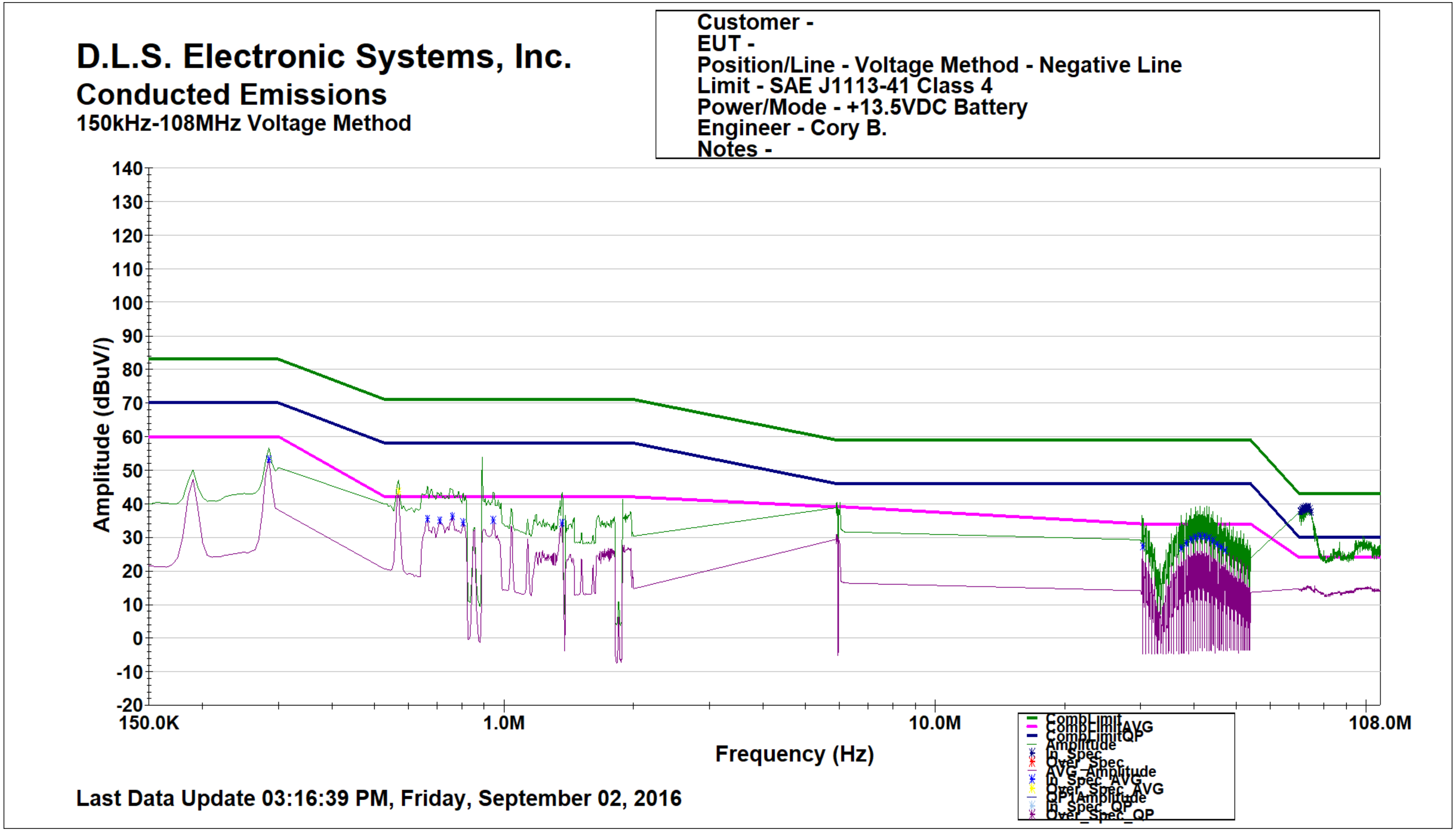


Service / Band	Frequency MHz	Levels in dB(μV)									
		Class 1		Class 2		Class 3		Class 4		Class 5	
		Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak	Peak	Quasi-peak
BROADCAST											
LW	0,15 - 0,30	110	97	100	87	90	77	80	67	70	57
MW	0,53 - 1,8	86	73	78	65	70	57	62	49	54	41
SW	5,9 - 6,2	77	64	71	58	65	52	59	46	53	40
FM	76 - 108	62	49	56	43	50	37	44	31	38	25
TV Band I	41 - 88	58	-	52	-	46	-	40	-	34	-

Service / Band	Frequency MHz	Levels in dB(μV)				
		Class 1	Class 2	Class 3	Class 4	Class 5
		AVG	AVG	AVG	AVG	AVG
BROADCAST						
LW	0,15 - 0,30	90	80	70	60	50
MW	0,53 - 1,8	66	58	50	42	34
SW	5,9 - 6,2	57	51	45	39	33
FM	76 - 108	42	36	30	24	18
TV Band I	41 - 88	48	42	36	30	24

Conducted Emissions Limits

Conducted Emissions Data Analysis



Conducted Emissions Data Analysis

Peak/Average Data Evaluation
Negative = dB of margain; Positive = dB over Limit
Margins of up to 20 highest peaks

Customer:

Frequency (MHz)	Complying Emissions Pk (dB)	Excessive Emissions Pk (dB)	Highest Emissions Pk (dBuV/m)	Complying Emissions AVG (dB)	Excessive Emissions AVG (dB)	Highest Emissions AVG (dBuV/m)
285.00 KHz				-6.780		53.220
570.00 KHz					1.657	43.657
665.00 KHz				-6.494		35.506
710.00 KHz				-6.890		35.110
760.00 KHz				-5.764		36.236
805.00 KHz				-7.549		34.451
945.00 KHz				-6.859		35.141
1.36 MHz				-7.739		34.261
30.37 MHz				-6.729		27.271
37.33 MHz				-7.146		26.854
38.31 MHz				-5.711		28.289
39.31 MHz				-4.609		29.391
40.24 MHz				-3.960		30.040
41.24 MHz				-3.612		30.388
42.23 MHz				-3.692		30.308
43.23 MHz				-4.268		29.732
44.23 MHz				-5.033		28.967
45.22 MHz				-6.089		27.911
46.22 MHz				-6.919		27.081
47.20 MHz				-7.845		26.155
70.40 MHz	-5.283		37.717			
70.60 MHz	-5.281		37.719			
70.95 MHz	-4.872		38.128			
71.10 MHz	-4.870		38.130			
71.30 MHz	-4.322		38.678			
71.45 MHz	-4.600		38.400			
71.65 MHz	-4.720		38.280			
71.85 MHz	-4.719		38.281			
72.00 MHz	-4.179		38.821			
72.20 MHz	-4.592		38.408			
72.40 MHz	-4.712		38.288			
72.55 MHz	-3.907		39.093			
72.75 MHz	-4.037		38.963			
72.95 MHz	-4.304		38.696			
73.10 MHz	-4.441		38.559			
73.30 MHz	-3.898		39.102			
73.45 MHz	-3.896		39.104			
73.60 MHz	-4.027		38.973			
74.20 MHz	-4.569		38.431			
74.75 MHz	-5.502		37.498			

Customer -
EUT -
Position/Line - Voltage Method - Negative Line
Limit - SAE J1113-41 Class 4
Power/Mode - +13.5VDC Battery
Engineer - Cory B.
Notes -

Questions about Conducted Emissions?

RF Immunity Testing

Test Method vs Frequency Range

ISO 11452-4 Bulk Current Injection	ISO 11452-2 Radiated Immunity
1MHz - 400MHz	80MHz – 18GHz
• Injected on Cables • Common Mode • Optional Differential Mode	• Vertical 80MHz – 18GHz • Horizontal 400MHz – 18GHz

ISO 11452-4 Bulk Current Injection

- Intended to provide a method for determining the immunity of electronic components for vehicles.
- Electromagnetic fields are generated using a Current injection probe supplied by an Amplifier and signal generator capable of producing the desired level.
- Current is injected into the DUT’s wiring Harness using a Current Probe as a transformer where the harness is the secondary winding.

