Načrtovanje elektronike za $E=MC^2$

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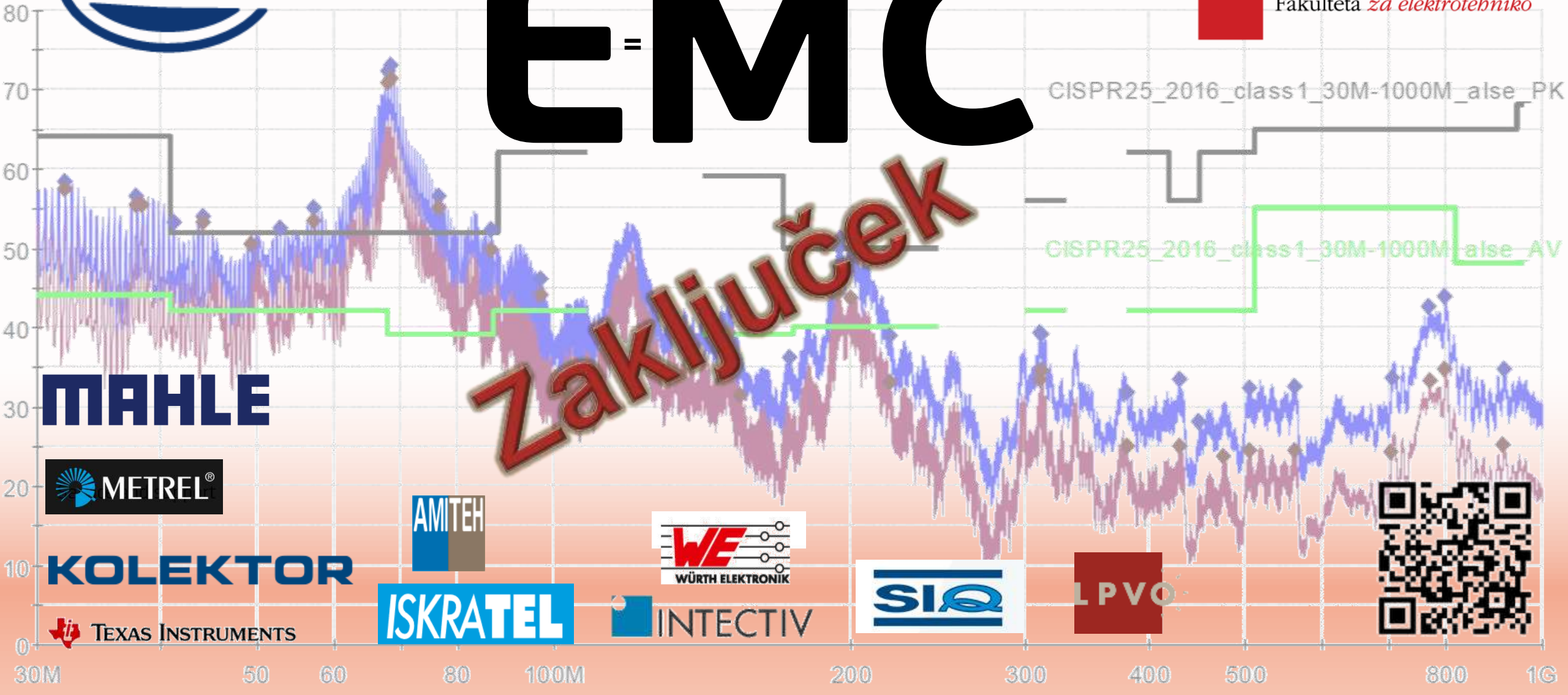
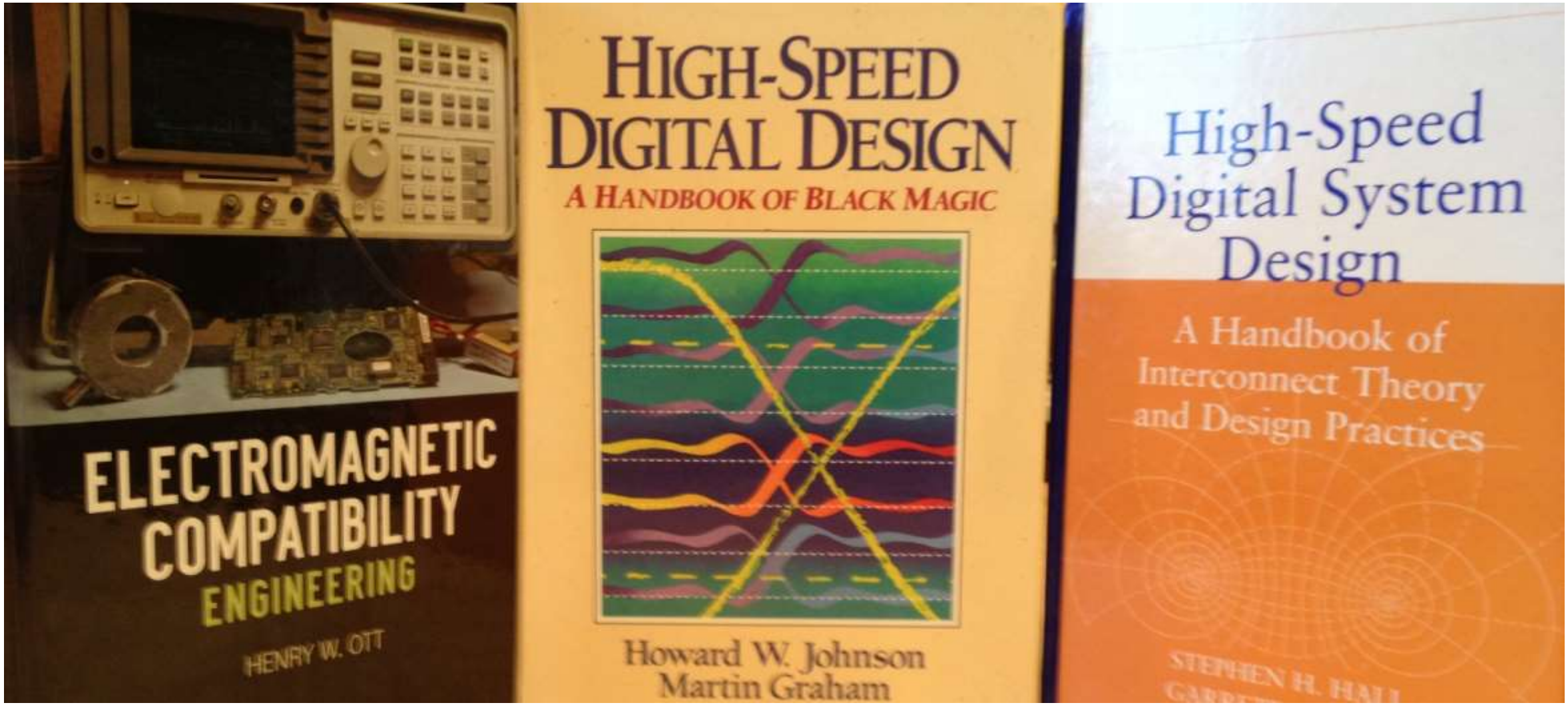


Zaključek

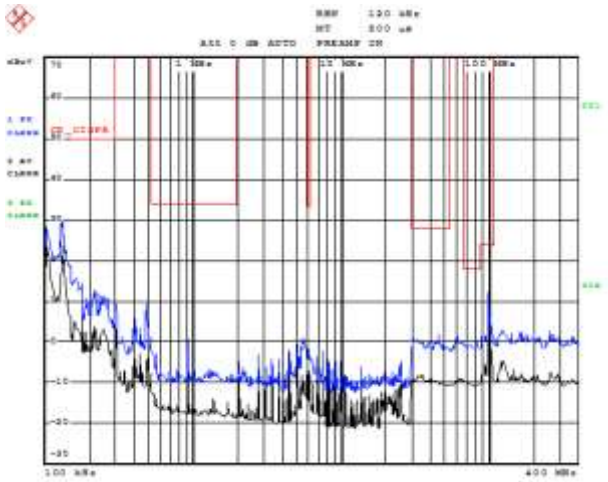
HELLA
MAHLE
METREL
KOLEKTOR
AMITEH
ISKRATEL
WÜRTH ELEKTRONIK
INTECTIV
SIQ
LPVO
TEXAS INSTRUMENTS

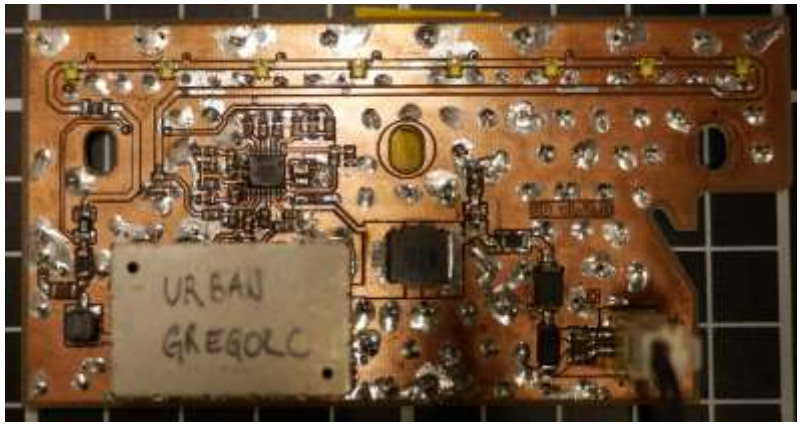
Čemu?

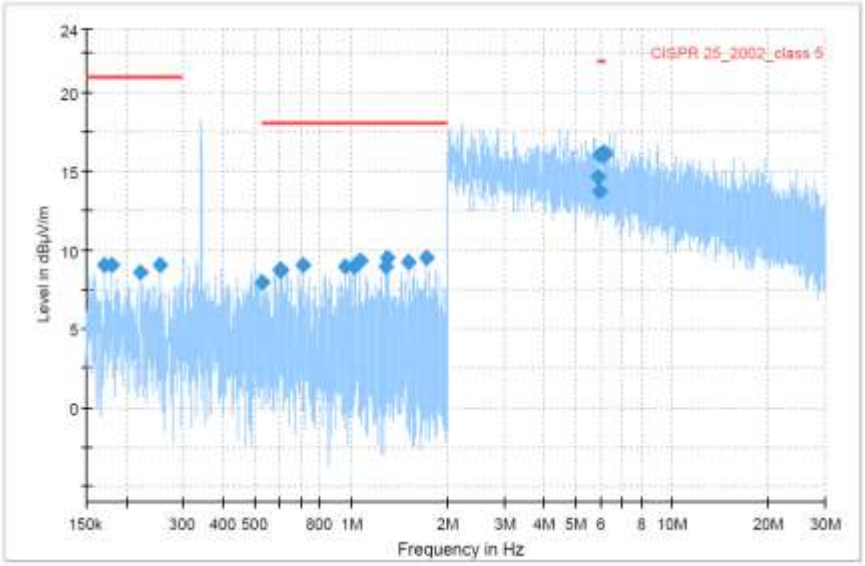

ELECTROMAGNETIC COMPATIBILITY ENGINEERING
HENRY W. OTT
HIGH-SPEED DIGITAL DESIGN
A HANDBOOK OF BLACK MAGIC
Howard W. Johnson
Martin Graham
High-Speed Digital System Design
A Handbook of Interconnect Theory and Design Practices