ISO 11452-4 BCI

2 Methods of Testing 1 - 400MHz

- Substitution Method
- Closed-Loop Method

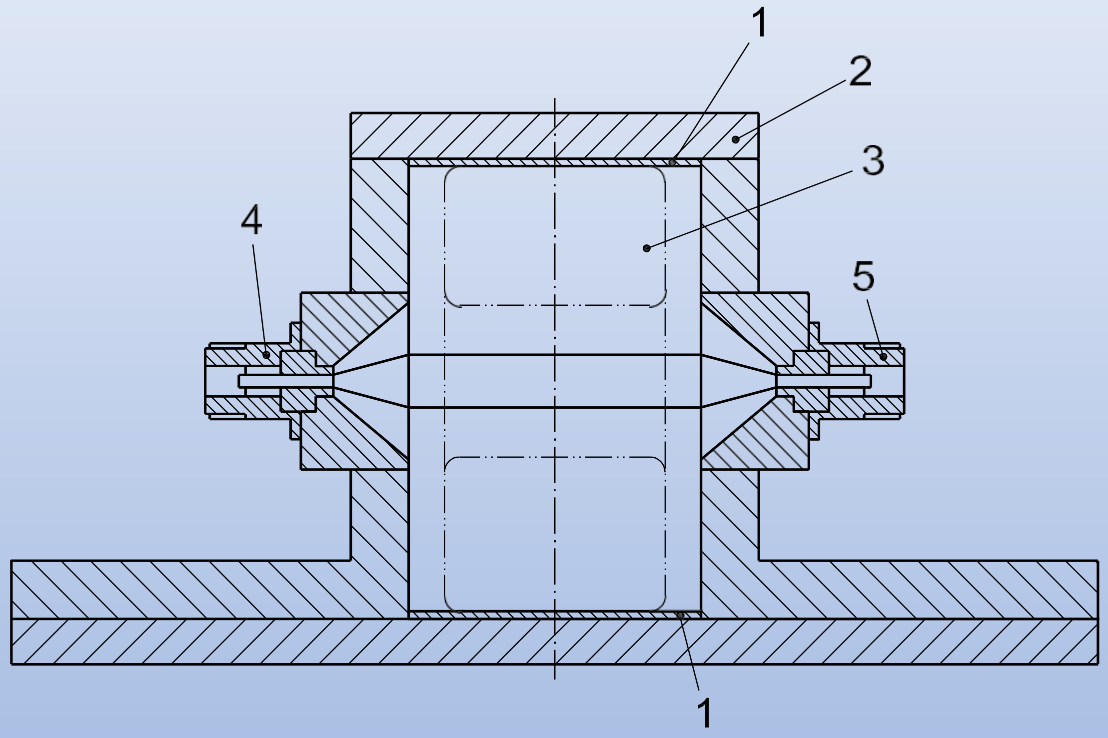
ISO 11452-4 BCI

- Substitution Method
  - Calibrate leveling to a Current Limit using CW
  - Record Forward Power as your reference
  - Test the DUT Leveling to forward Power from Calibration
  - Apply specific Modulation with Peak Conservation

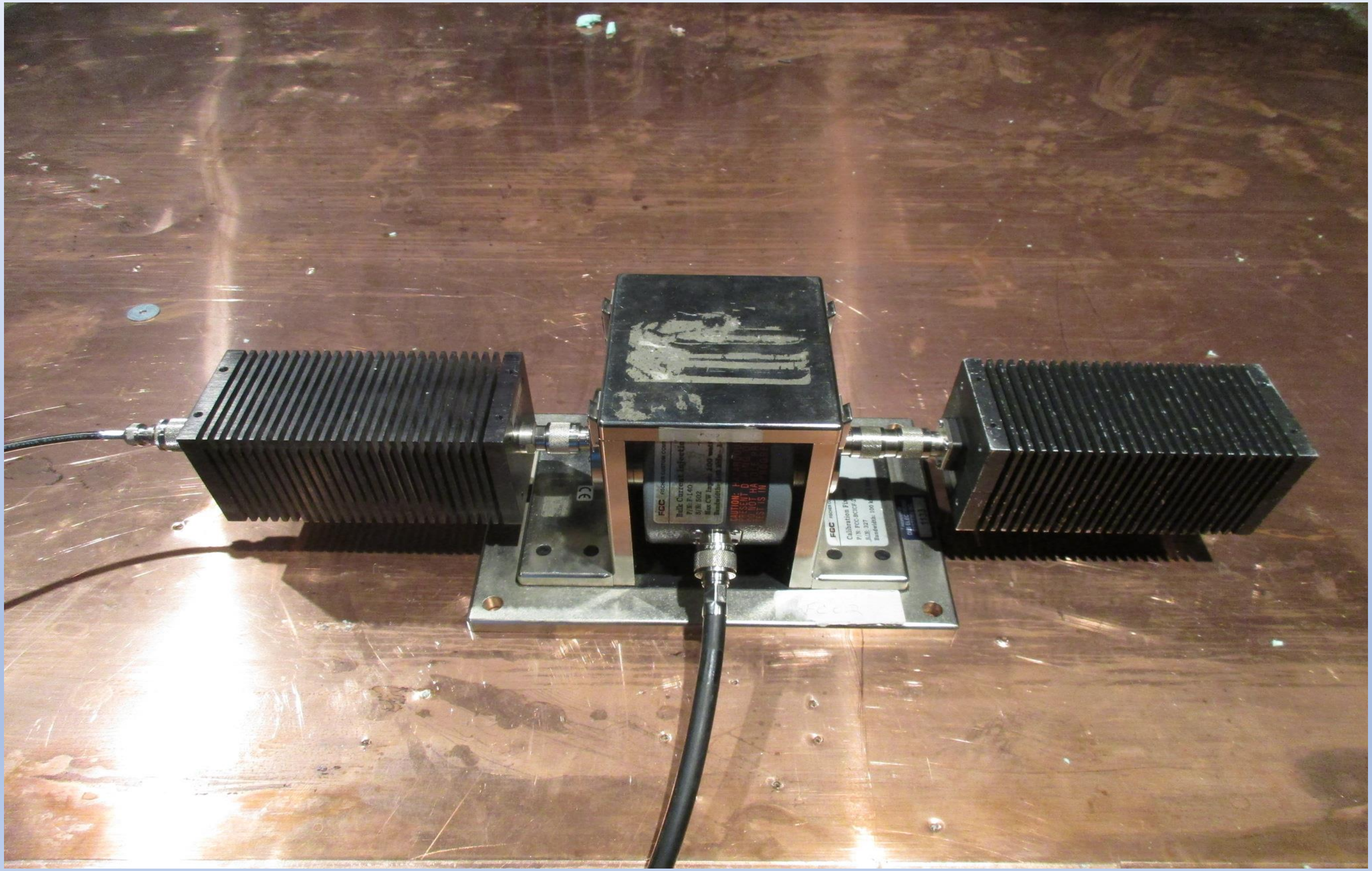
ISO 11452-4 Bulk Current Injection Calibration Fixture

Key

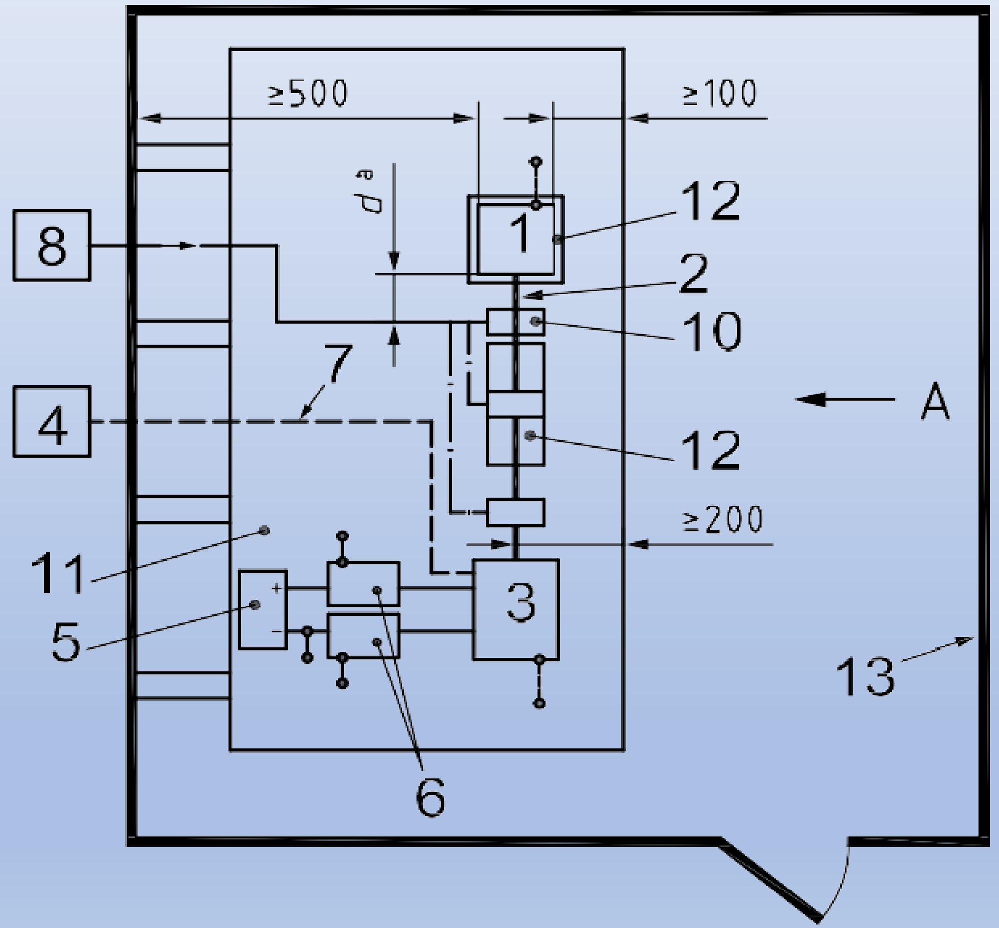
1. insulation
2. removable metal cover
3. current injection probe
4. direct connection to 50 ∧ measurement equipment
5. direct connection to 50 ∧ load

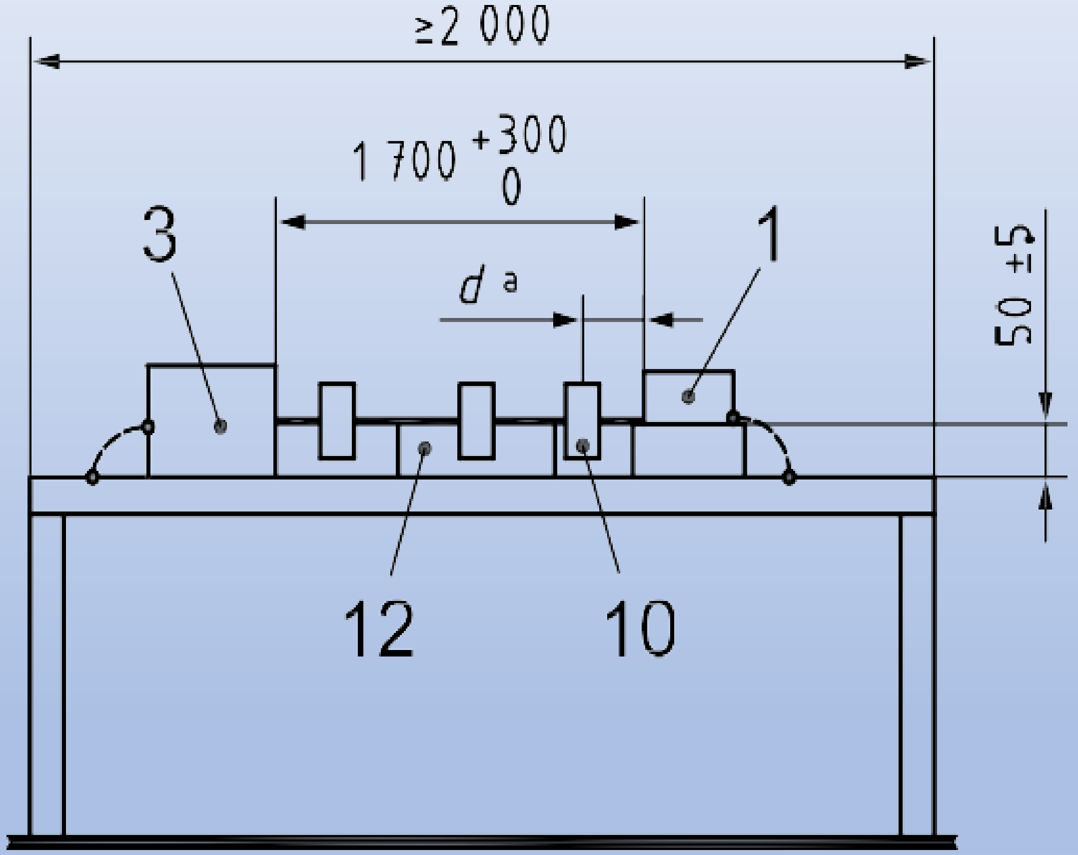


ISO 11452-4 Bulk Current Injection Calibration Setup

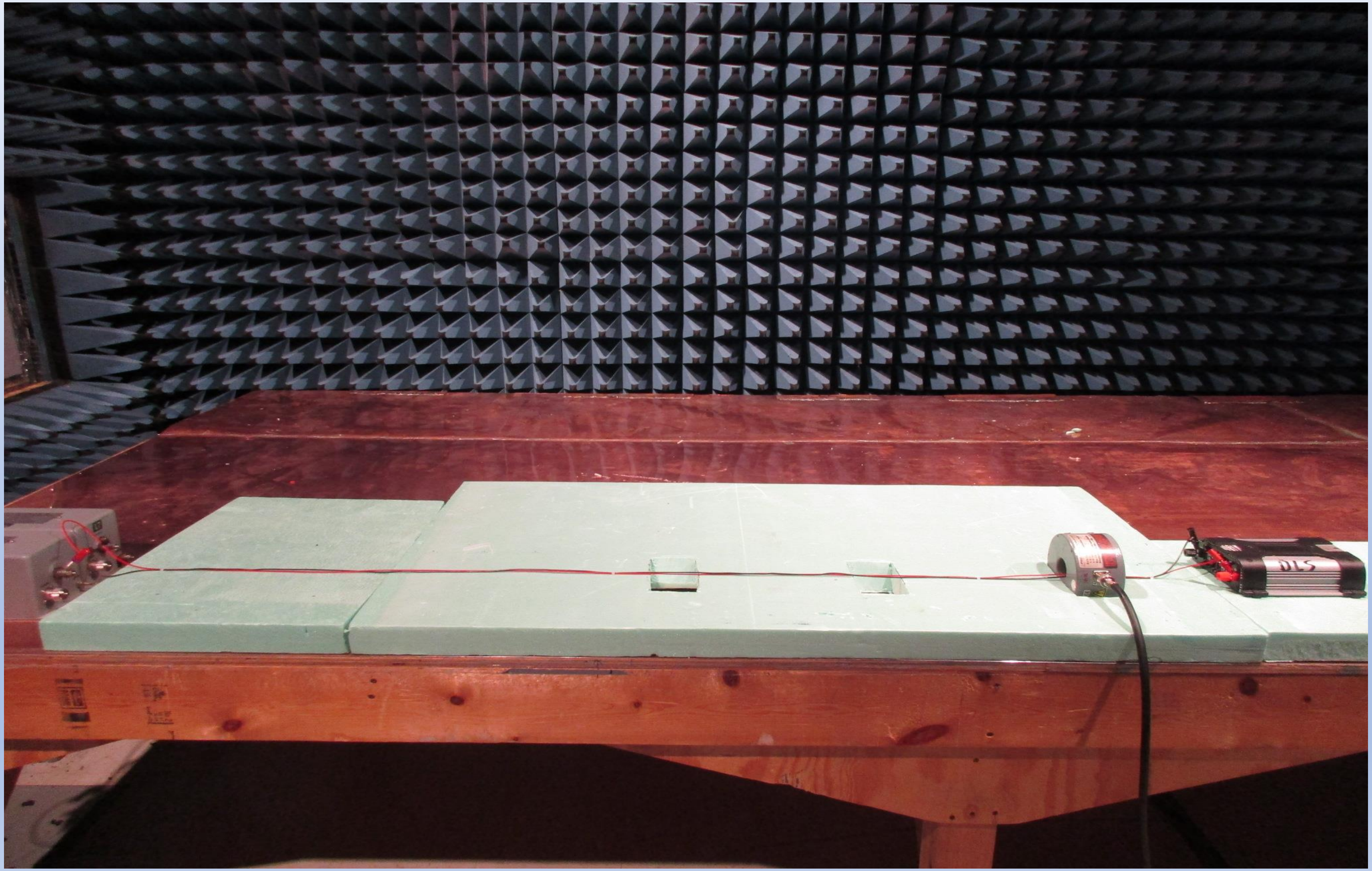


ISO 11452-4 Bulk Current Injection Test Setup



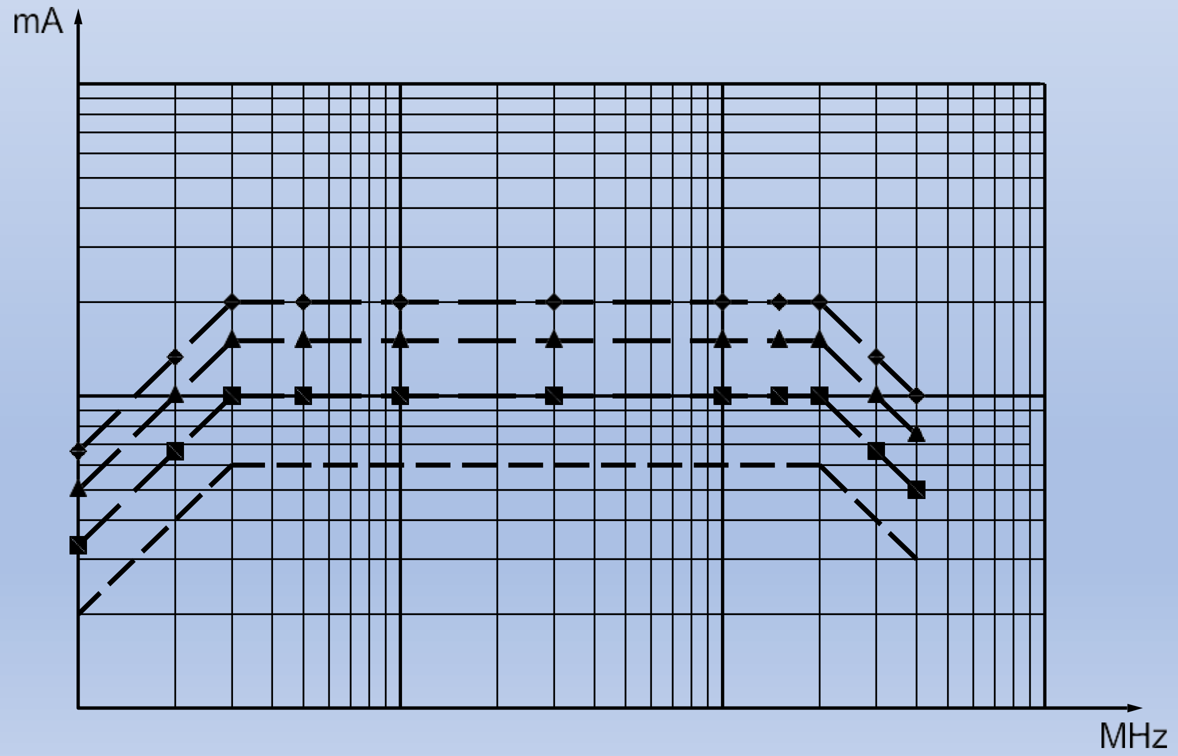


ISO 11452-4 Bulk Current Injection Test Setup

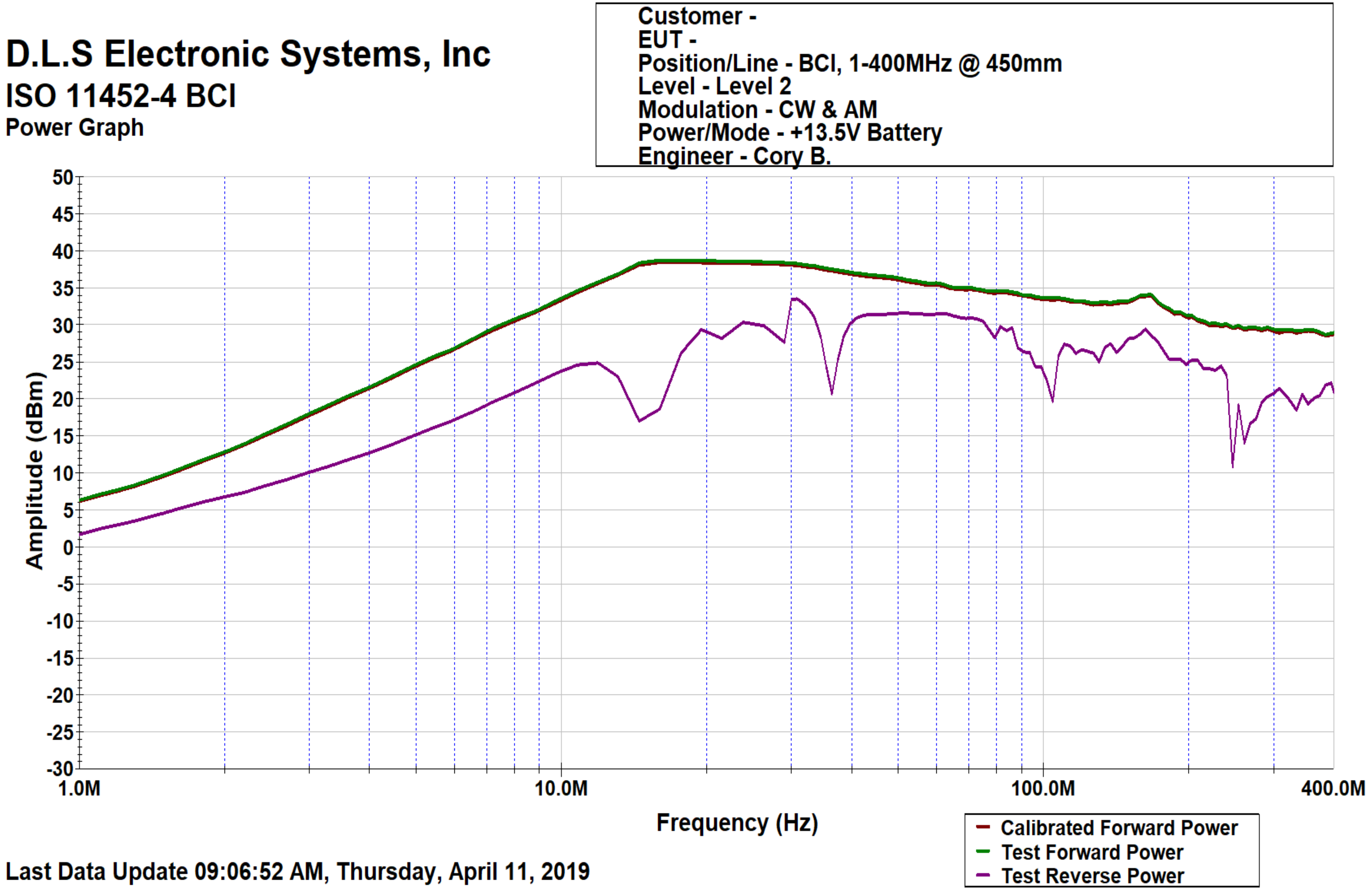


ISO 11452-2 Radiated Immunity – BCI Suggested Levels

Frequency band MHz	**Test level I** mA	**Test level II** mA	**Test level III** mA	**Test level IV** mA	**Test level V** mA
1 to 3	60 ´ *F*(MHz) / 3	100 ´ *F*(MHz) / 3	150 ´ *F*(MHz) / 3	200 ´ *F*(MHz) / 3	Specific values agreed between the users of this part of ISO 11452
3 to 200	60	100	150	200	
200 to 400	60 ´ 200 / *F*(MHz)	100 ´ 200 / *F*(MHz)	150 ´ 200 / *F*(MHz)	200 ´ 200 / *F*(MHz)	



Bulk Current Injection Data



Questions about BCI?

ISO 11452-2 Radiated Immunity

- Intended to provide a method of testing the immunity (off-vehicle radiation source) of electronic components for vehicles.
- Electromagnetic fields are generated using an Antenna supplied by an Amplifier and signal generator capable of producing the desired field.
- The DUT and its wiring Harness are subjected to electromagnetic disturbances generated inside an absorber-lined enclosure.

ISO 11452-2 Radiated Immunity

- <u>Substitution Method</u>
  - Calibrate leveling to a Field Probe using CW
  - Record Forward Power as your reference
  - Test DUT Leveling to forward Power from Calibration
  - Apply specific Modulation with Peak Conservation