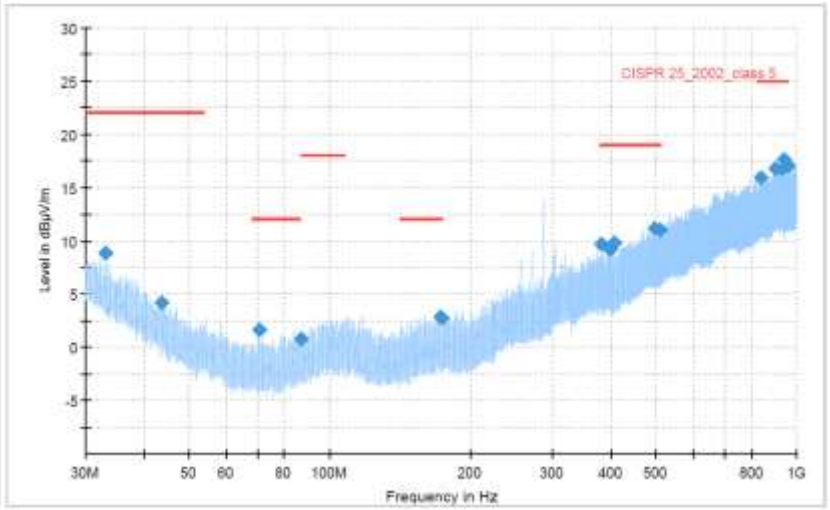
1. EMC delavnica 2016: HELLA SATURNUS

Urban Gregorc



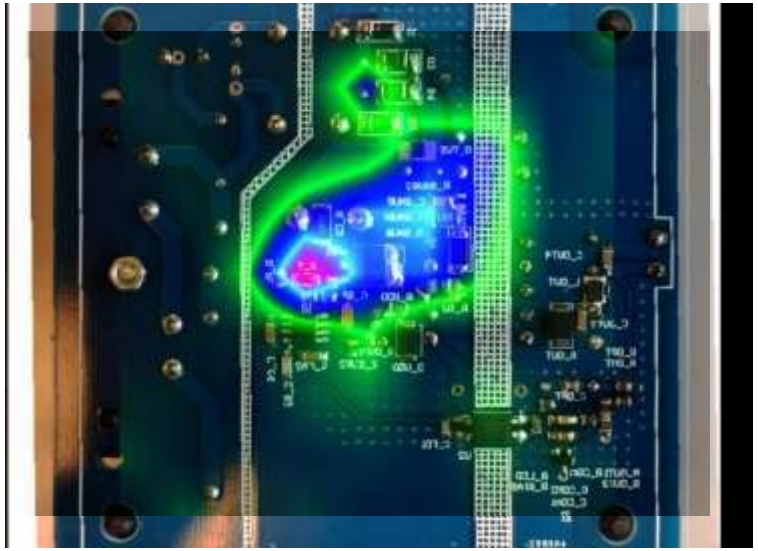


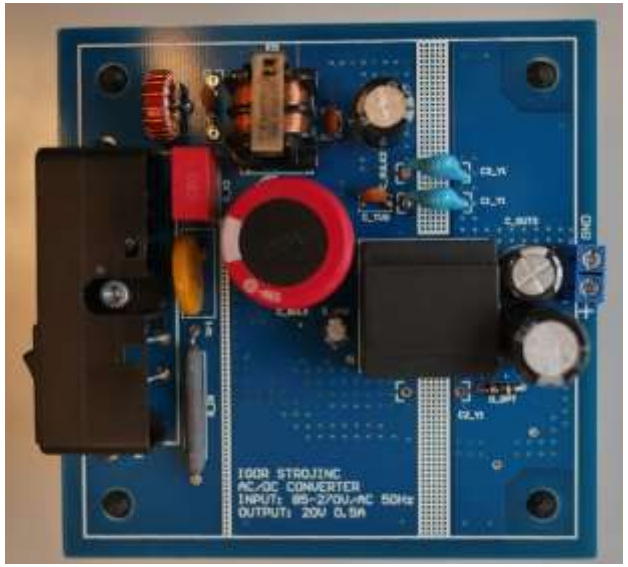


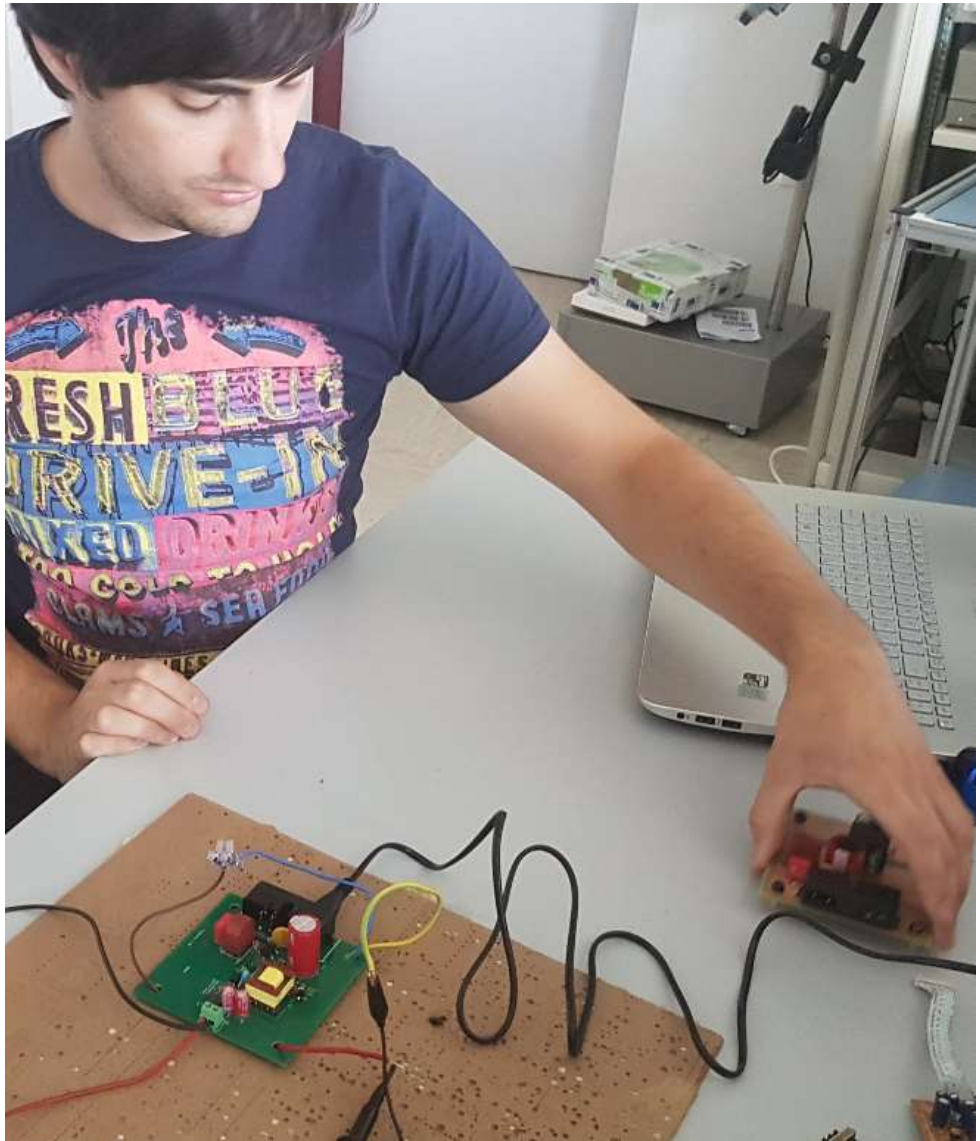


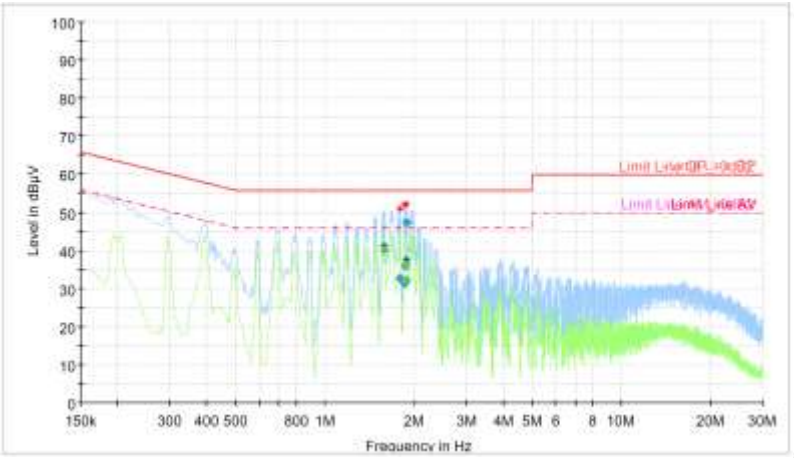
2. EMC delavnica 2017: ISKRA EMECO

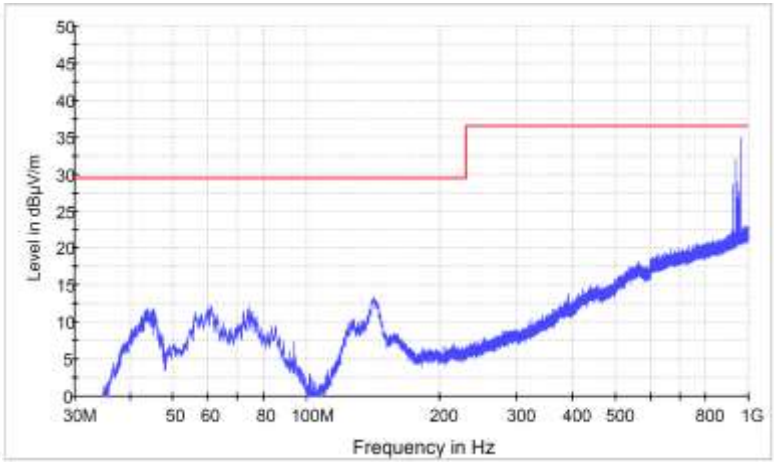
Igor Strojinc



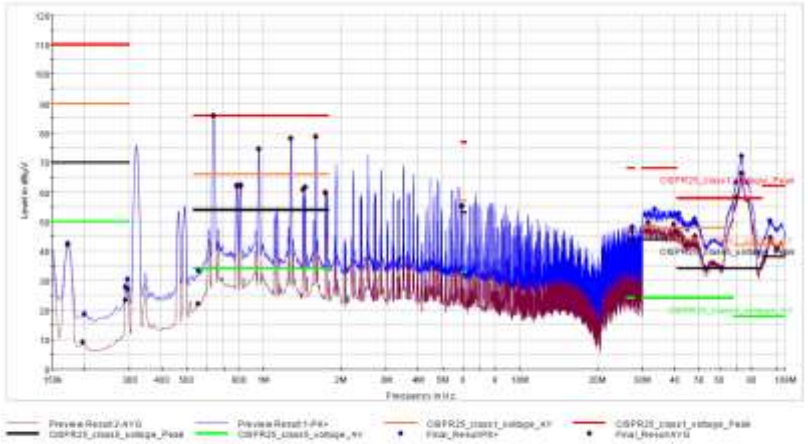






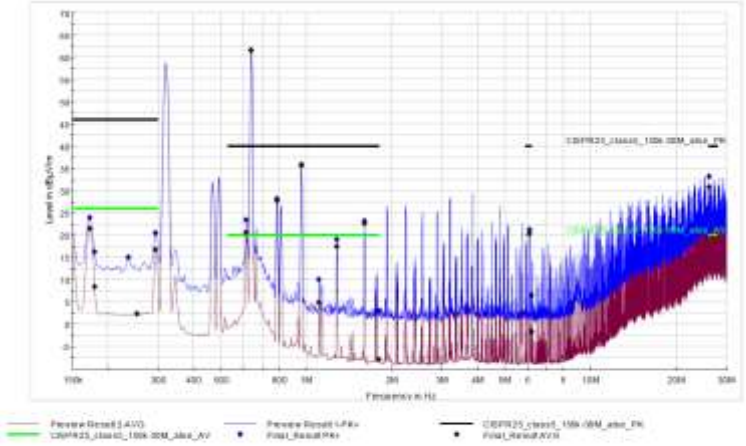


3. EMC delavnica 2018: MAHLE EDS



Slika 25: Rezultat na 48V+ priključku s PKAV detektorji in razredom 5 mejnimi vrednostmi

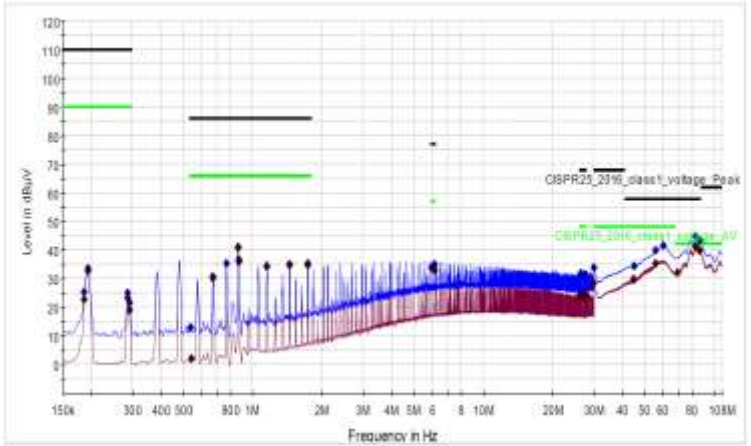
Slika 52: Rezultat s PKAV detektorji in razredom 5 mejnimi vrednostmi v frekvenčnem področju 30 MHz – 1000 MHz

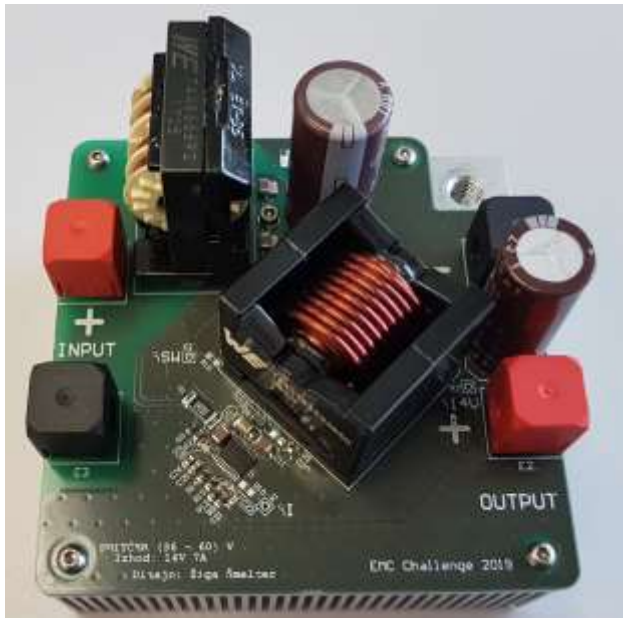


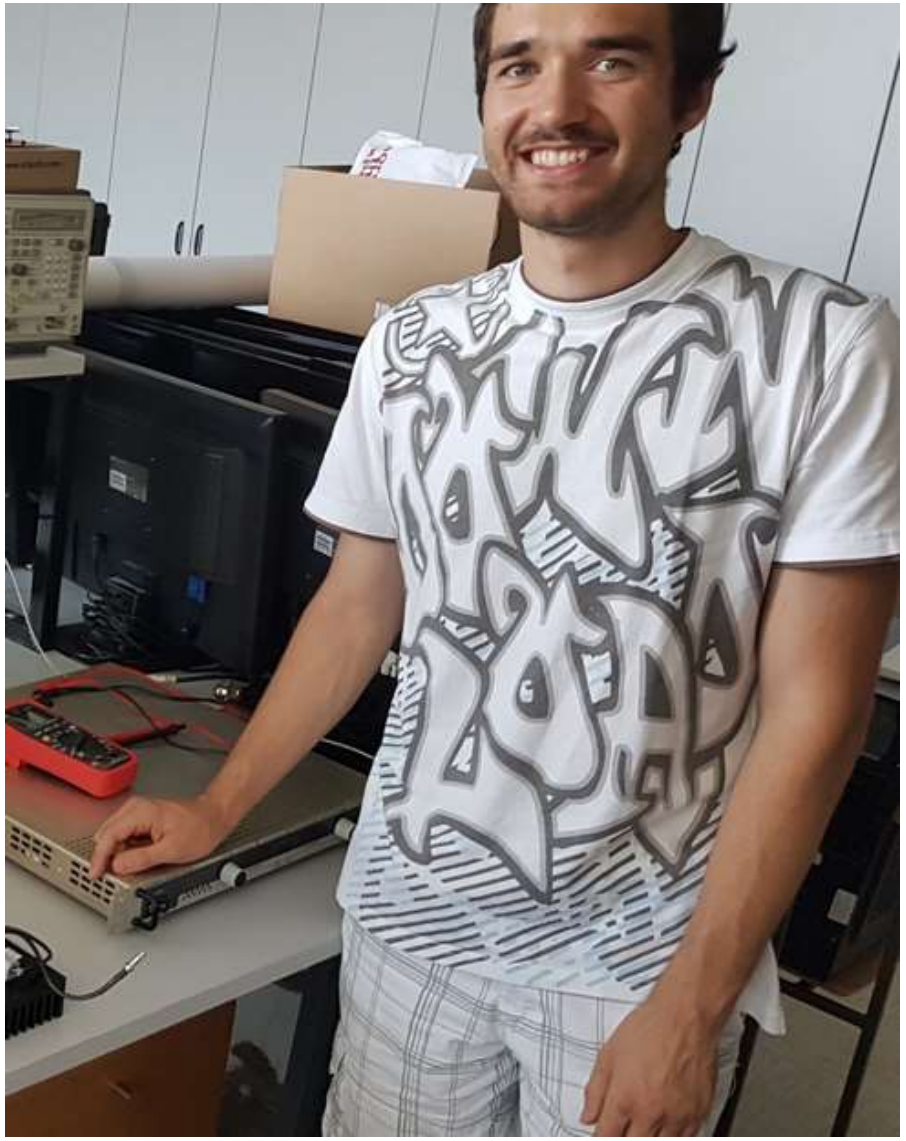
Slika 50: Rezultat s PKAV detektorji in razredom 5 mejnimi vrednostmi v frekvenčnem področju 150 kHz – 30 MHz

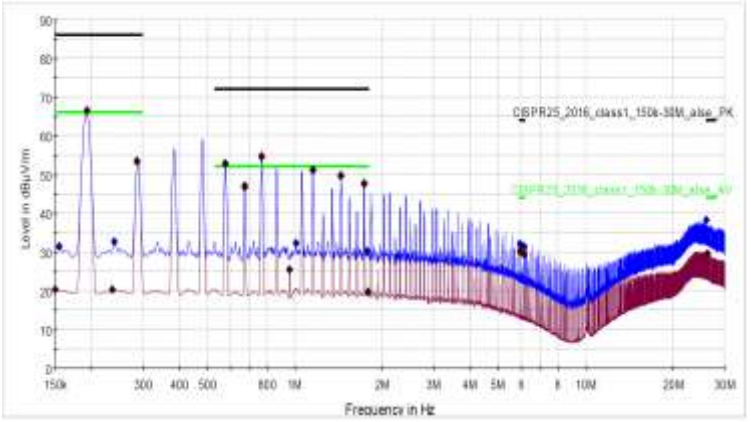
4. EMC delavnica 2019: MAHLE EDS

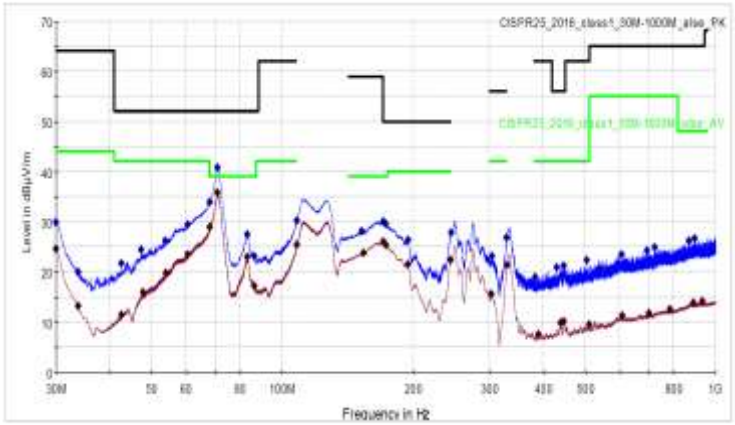
Žiga Šmelcer











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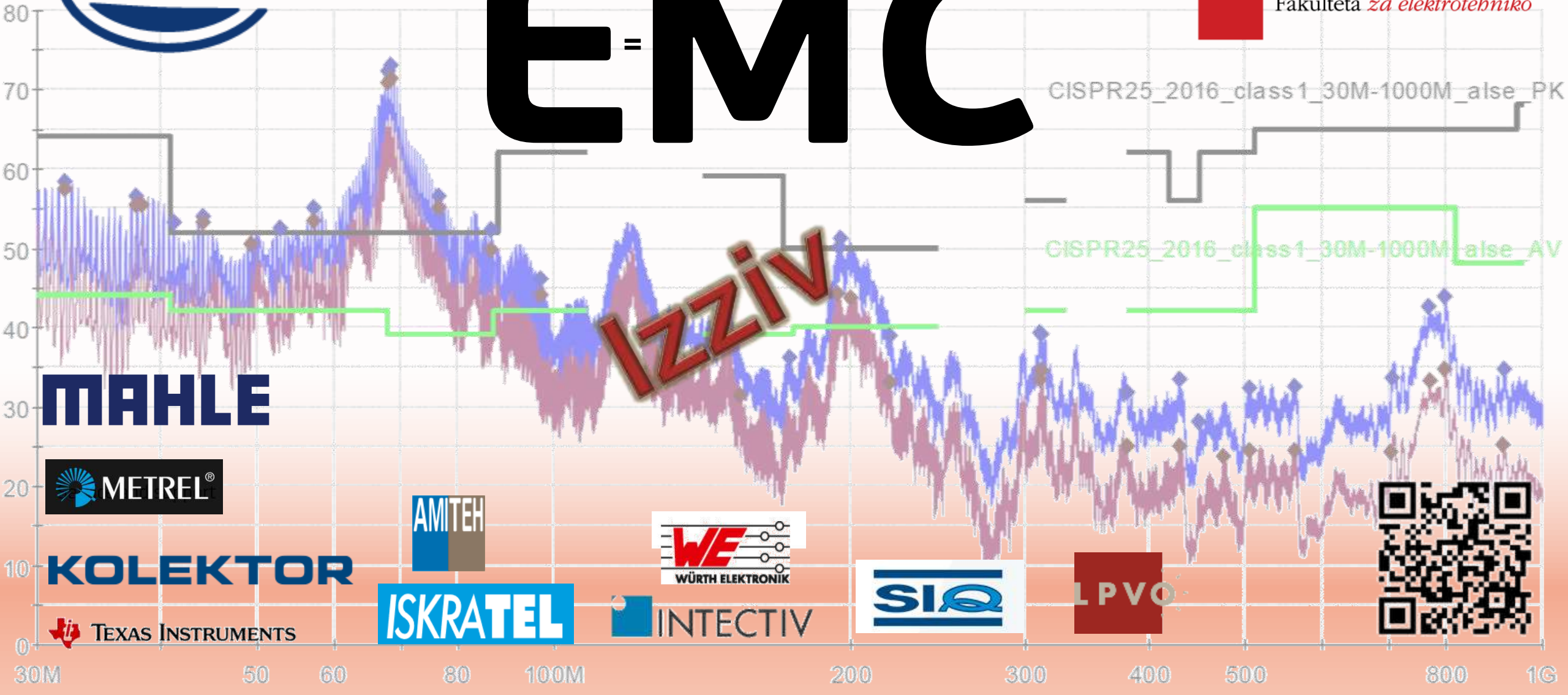
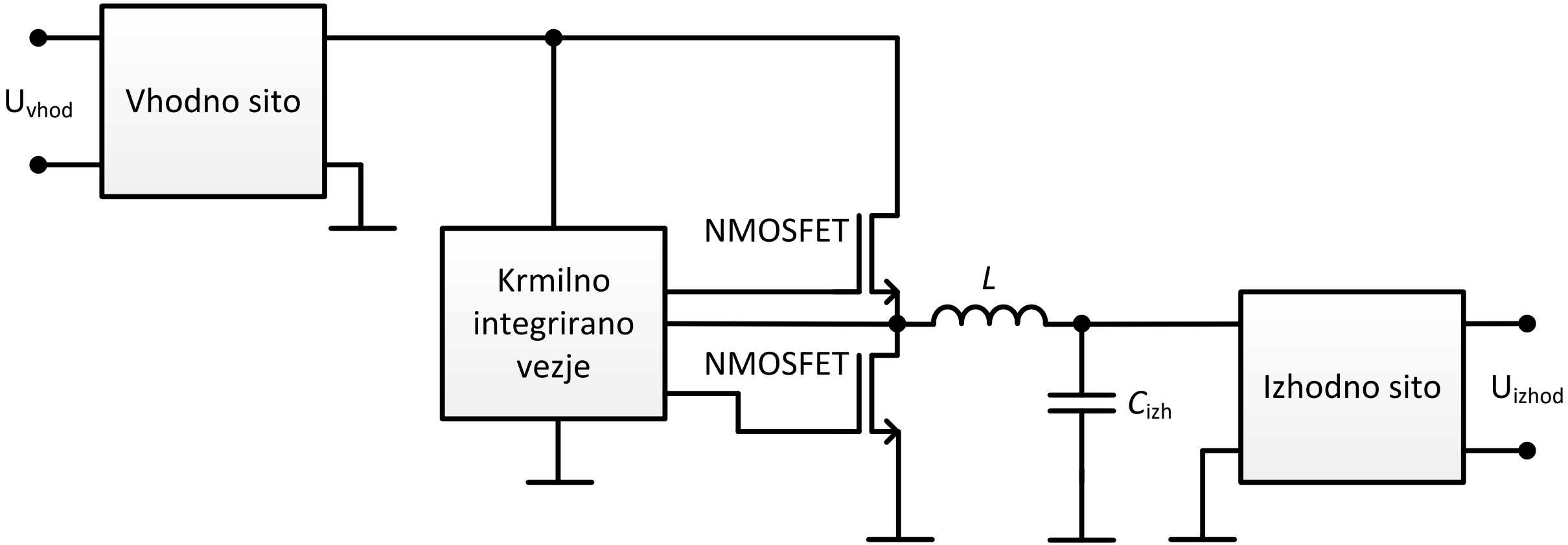


Izziv

HELLA
MAHLE
METREL
KOLEKTOR
AMITEH
ISKRATEL
WÜRTH ELEKTRONIK
INTECTIV
SIQ
LPVO
Texas Instruments

Izziv: DC/DC stikalni napajalnik za LED žaromet



S čim?

- TI: Donira integrirana vezja
- Hella Saturnus: Pripravi ohišja in testna bremena
- Würth elektronik: Donira vso magnetiko in kondenzatorje
- Ostale elemente kupite s Farnella (IC elektronika?)
- FE, LPVO:
  - pomoč pri fizični izdelavi prototipa TIV
  - pomoč pri meritvah (napajalniki, multimetri, osciloskopi, spektralni analizator, EMC sonde)
- Amiteh: Preliminarna EMC meritev z Detectusom
- SIQ, Hella Saturnus: Končne meritve

Kako?

Termin	Vsebina	Predavatelj
torek 18.2.	Predstavitev EMC delavnice	Marko Jankovec (LPVO, FE)
ponedeljek 24.2.	Sinhroni stikalni napajalniki	Peter Kržič (HELLA)
torek 3.3.	Teoretična delavnica načrtovanja EMI filtrov	Marko Jankovec in Gregor Ergaver (MAHLE)
torek 10.3 (LAE)	Praktična delavnica načrtovanja EMI filtrov	Tomo Kozeljnik in Sašo Božjak (Wurth elektronik)
torek 17.3. (LAE)	*Altium delavnica (SCH)*	*Jankovec/Tome*
torek 24.3. (LAE)	*Altium delavnica (PCB)*	*Jankovec/Tome*
torek 31.3.	*Tehnologije in načrtovanje za proizvodnjo TIV*	*Gregor Črv (Intectiv) / Dejan Jeraj (Iskratel)*
ponedeljek, 6.4.	*Naročilo materiala Würth eletronik in tiskanih vezij*	
ponedeljek, 18.5.	*Oddaja izdelanih končanih projektov.*	
sreda 20.5.	*Ekskurzija v SIQ*	
??	*Ekskurzija v HELLA*	
ponedeljek, 2.6.	*Razglasitev rezultatov*	

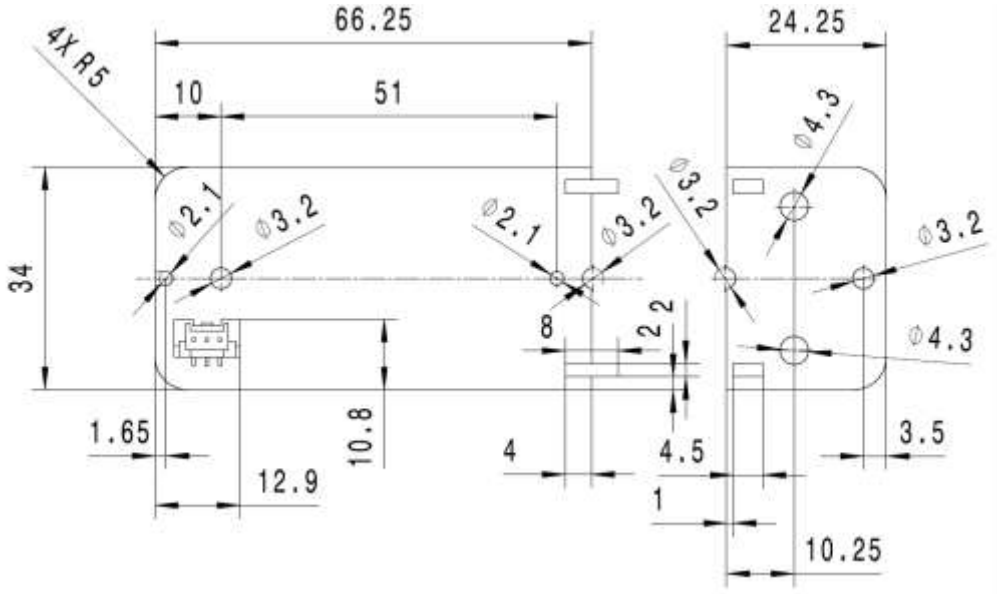
Električne zahteve

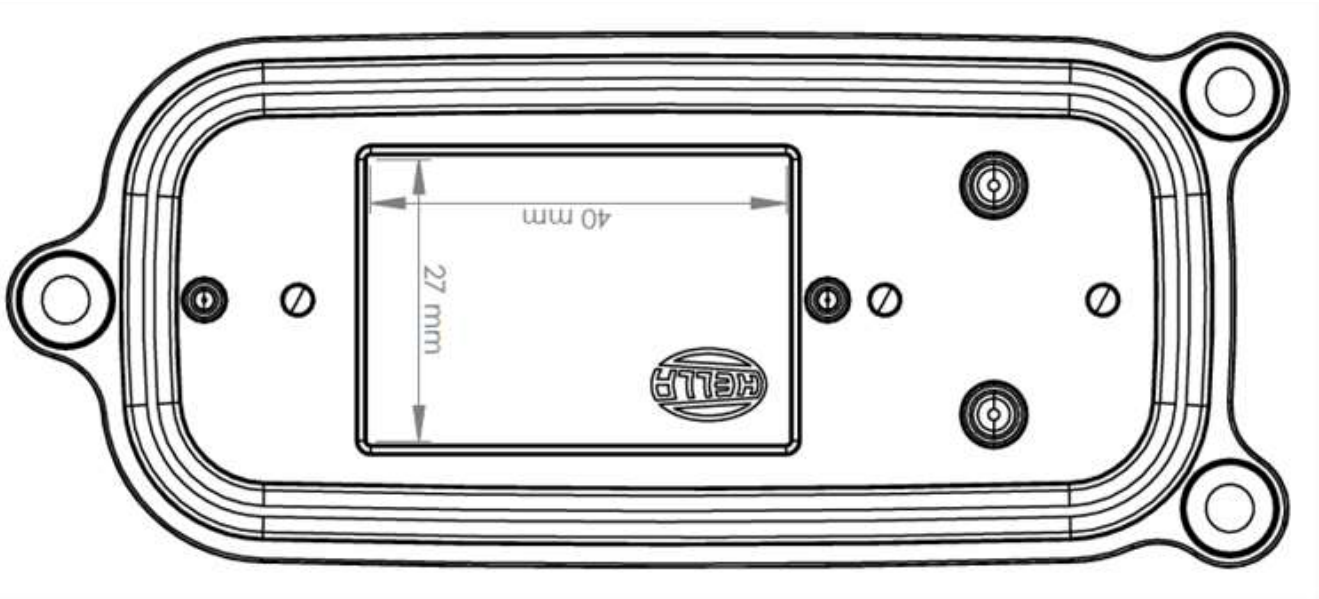
Lastnost	Vrednost	Opomba
Topologija	DC/DC pretvornik navzdol	Integrirano vezje TPS92641
Območje vhodne napetosti za polno delovanje	[8 – 18] V	V tem področju mora pretvornik zagotavljati nazivni izhodni tok
Nazivni izhodni tok	6 A ±10%	Pretvornik mora v predpisanem območju delovati v neprekinjenem režimu.
Območje izhodne napetosti	[3 – 4] V	1x LED Osram oslon boost
Vršna vrednost valovitosti izhodne napetosti	0,2 V	Pri osnovni frekvenci
Vršna vrednost valovitosti izhodnega toka	0,2 A	Vse skupaj
Izhodno breme	1 x LED OSLON® Boost HL	Bremena bo zagotovilo podjetje Hella Saturnus.