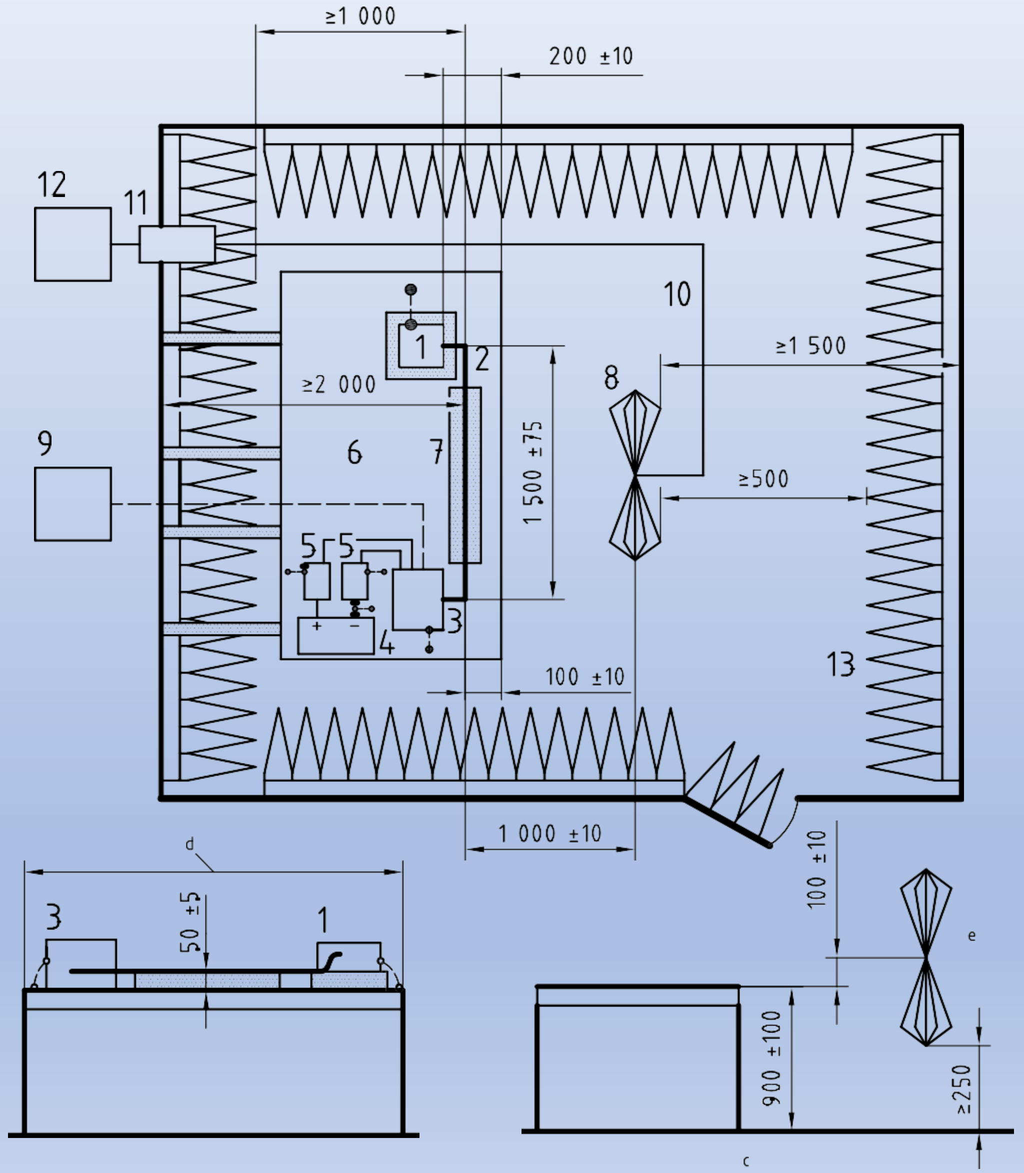
ISO 11452-2 Radiated Immunity - ALSE

Frequency Range vs Modulation

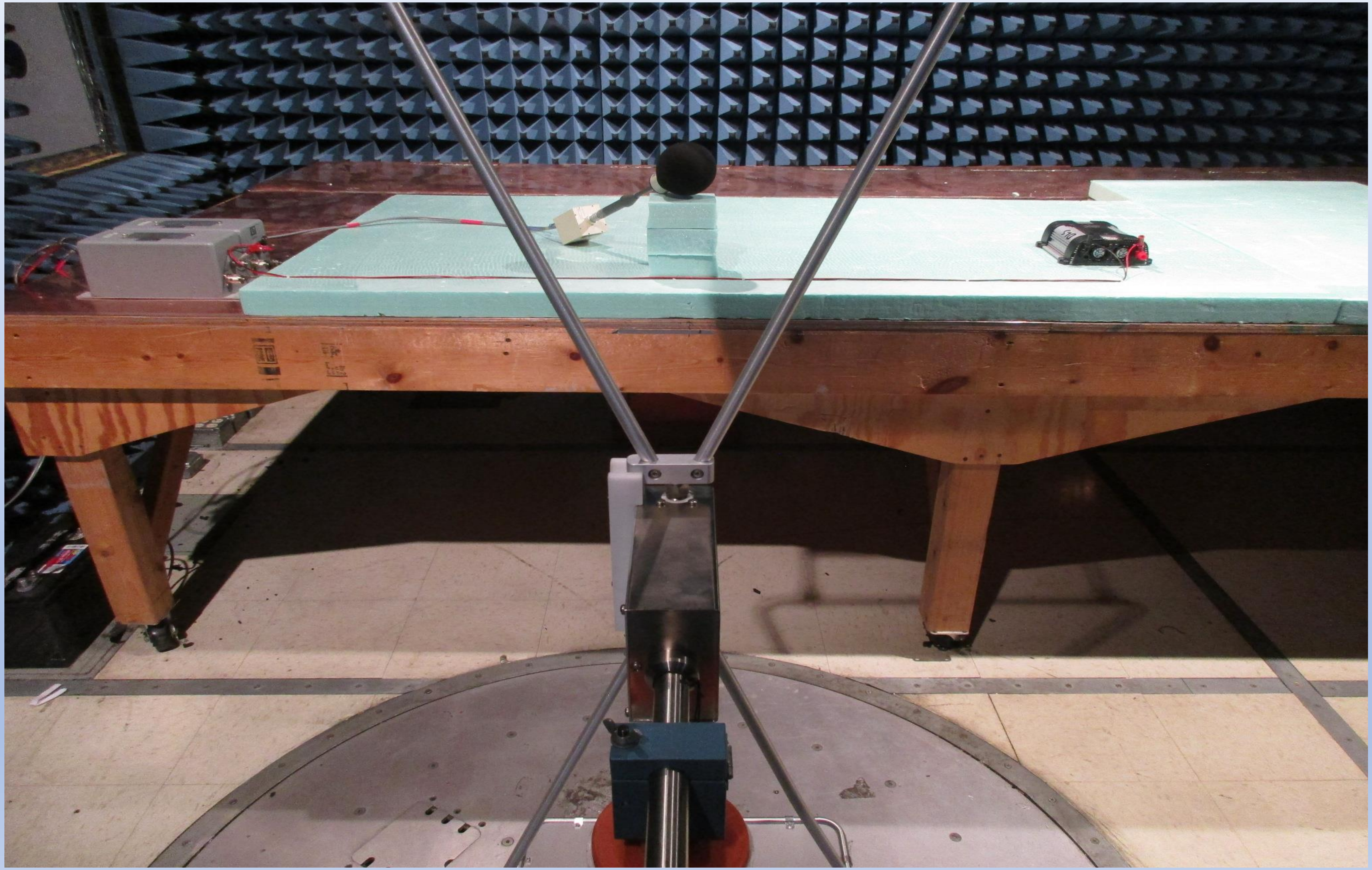
Biconical Antenna	Log or Horn Antenna	Horn Antenna
80MHz – 200MHz	200-1000MHz	1GHz – 18GHz
• Vertical Only • CW & AM	• Vertical only <400MHz • CW & AM 200-800MHz • CW & PM 800-1000MHz	• Horizontal & Vertical • CW & PM

DLS

ISO 11452-2 Radiated Immunity – ALSE
80 – 1000MHz



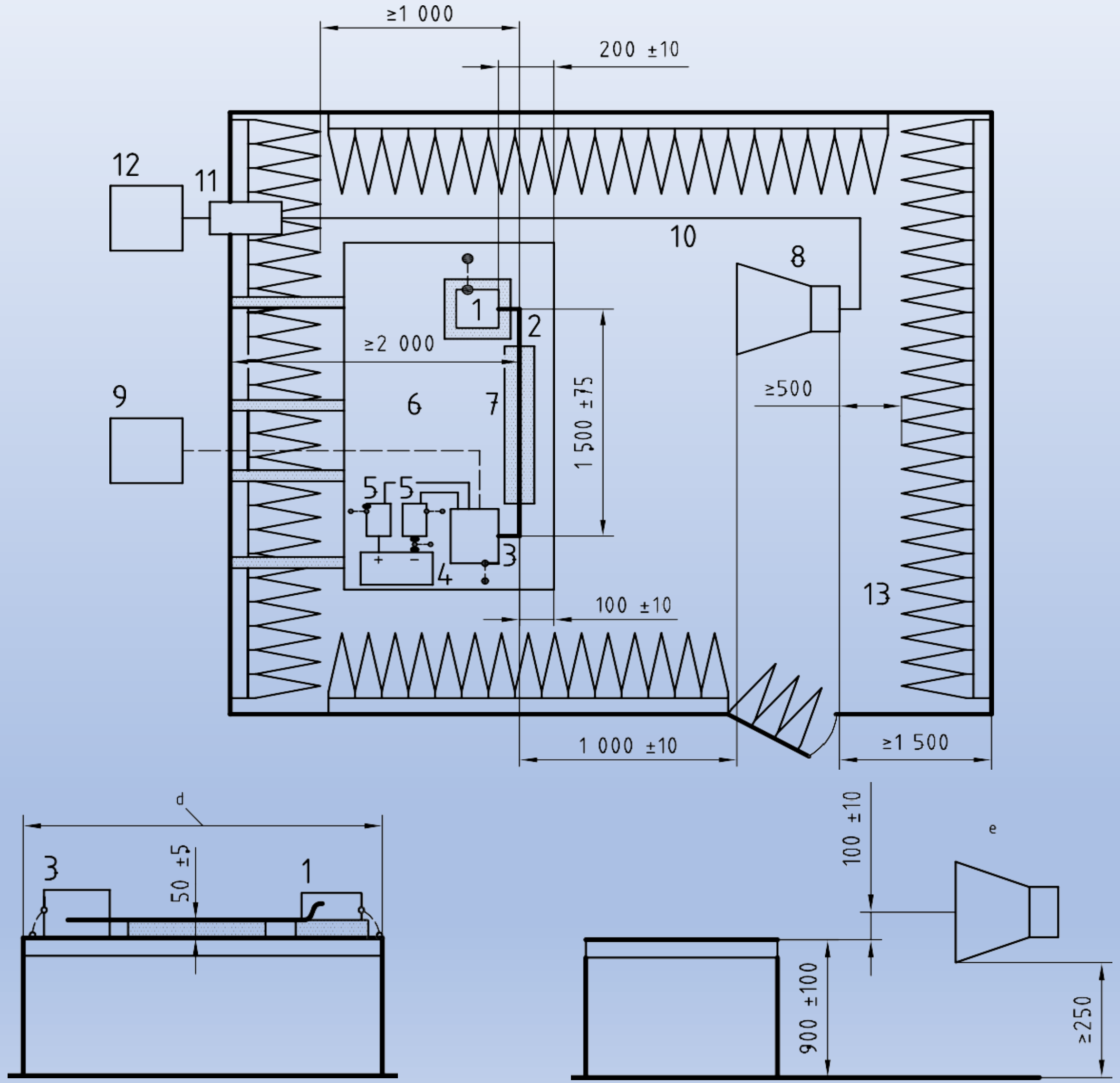
ISO 11452-2 Radiated Immunity – ALSE
80 – 200MHz