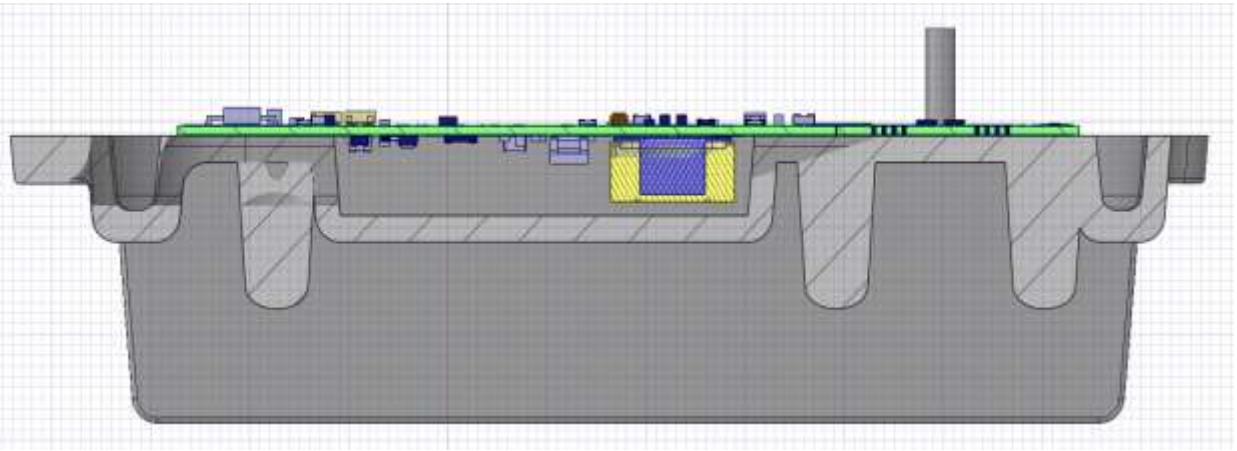
Električne zahteve

Lastnost	Vrednost	Opomba
Izkoristek pretvornika	>85%	Merjen pri temperaturi okolice 25 °C, vhodni napetosti 13,5 V in izhodnem toku 6 A.
Dolgotrajno delovanje	Pri sobni temperaturi (T_{amb} = 25 °C), temperatura nikjer na vezju ne sme preseči 125 °C	Nobena komponenta ne sme biti preobremenjena pri temperaturi okolice 25 °C. Lega vezja je vodoravna, položena na mizo s hladilnim telesom navzdol. Temperatura se izmeri po 30 minutah delovanja vezja.
Zaščita obrnjene polaritete	-20 V	Vhodna zaščita proti napačni priključitvi napajalnih sponk
Podnapetostna zaščita	U_{supp} <6 V	Izklop pretvornika, ko je vhodna napetost manjša od 6V
Kratko-stična zaščita	U_{iz} < 2 V	Zaščita proti kratkemu stiku na izhodnih sponkah bremena . Zahtevan izklop stikalnega dela.
Odprte sponke na bremenu	U_{iz} > 6 V	Zaščita v primeru odprtih sponk na bremenu. Zahtevan izklop stikalnega dela.

Mehanske zahteve







Točkovanje

- Načrtovalske zahteve
  - Za vsako doseženo alinejo 5 točk (do 50 točk)
  - Izkoristek: za vsak % nad 85% se dobi 5 točk
- EMC
  - Prevodne emisije do 35 točk
  - Sevalne emisije do 35 točk
  - Imunost na vsiljene tokove do 30 točk
- Cena (L, Q, C)
  - Iskalnik octopart iz redne ponudbe za 1000 izdelkov
  - Za vsak € se odbije 5 točk.

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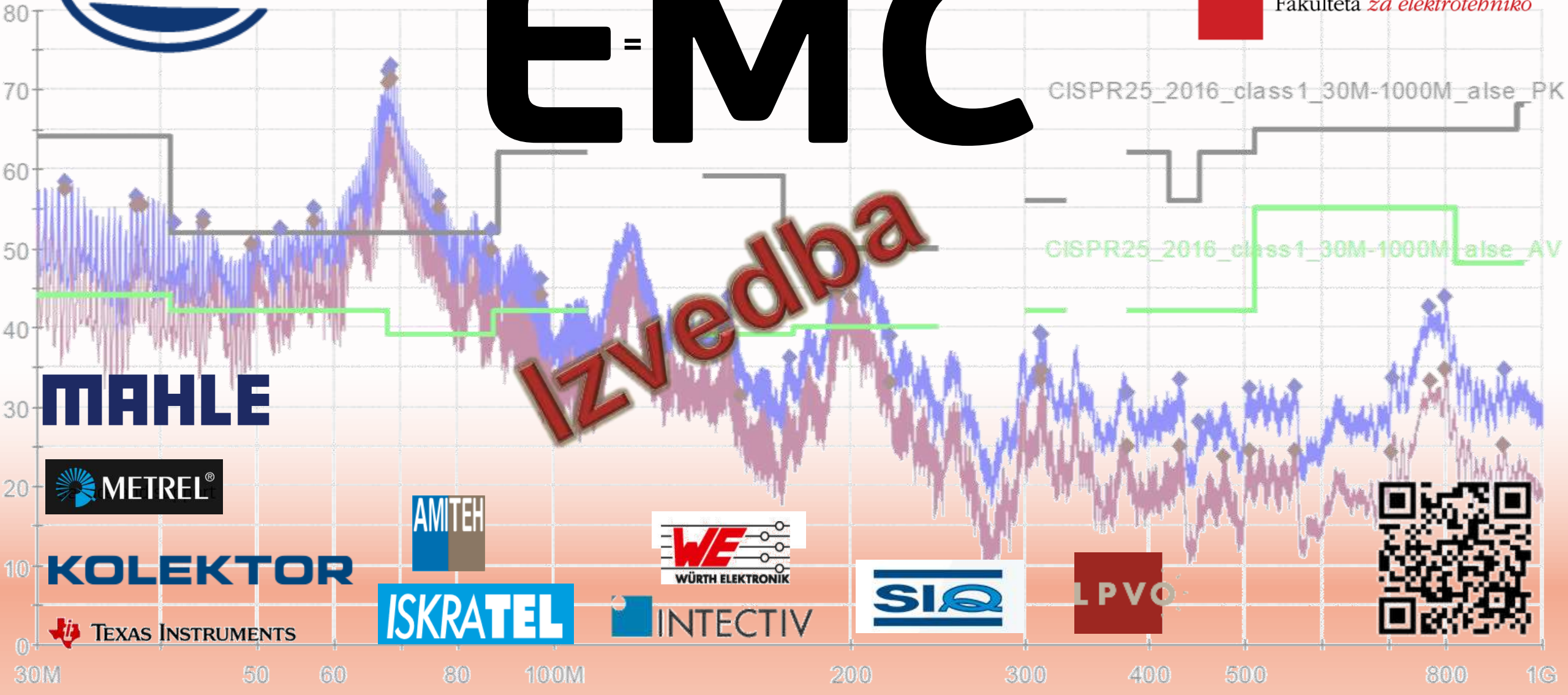
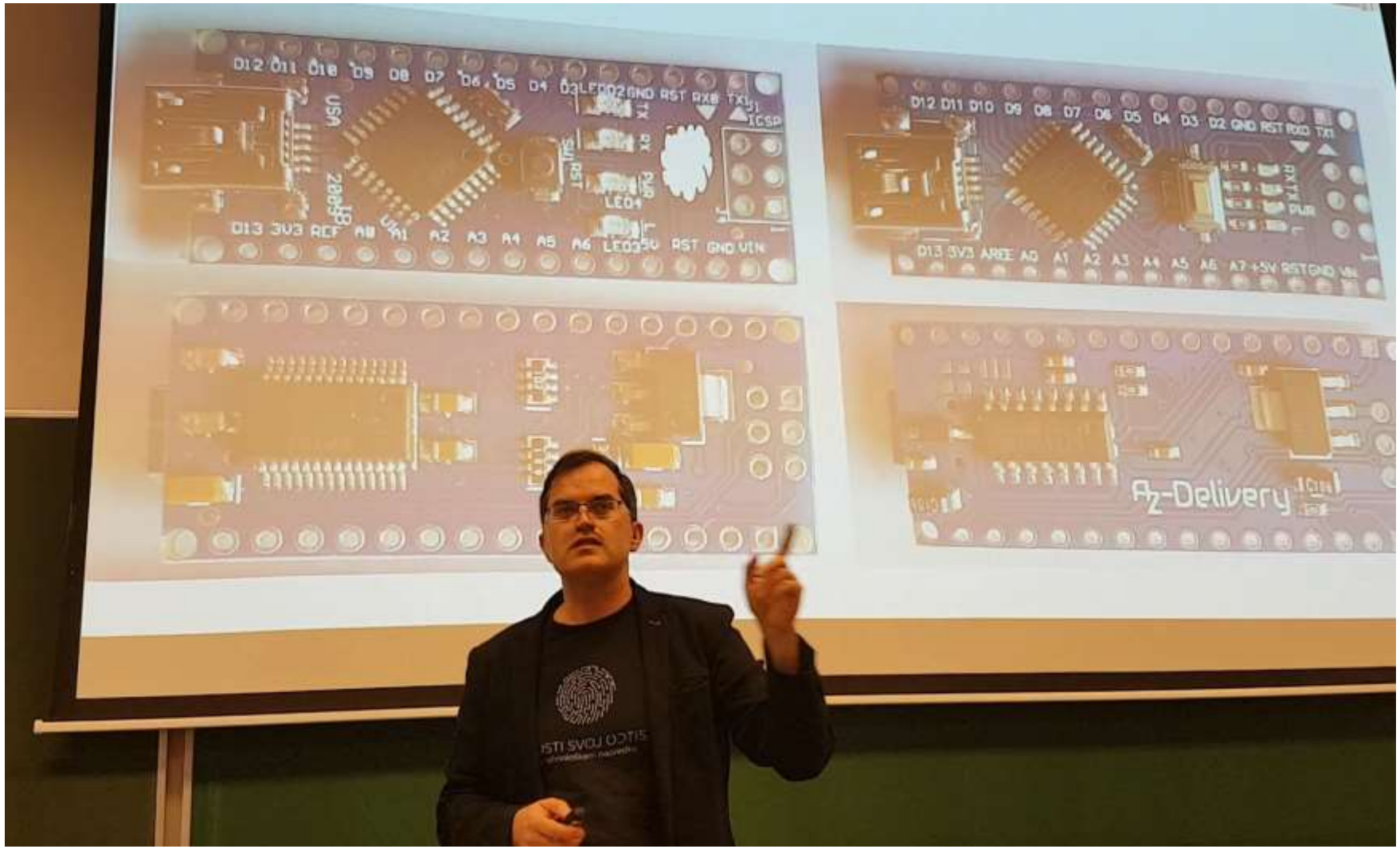


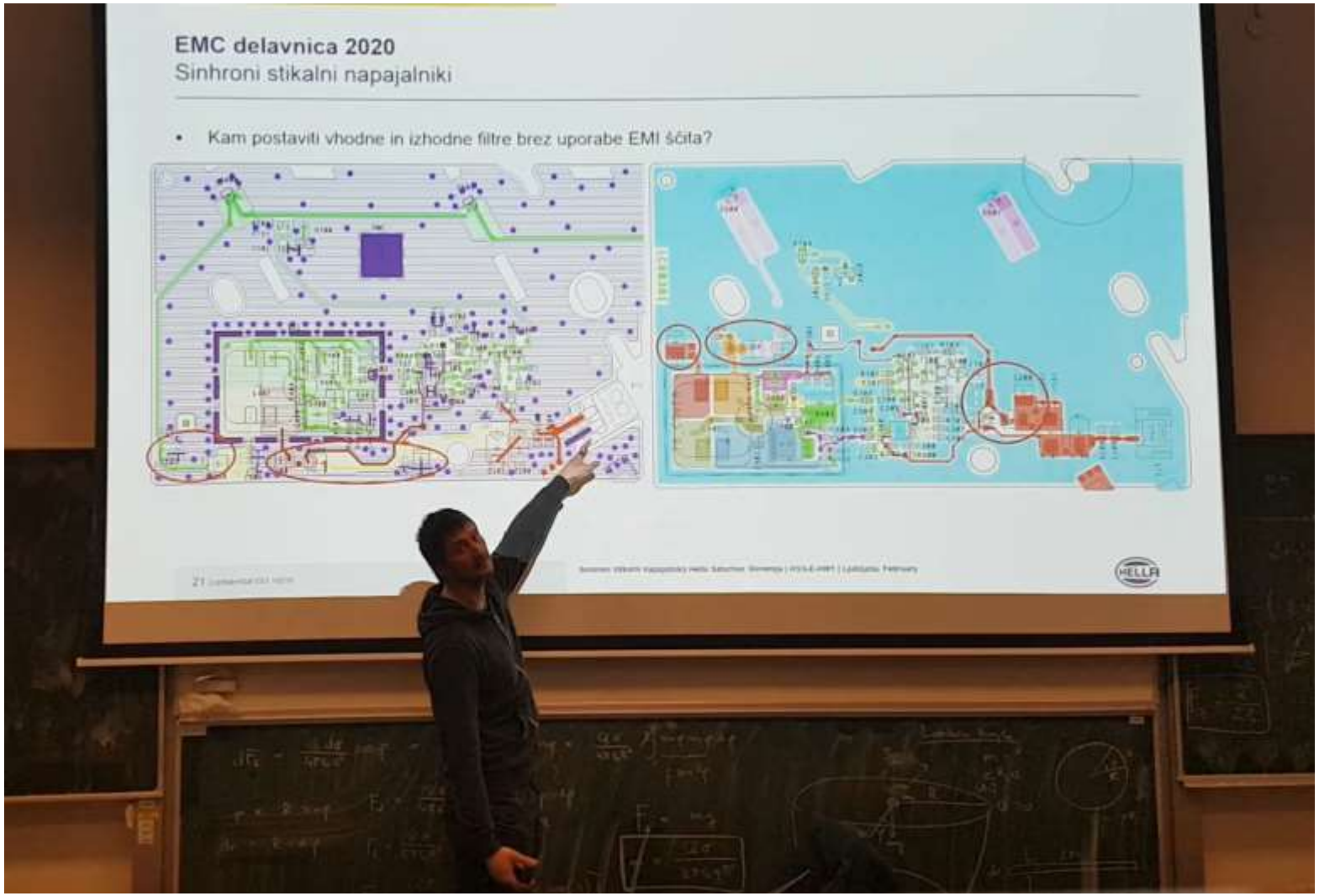
Izvedba

HELLA
MAHLE
METREL
KOLEKTOR
AMITEH
ISKRATEL
TEXAS INSTRUMENTS
WÜRTH ELEKTRONIK
INTECTIV
SIQ
LPVO

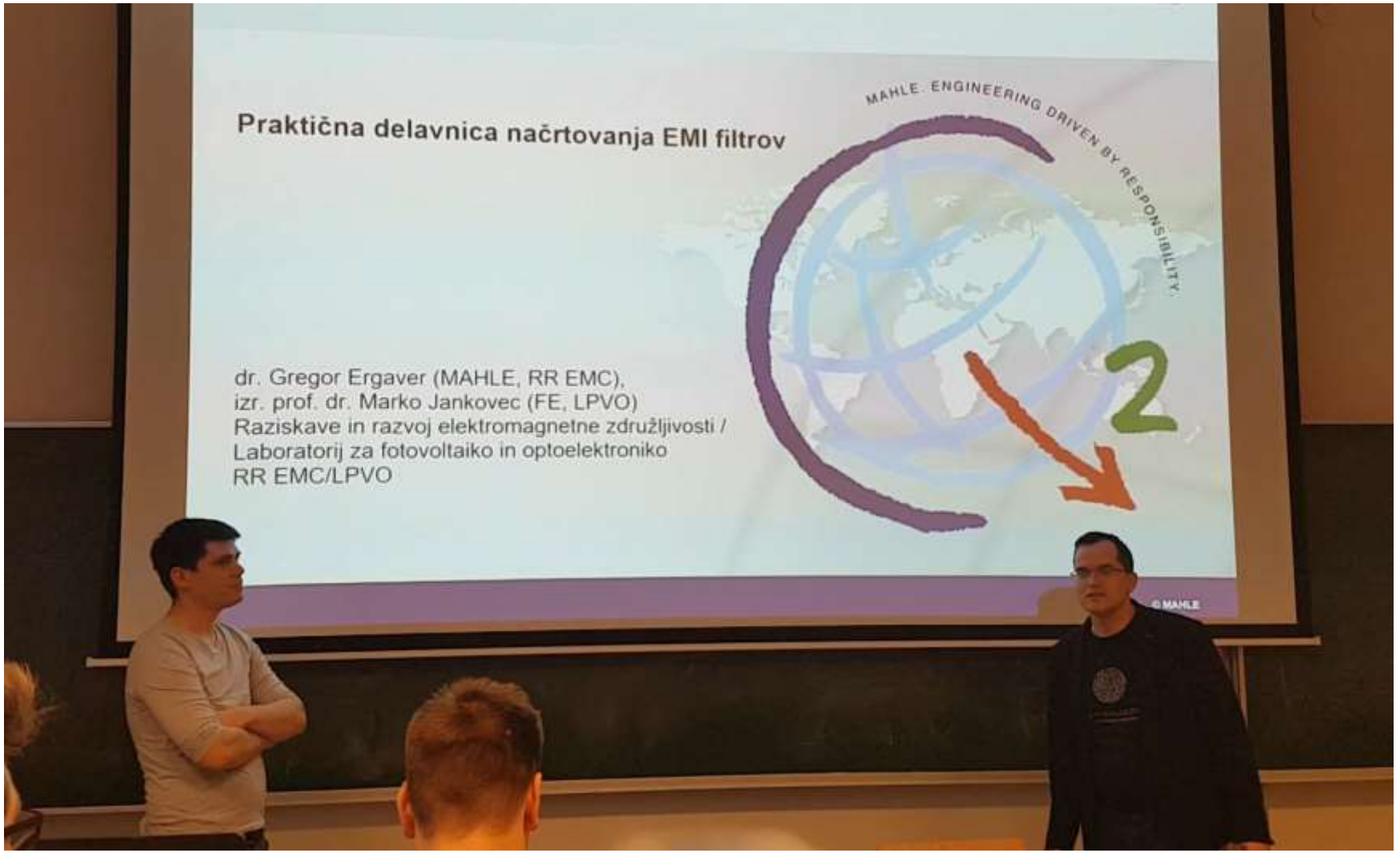
Uvod v delavnico (Jankovec, ULFE)



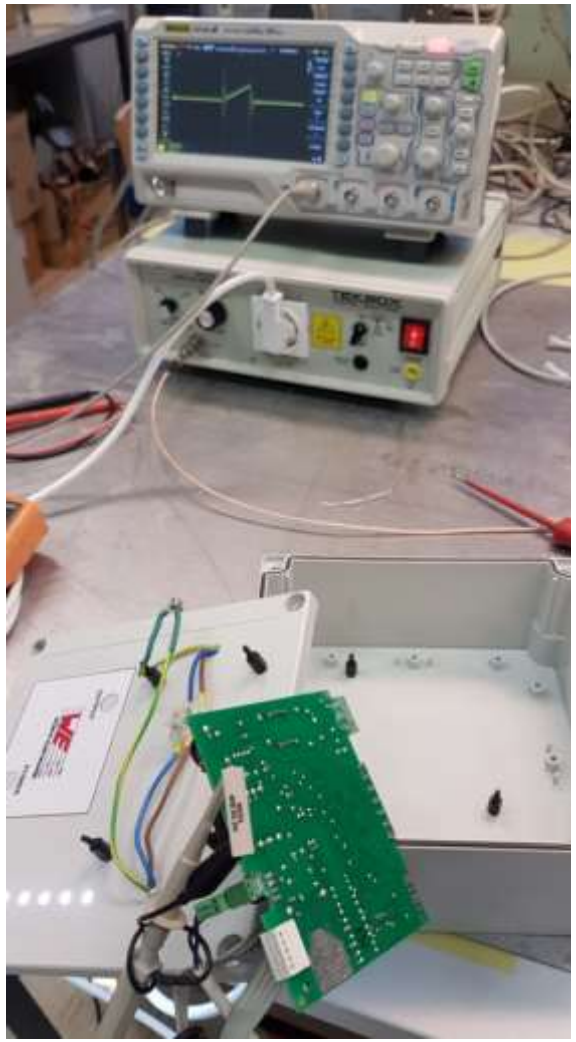
Predavanje o stikalnih napajalnikih (Kržič, Hella)

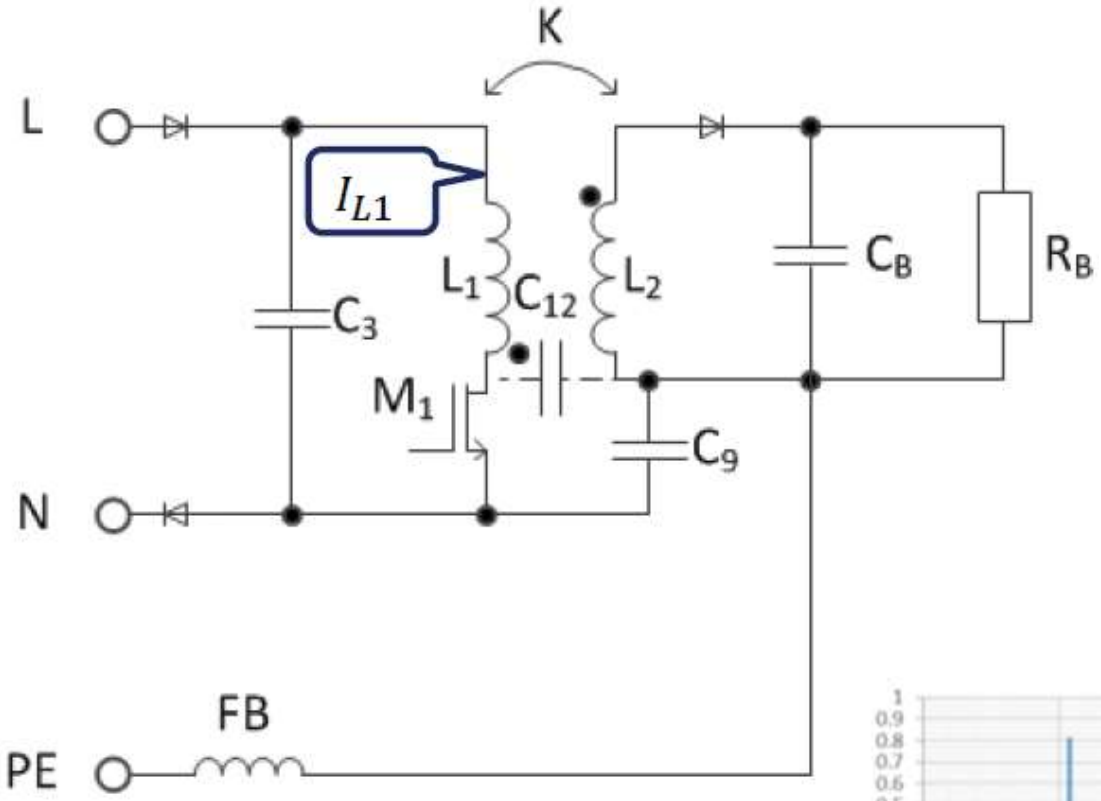


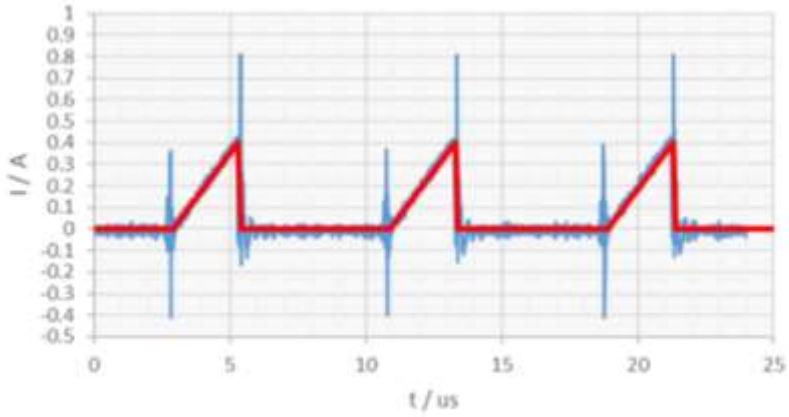
Delavnica načrtovanja filtrov (Jankovec, Ergaver, MAHLE EDS)



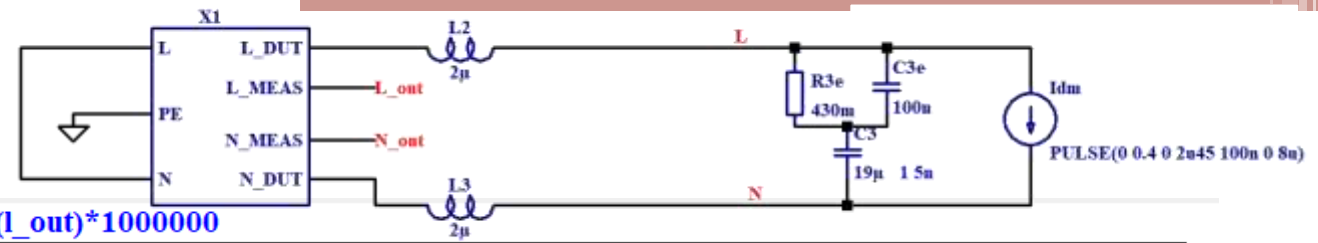
Karakterizacija agresorja in merilne postavitve