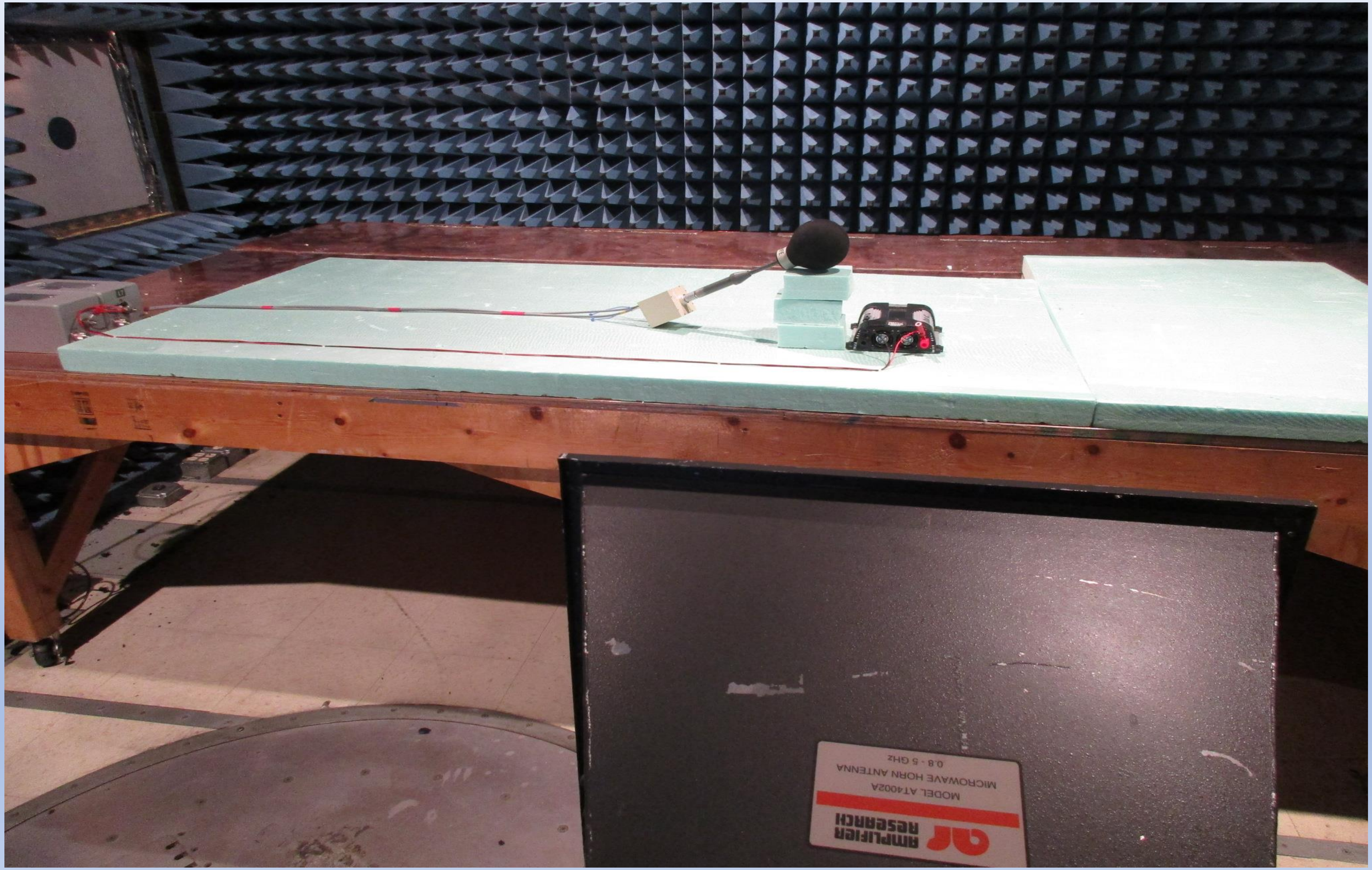
ISO 11452-2 Radiated Immunity – ALSE
200 – 1000MHz

DLS

ISO 11452-2 Radiated Immunity – ALSE Above 1GHz



ISO 11452-2 Radiated Immunity – ALSE Above 1GHz

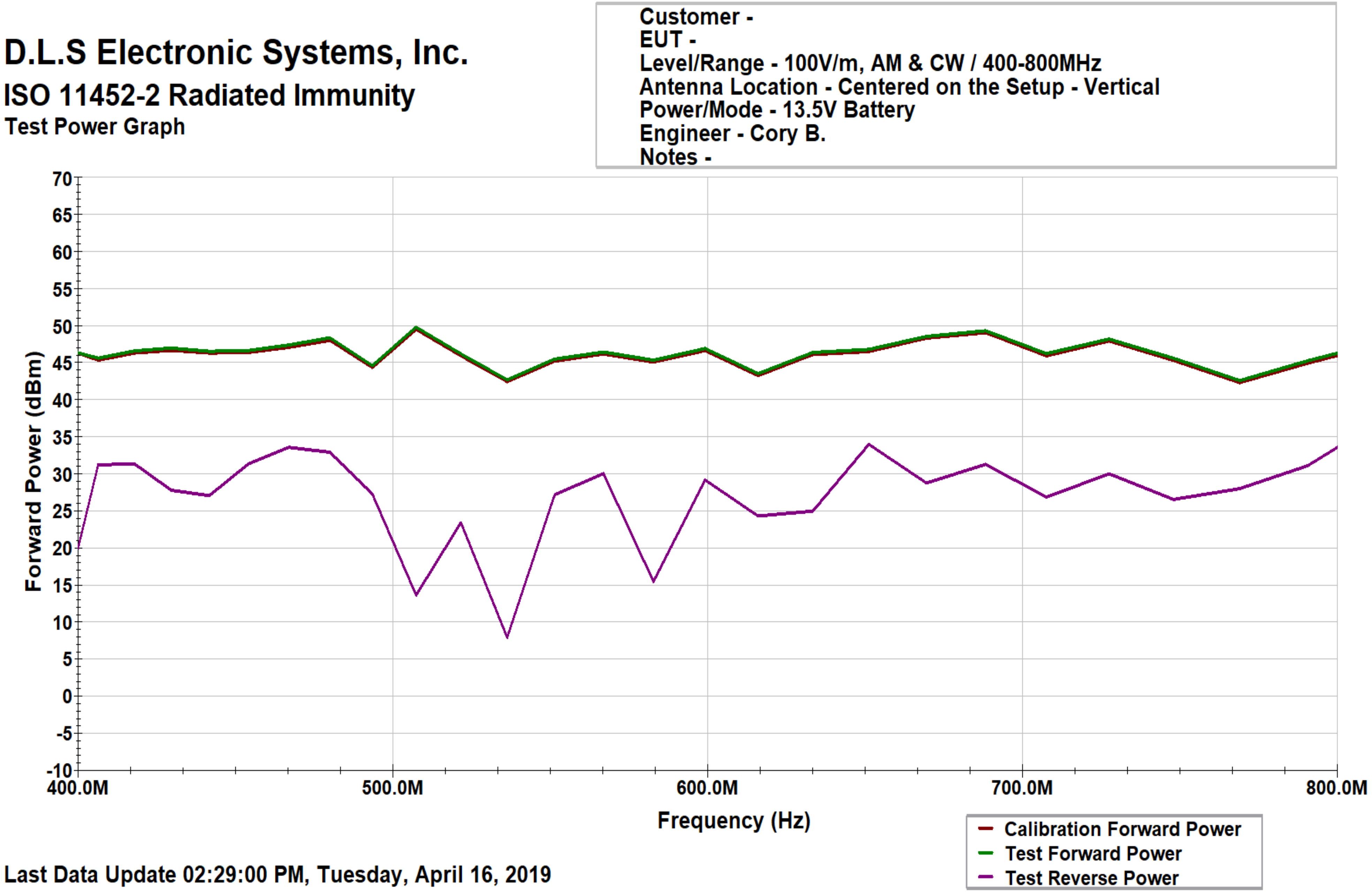


ISO 11452-2 Radiated Immunity – ALSE Suggested Levels

Table C.1 — Suggested test severity levels

Test severity level	Value V/m
I	25
II	50
III	75
IV	100
V	Specific value agreed between the users of this part of ISO 11452, if necessary

Radiated Immunity Data



Last Data Update 02:29:00 PM, Tuesday, April 16, 2019

Questions about Radiated Immunity?

ISO 10605 Electrostatic Discharge

- Describes the test methods necessary for evaluating components and complete vehicles.
- Simulates ESD generated during Vehicle Assembly.
- Simulates ESD generated by the occupant and vehicle Service staff.
- This Standard applies to all types of road vehicles regardless of the propulsion system (e.g. spark-ignition engine, diesel engine, electric motor).