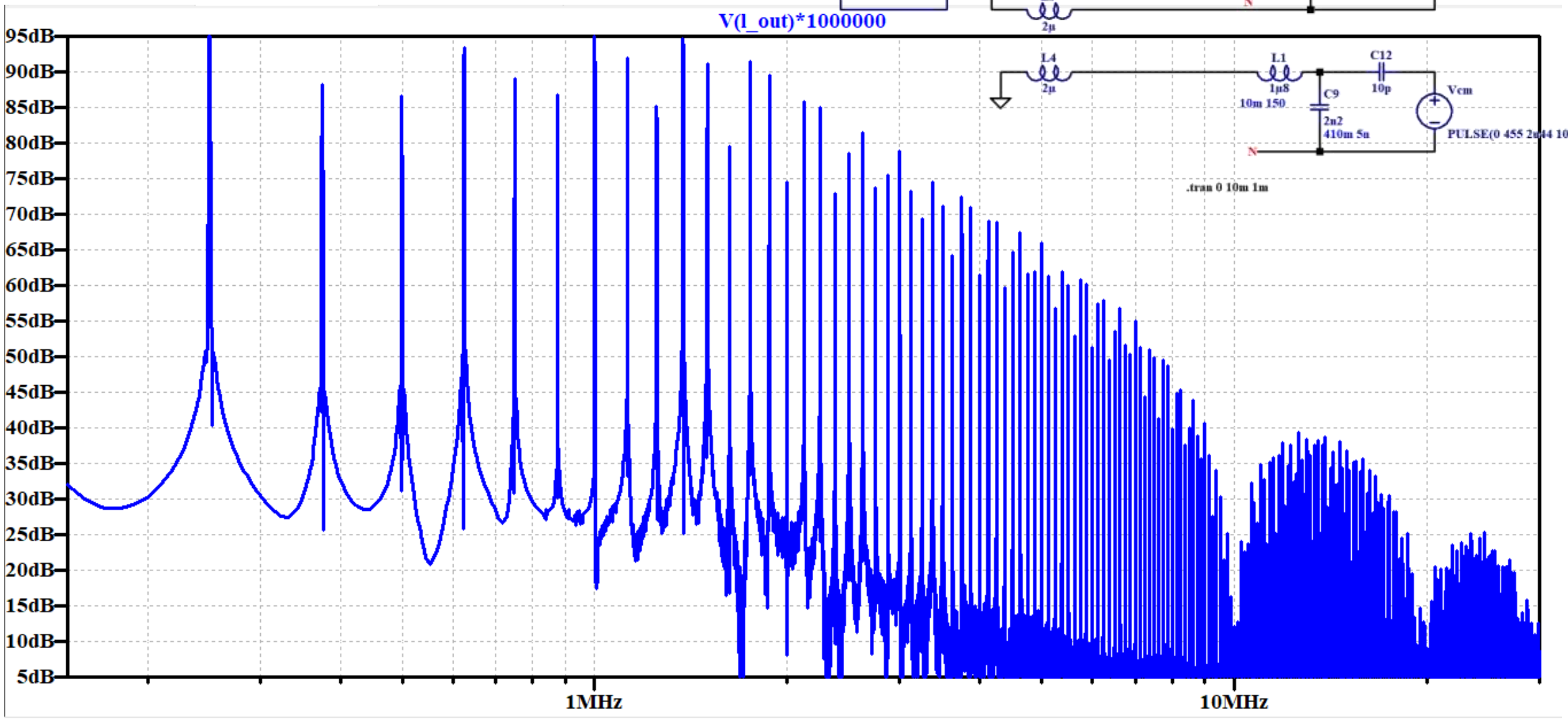




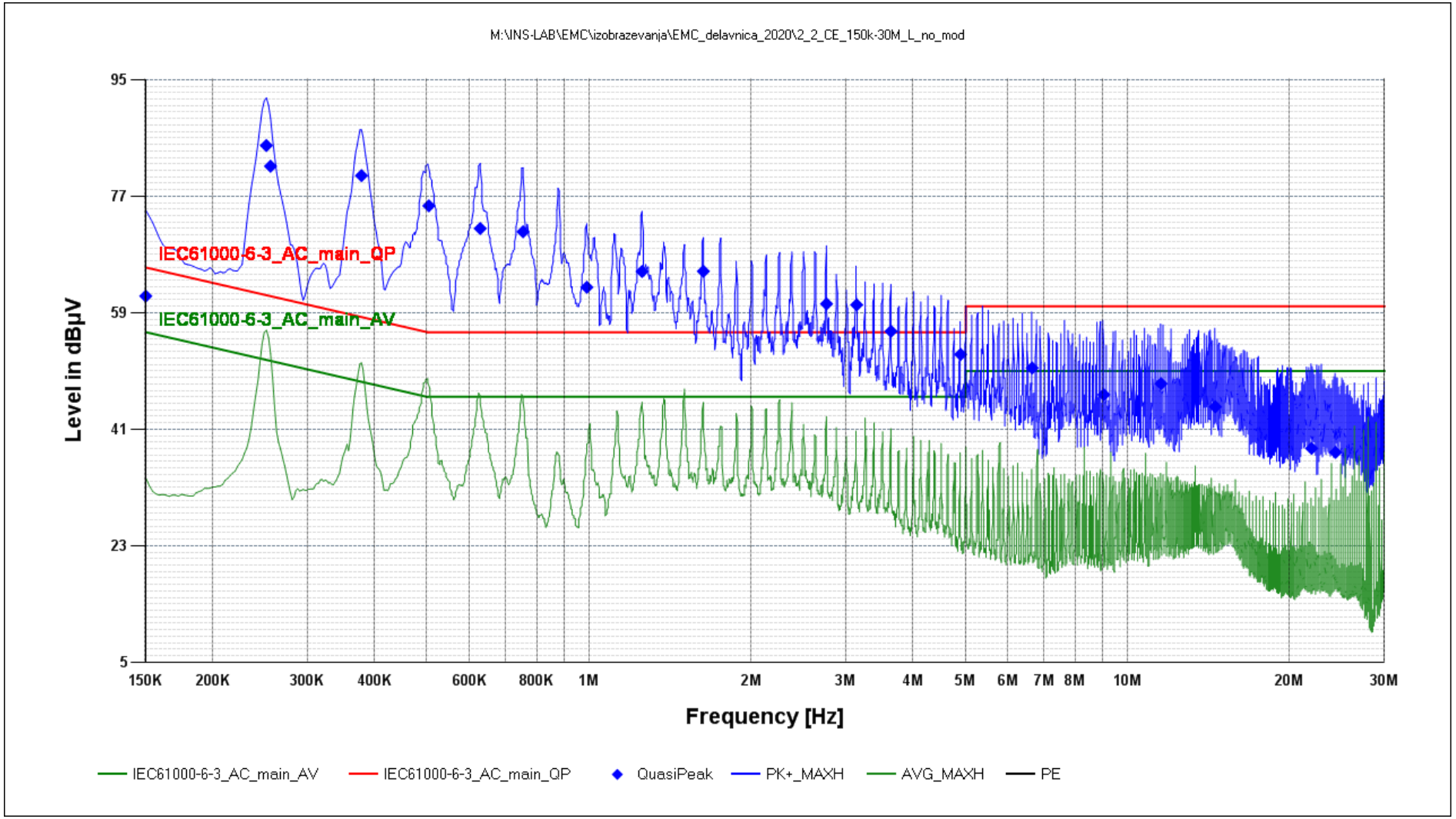


Simulacije agresorja

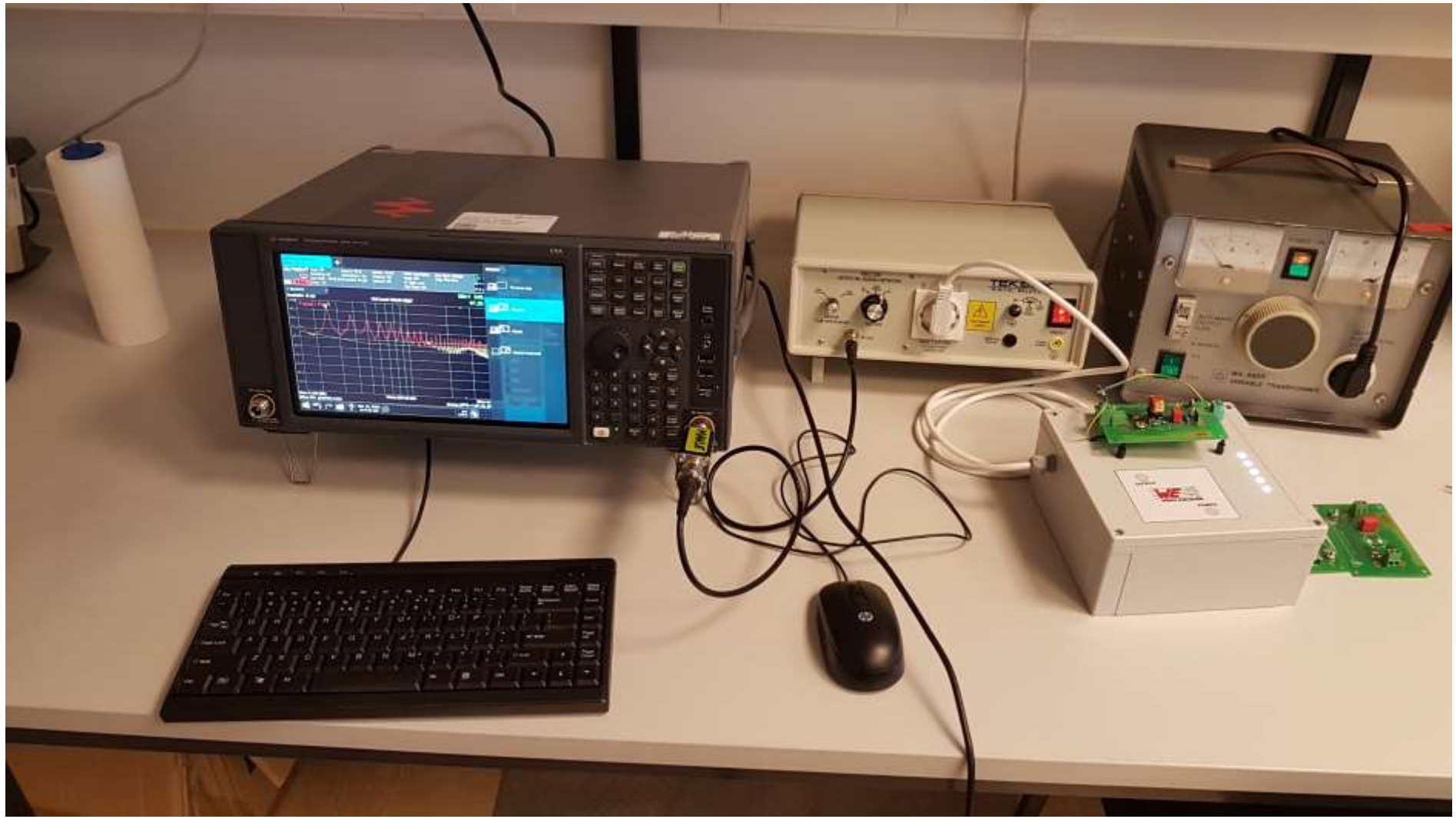




Meritve agresorja

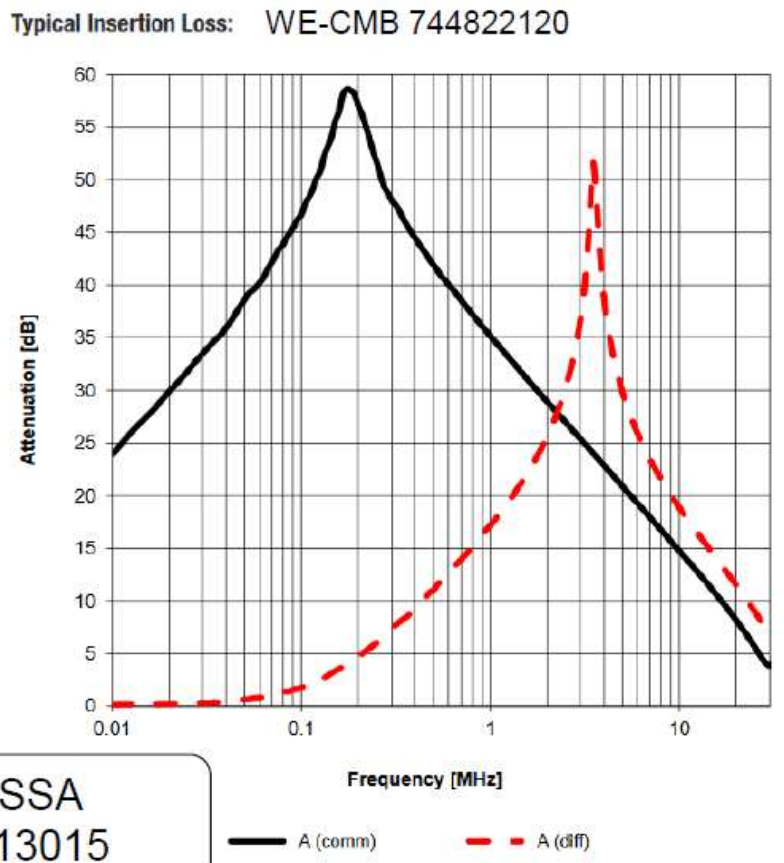


Wurth praktična delavnica načrtovanja filtrov



Izbira filtra

- Wuerthov dodatni filter



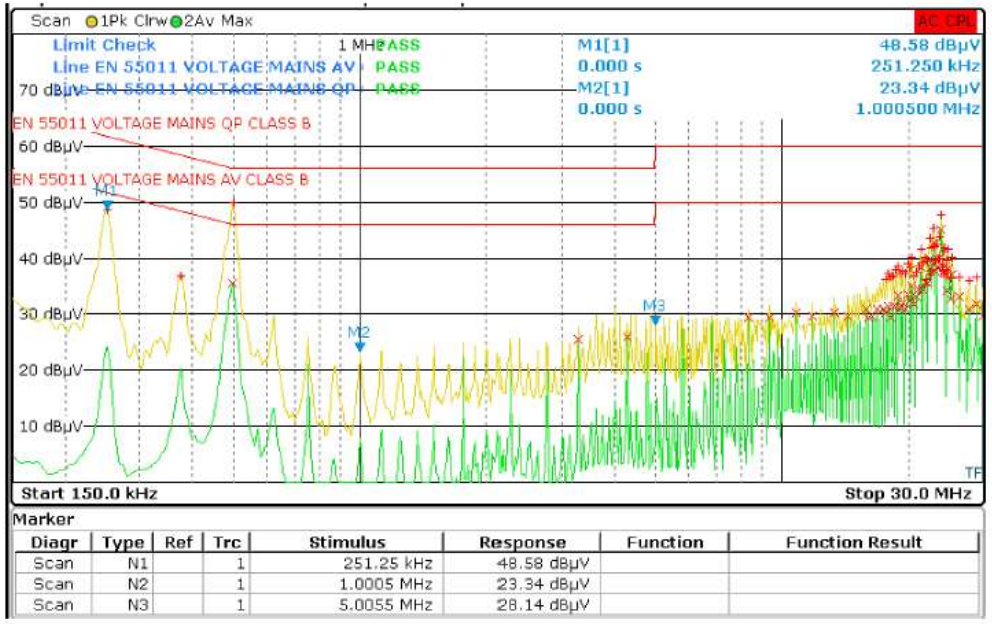
Wurth praktična delavnica načrtovanja filtrov

Rezultati

Column1	Študent - ekipa	Napoved 250k	Napoved 1M	Napoved 5M	Meritev 250k	Meritev 1M	Meritev 5M	Min. raz. do stand.	Razlika 250k	Razlika 1M	Razlika 5M	Povprečna razlika
Luka Pogačnik	LP	50.7	25	25	48.5	23.3	28.14	−6	2.2	1.7	3.14	2.35
Žiga Šmelcer	ŽŠ	35.9	27.2	26.3	33.12	21.69	28.35	−16.34	2.78	5.51	2.05	3.45
B. Brzec #speed	BB	53	37	32	52	28.39	27.47	−6.74	1	8.61	4.53	4.71
Marko Remec	MR	35	28	25	26.11	25.6	29.3	-25	8.89	2.4	4.3	5.20
B. Čeferin in C Šivic	BČ in CŠ	55.35	38.19	33.16	50.28	30.07	30	−11.51	5.07	8.12	3.16	5.45
Smodiš	SS	60	42	14	74.7	28.9	25.5	12.9	14.7	13.1	11.5	13.10
K. Pivk in L. Nagode	KP in LN	50	30	20	68.15	16.3	27.6	6.43	18.15	13.7	7.6	13.15
Jan C Hudoklin	JCH	53.5	11.5	2.5	49.09	28.58	30	−12.7	4.41	17.08	27.5	16.33
M. Oblak	MO	-	-	-	70.97	35	27	9.18	-	-	-	-