ISO 10605 ESD

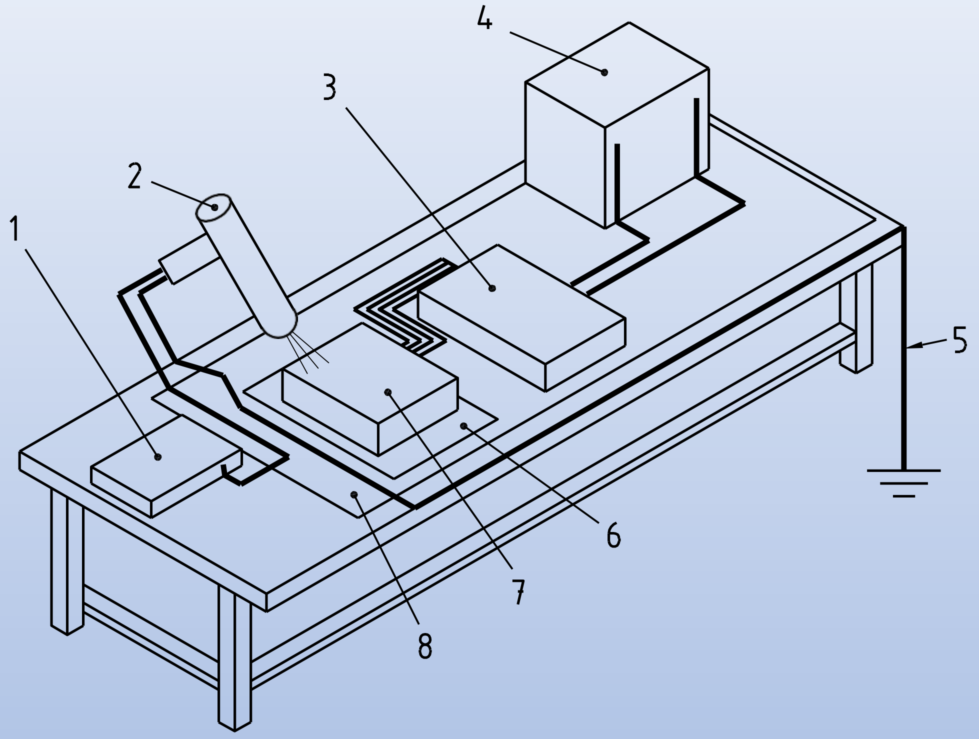
2 Aspects of Testing

- Powered
- Unpowered (Package and Handling)

ISO 10605 ESD

- Powered ESD
  - 2001 Version is performed on a Ground Plane
  - 2008 Version is performed on a HCP Isolated from GND
  - 2008 Version incorporates Indirect discharges
  - Testing is performed starting with lower levels first

ISO 10605:2001 Powered ESD Setup

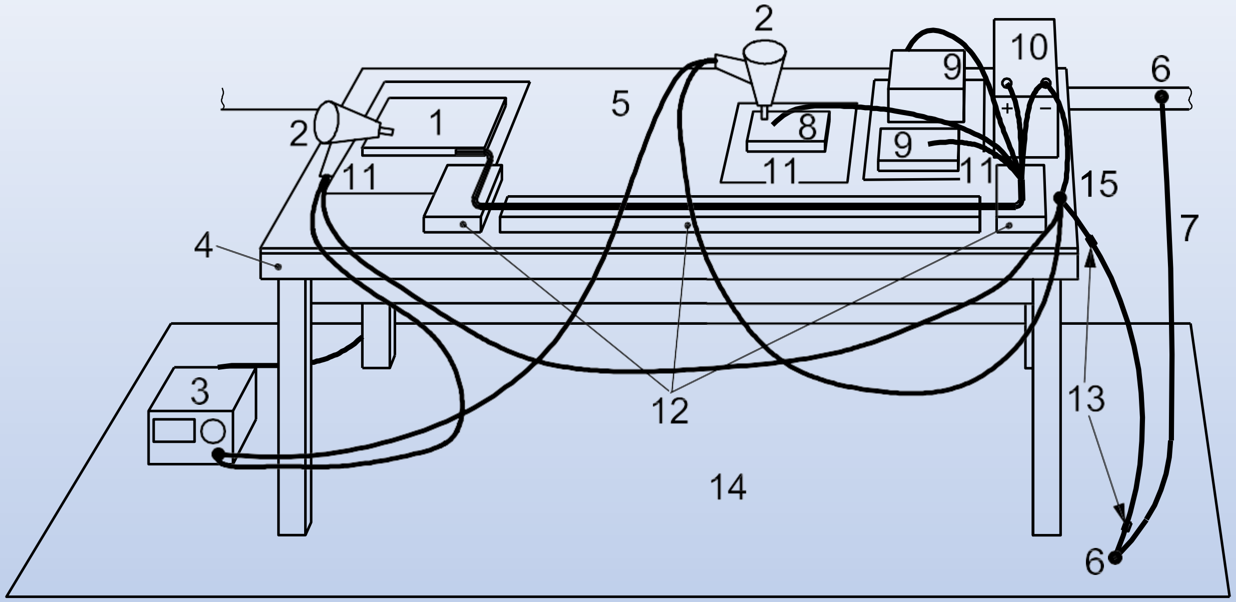


Key

1	ESD power supply	5	Ground strap
2	ESD simulator	6	Insulation block (if necessary)
3	Exerciser	7	Device under test
4	Battery	8	Ground plane

ISO 10605:2001 Powered ESD Setup Photo

ISO 10605:2008 Powered ESD Setup



Key

1	DUT	9	periphery
2	ESD generator	10	battery
3	ESD generator main unit	11	isolating support, if required
4	non-conductive table	12	insulating blocks
5	HCP	13	470 k ohm resistors
6	ground point	14	GRP optional
7	ground connection	15	HCP ground connection
8	remotely accessible parts of the DUT		

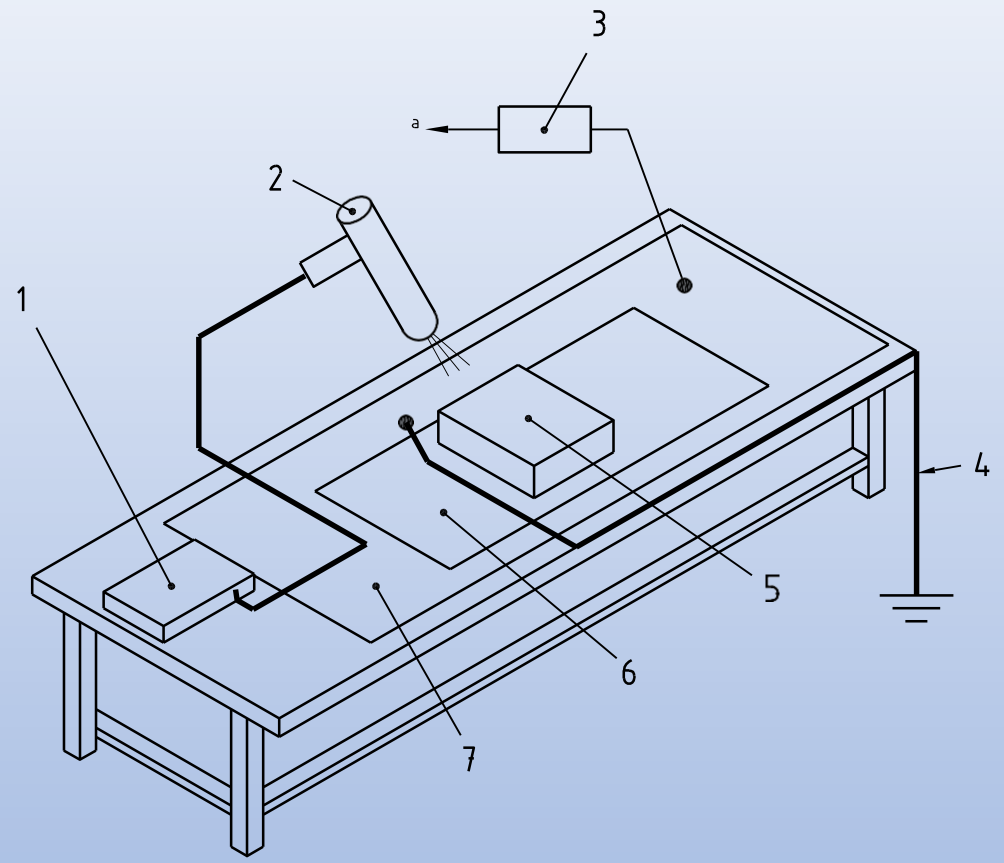
ISO 10605:2008 Powered ESD Setup

DLS

ISO 10605 ESD

- Unpowered ESD
  - Setup is similar between Standard Versions
  - Unit is tested on an ESD dissipative mat
  - Bleed off resistor used in between discharges
  - Includes Testing of Connector pins directly