Zmagovalec

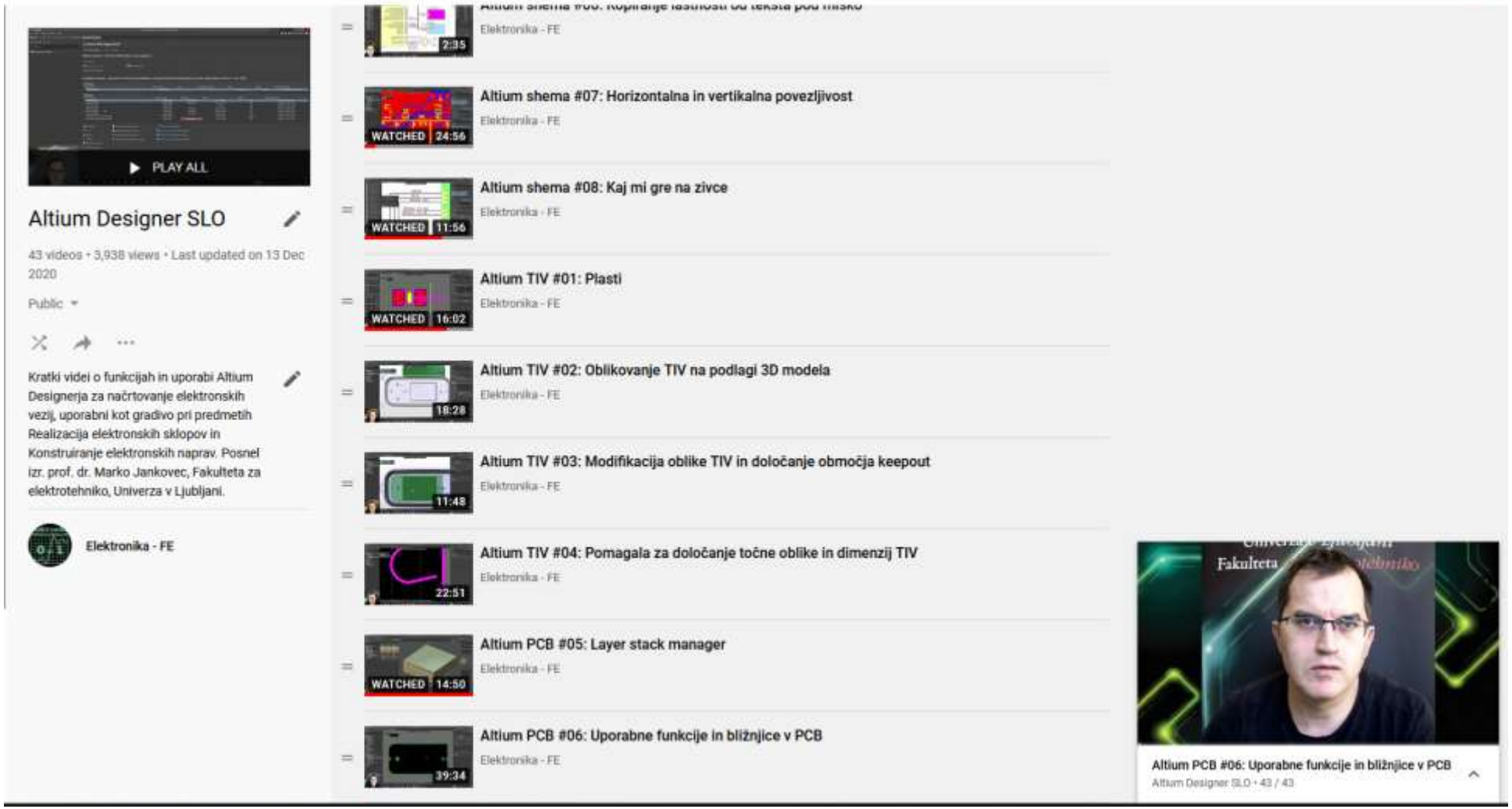
Luka Pogačnik



LP	50.7	25	25	48.5	23.3	28.14	-6	2.2	1.7	3.14	2.35

Youtube Elektronika FE: Altium designer tutorial

Vaš kanal
Elektronika - FE



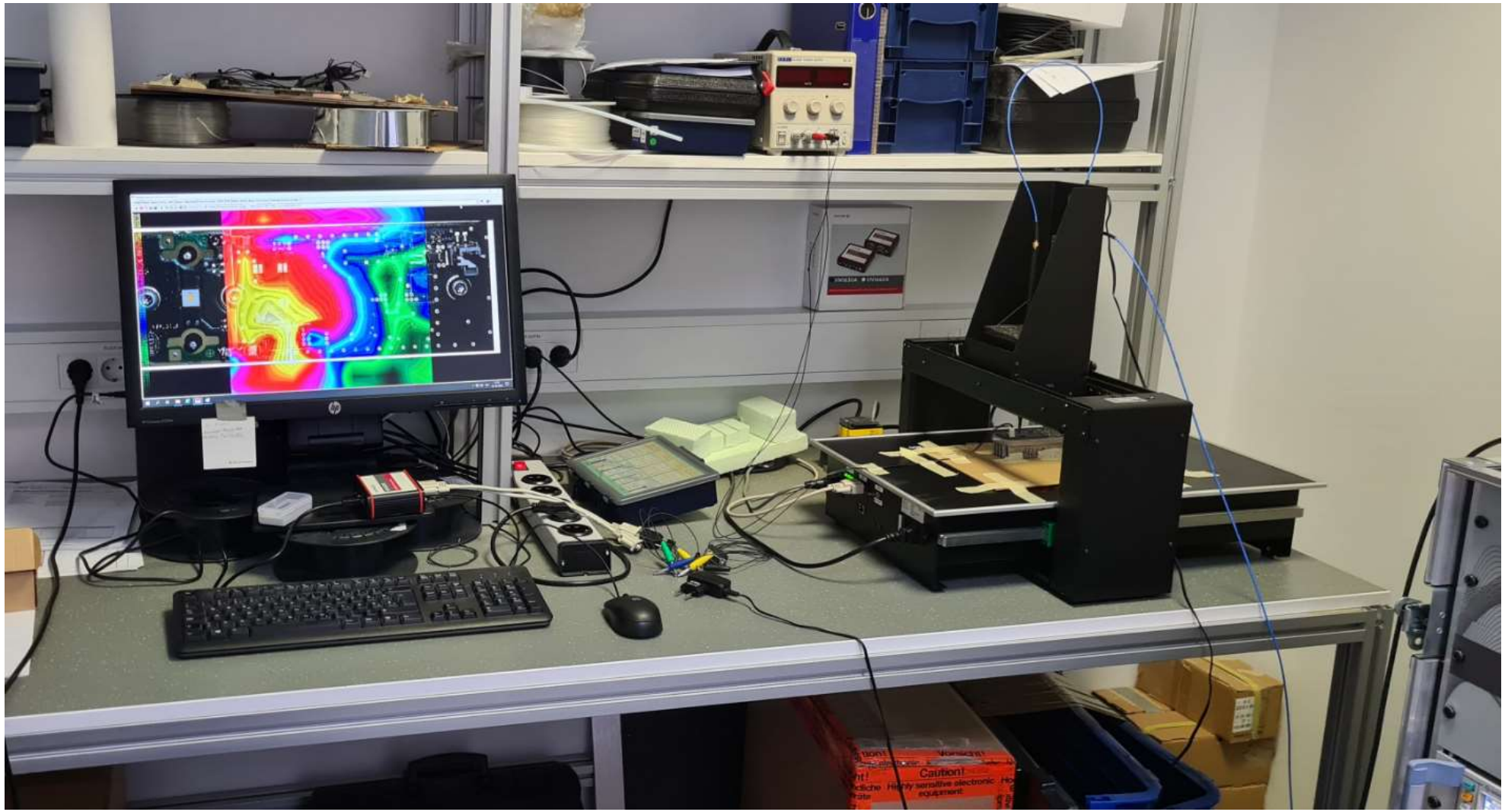
https://www.youtube.com/playlist?list=PLqo30NsEJyY0CWY3p9cGxnvCJXejgsRGZ

Obisk Hella Saturnus Slovenija

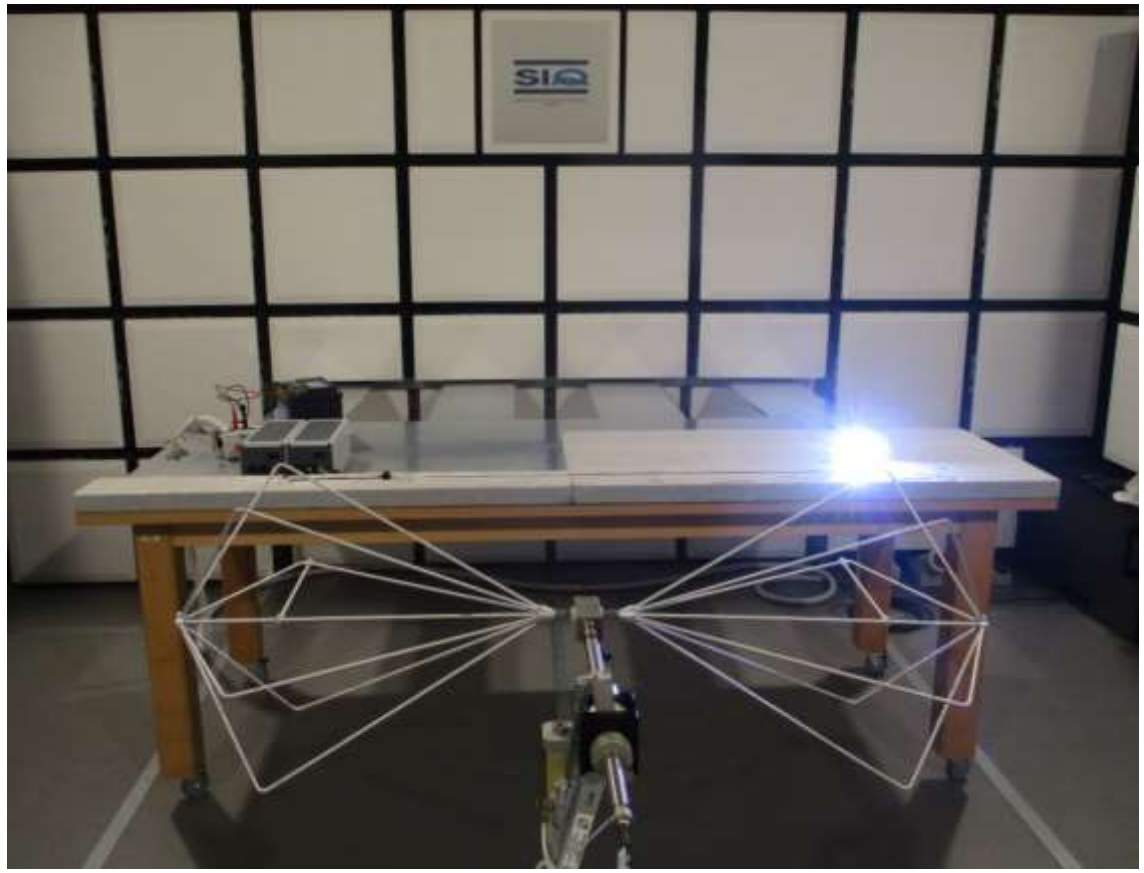
Obisk Hella Saturnus Slovenija

Oddani izdelki

Meritve na Hella Saturnus Slovenija



Meritve na SIQ



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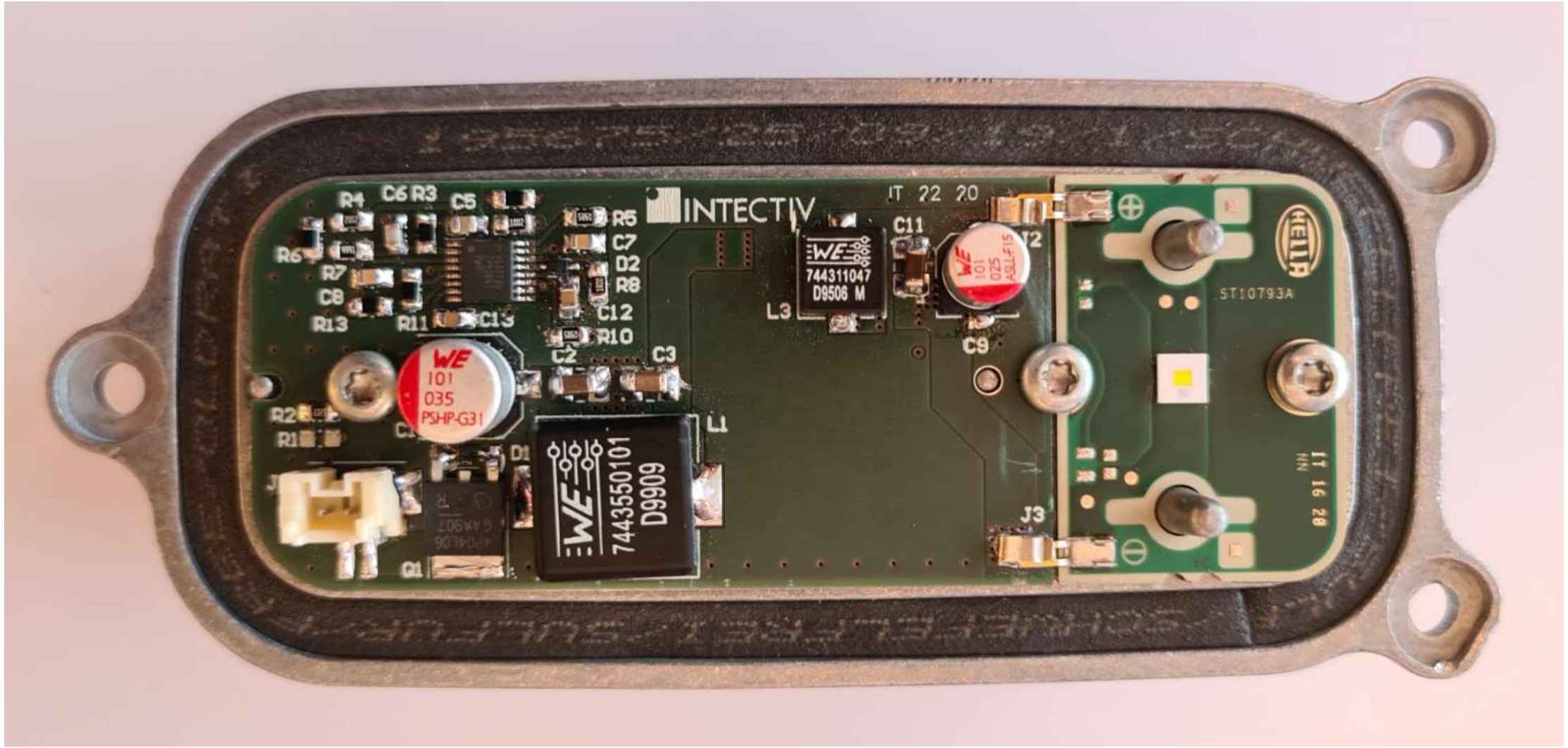
Predstavitev projektov

Kristan Pivk in Luka Nagode



Pivk in Nagode: Delovanje

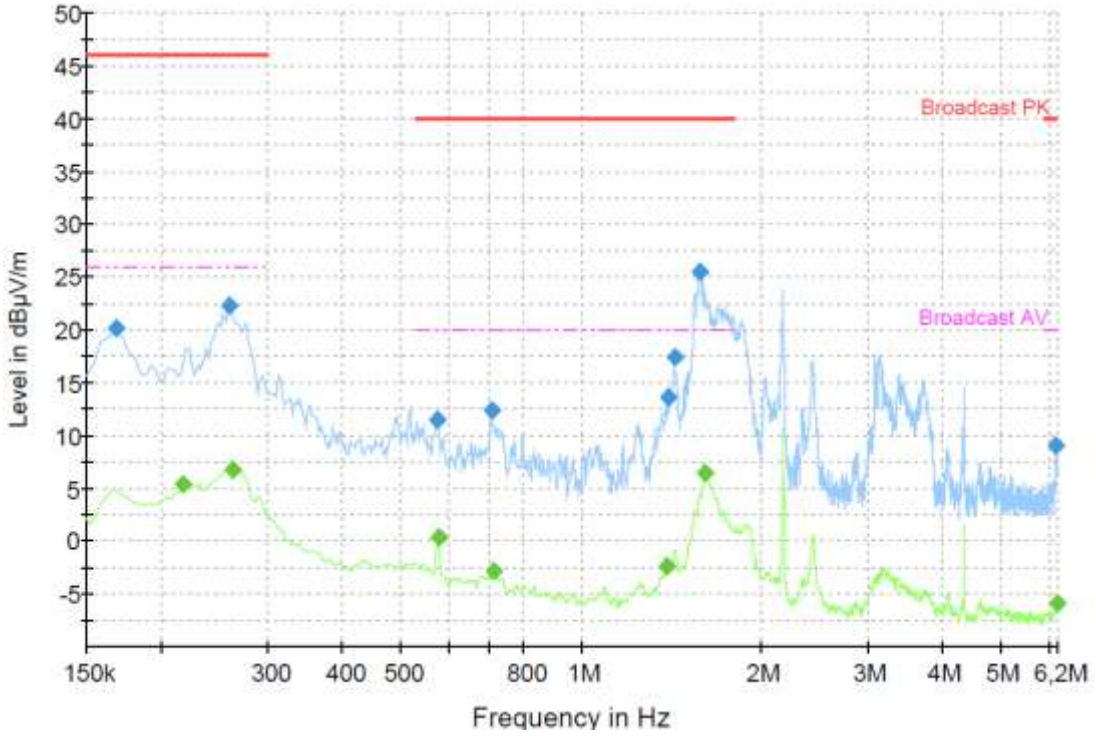
Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
7	18	1.1	13.5	14.85