ISO 10605:2001 Unpowered ESD Setup

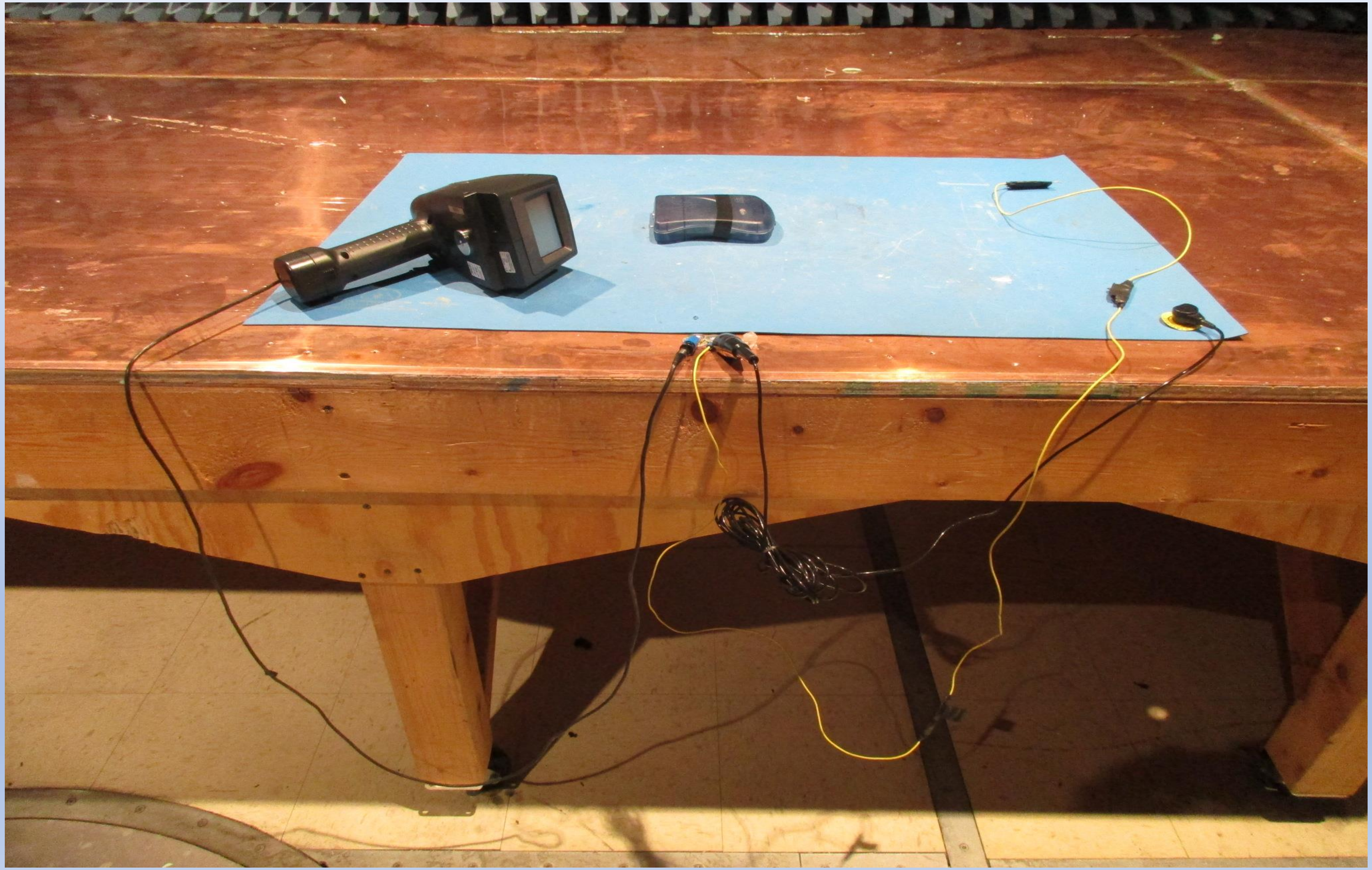


Key

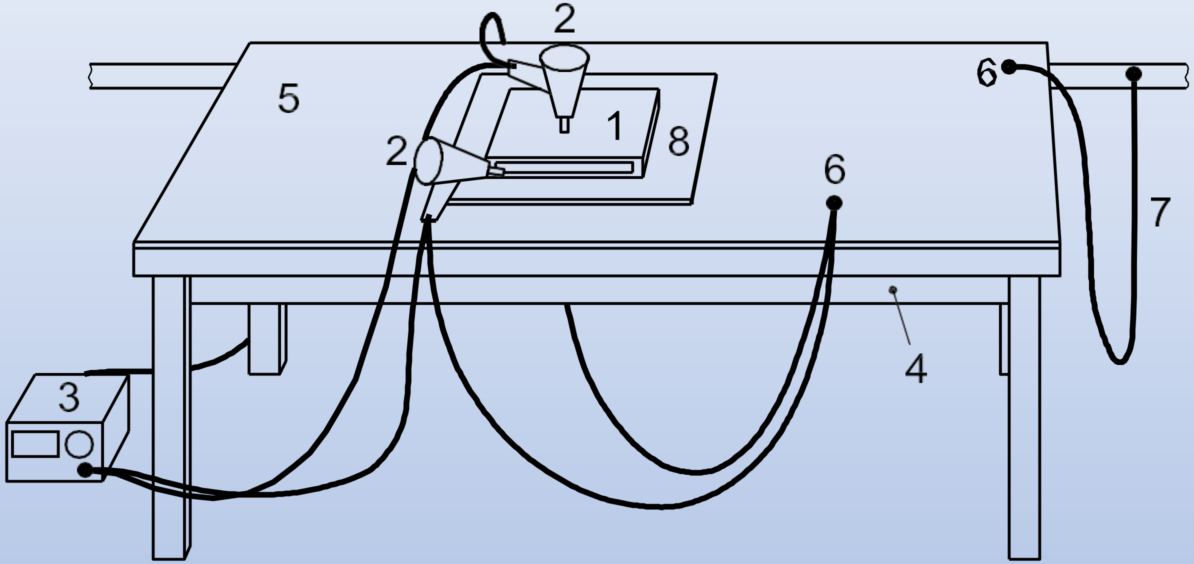
1. Simulator power supply
2. ESD simulator
3. 1 MΩ bleed-off resistor
4. Ground strap

5 Device under test
6 Static dissipative material
7 Ground plane (if required by manufacturer)

ISO 10605:2001 Unpowered ESD Setup Photo



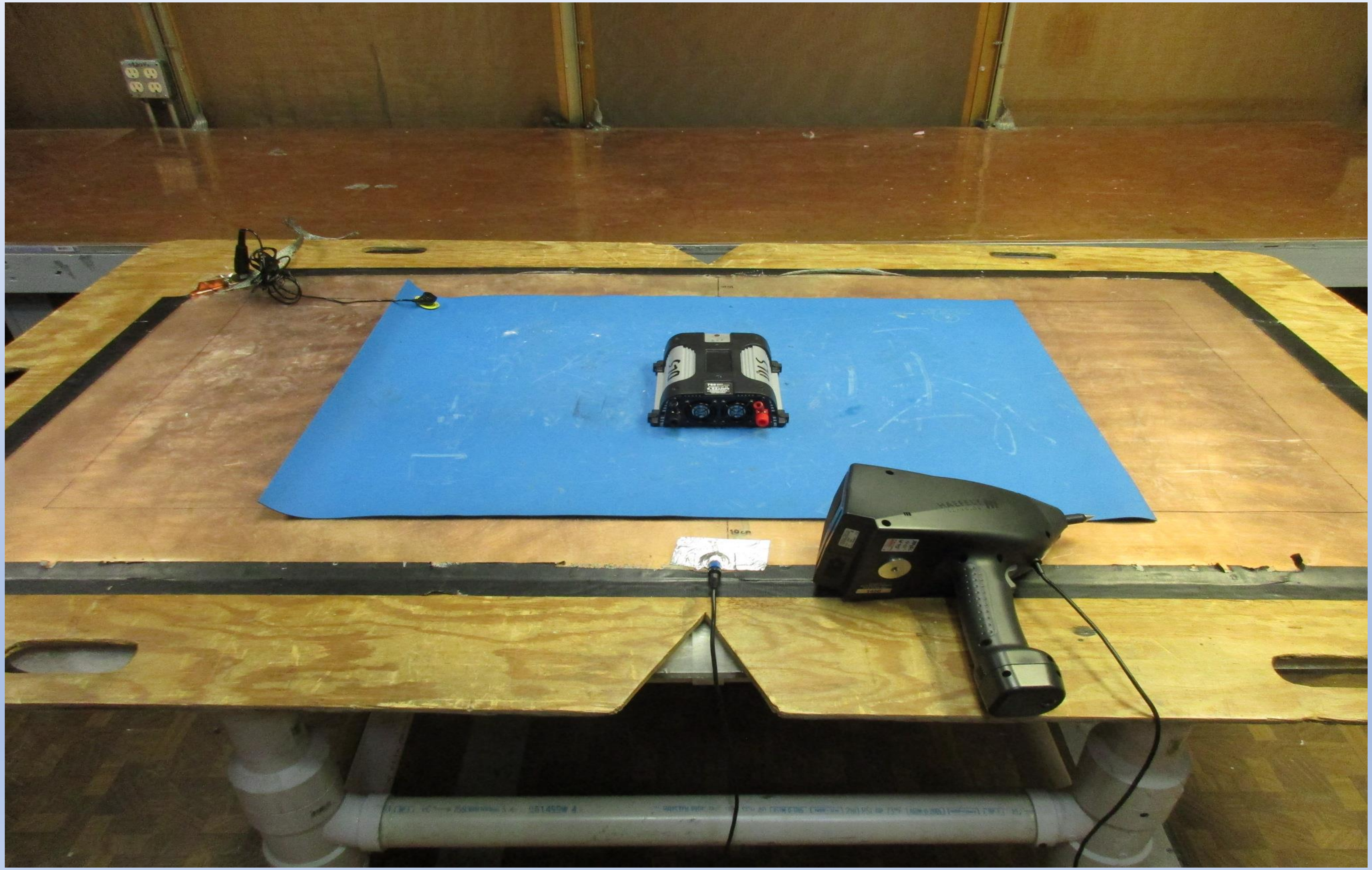
ISO 10605:2008 Unpowered ESD Setup



Key

1	DUT	5	HCP
2	ESD generator	6	ground point
3	ESD generator main unit	7	ground connection
4	non-conductive table	8	dissipative mat, if required

ISO 10605:2008 Unpowered ESD Setup Photo



Questions about ESD?

Thank You!

D.L.S. Electronic Systems, Inc.

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