Iout [A]	Uout [V]	Pout [W]	n [%]
2.8	2.2	11	74.1

Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
7500	0	7.5	3800

Pivk in Nagode: RE 150 kHz-30 MHz

Broadcast

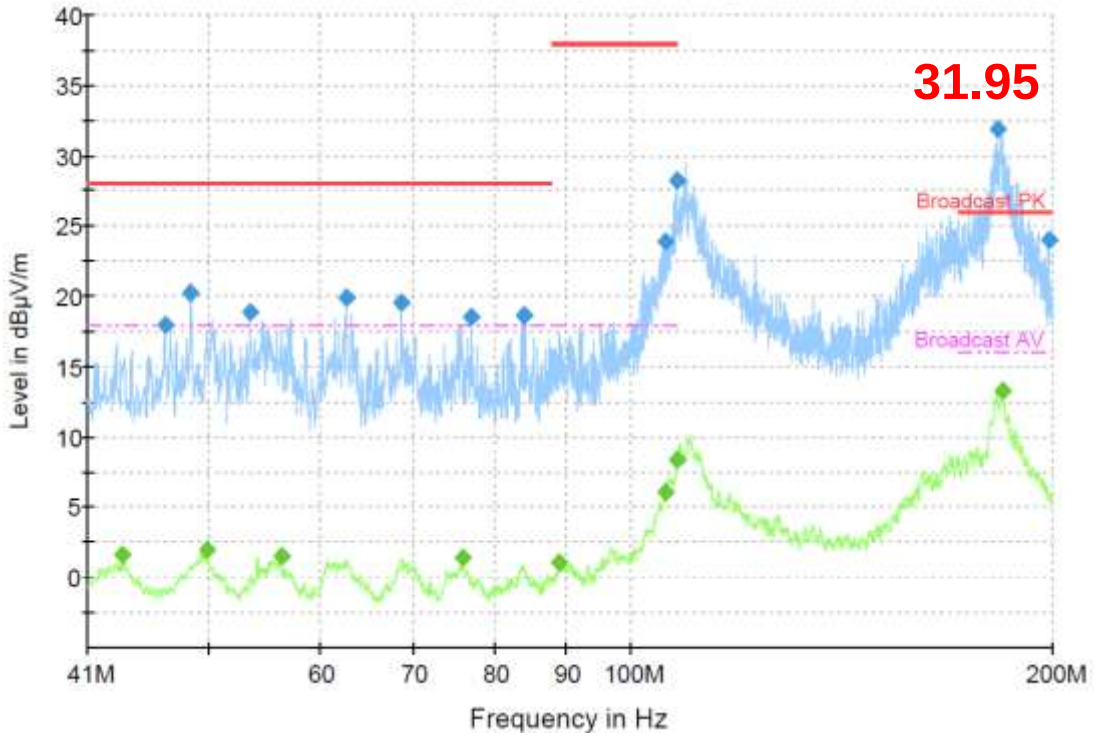


Mobile

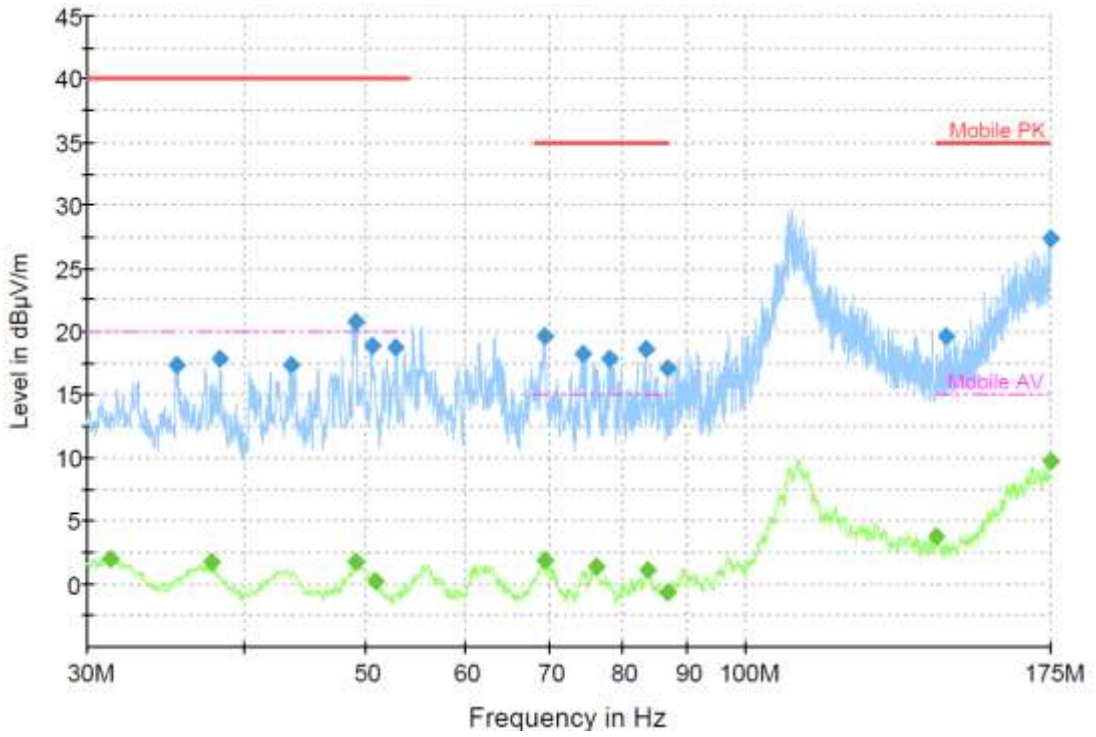
Pivk in Nagode: RE 30 MHz – 200 MHz

Broadcast

Razred 4

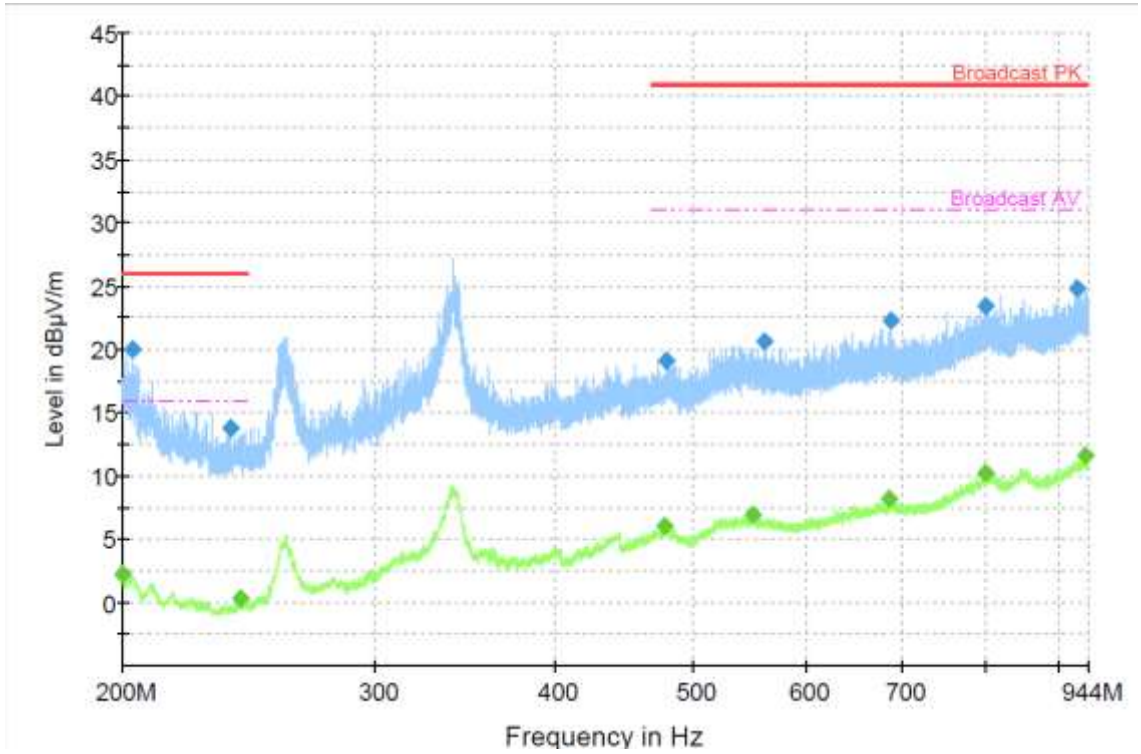


Mobile

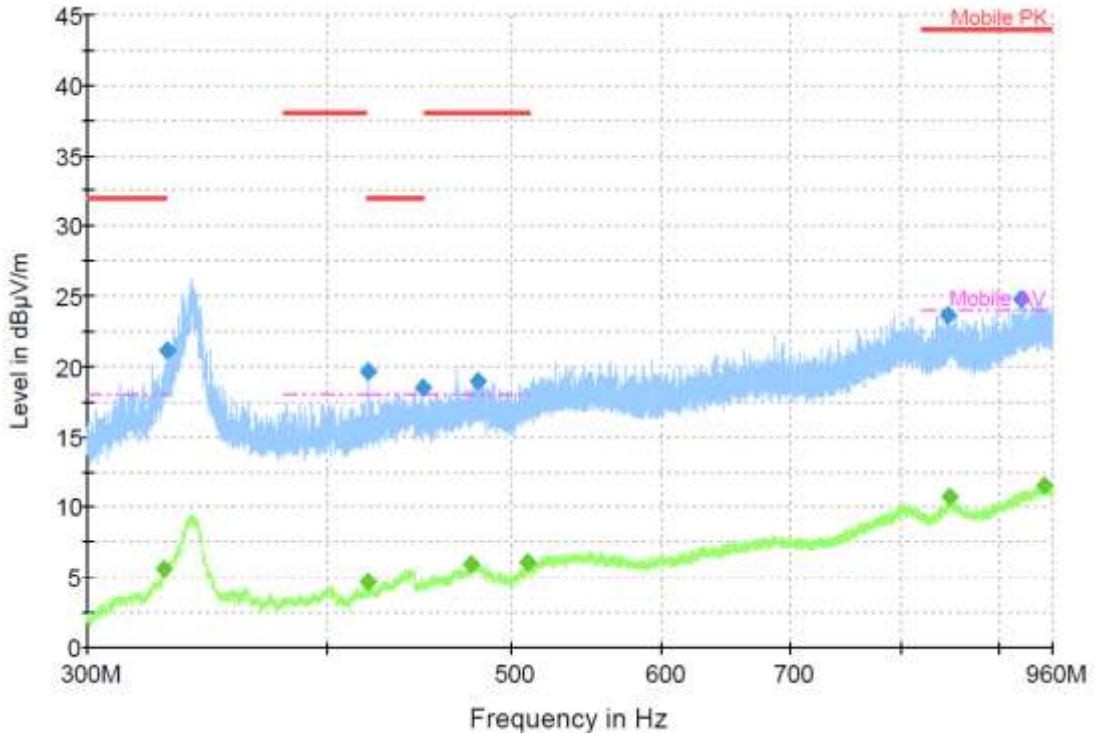


Pivk in Nagode: RE 200 MHz – 1 GHz

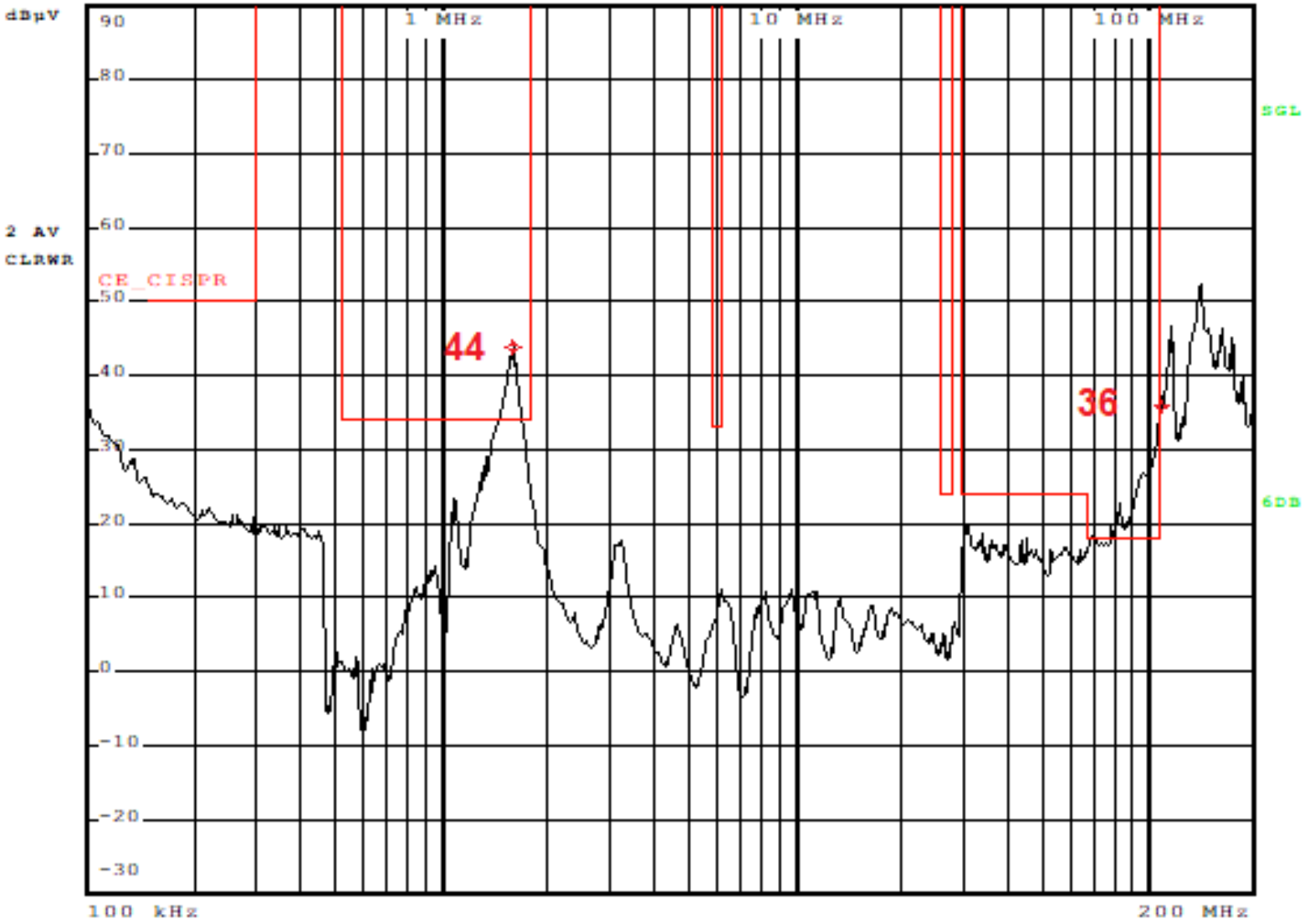
Broadcast



Mobile



Pivk in Nagode: CE



Razred 2

Pivk in Nagode: BOM

OZNAK	IME	CENA (€ / 1000 kos
L3	744311047 (wurth)	2.55
L1	7443550101 (wurth)	2.326
L2	744373965068 (wurth)	1.842
Q1	IPD85P04P4L-06	0.564
C9	875105345011 (ELKO D)	0.365
C4	885012209048	0.358
Q2	PSMN3R2-40YLDX	0.34
Q3	PSMN3R2-40YLDX	0.34
C2	885012208069	0.292
C3	885012208069	0.292
C10	885012208069	0.292
C11	885012208069	0.292
C1	865060445005 (ELKO F)	0.184
C5	885012107018	0.12
C12	885012107016	0.11
C6	885012007040	0.046
C7	885012207098	0.032
C8	885012207098	0.032
C13	885012207098	0.032
Total		**10.409**

Bruno Čeferin #1

Bruno Čeferin #2

Čeferin: Delovanje

Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
7	18	1.86	13.5	25.11
8	18	1.82	13.5	24.57

Iout [A]	Uout [V]	Pout [W]	n [%]
5.74	3.67	21.0658	**83.9**
5.9	3.42	20.178	**82.1**

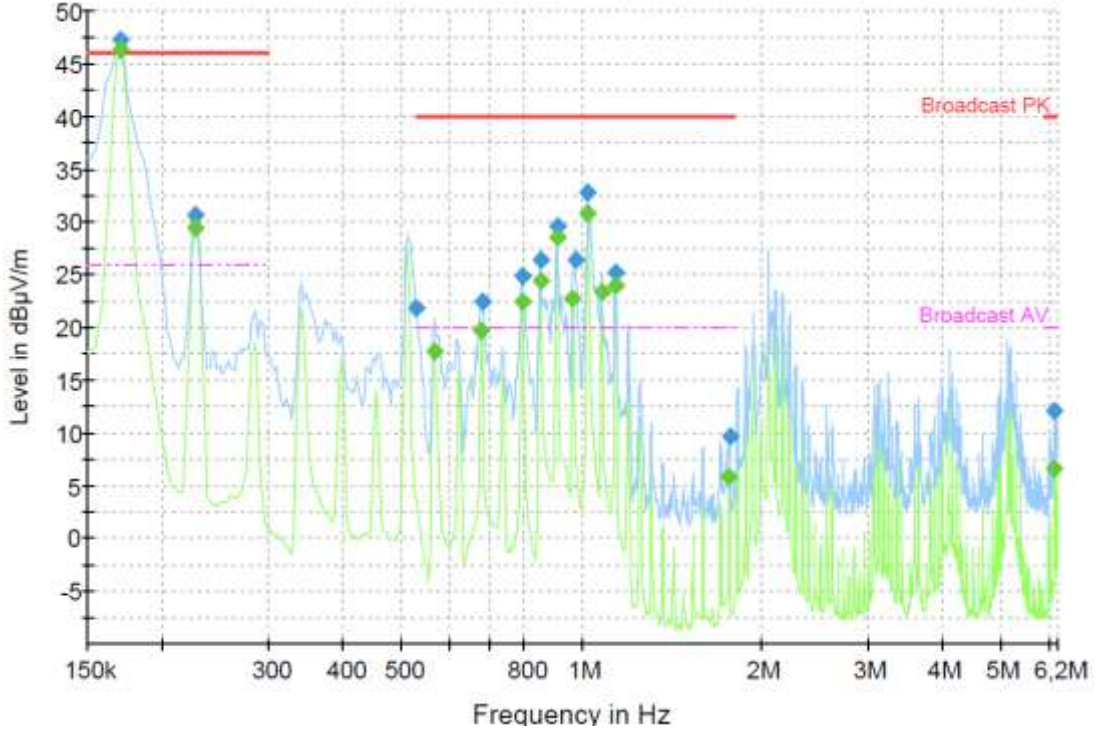
Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
480	5.44	5.92	160
180 **	**		30

Čeferin #1: RE 150 kHz-30 MHz

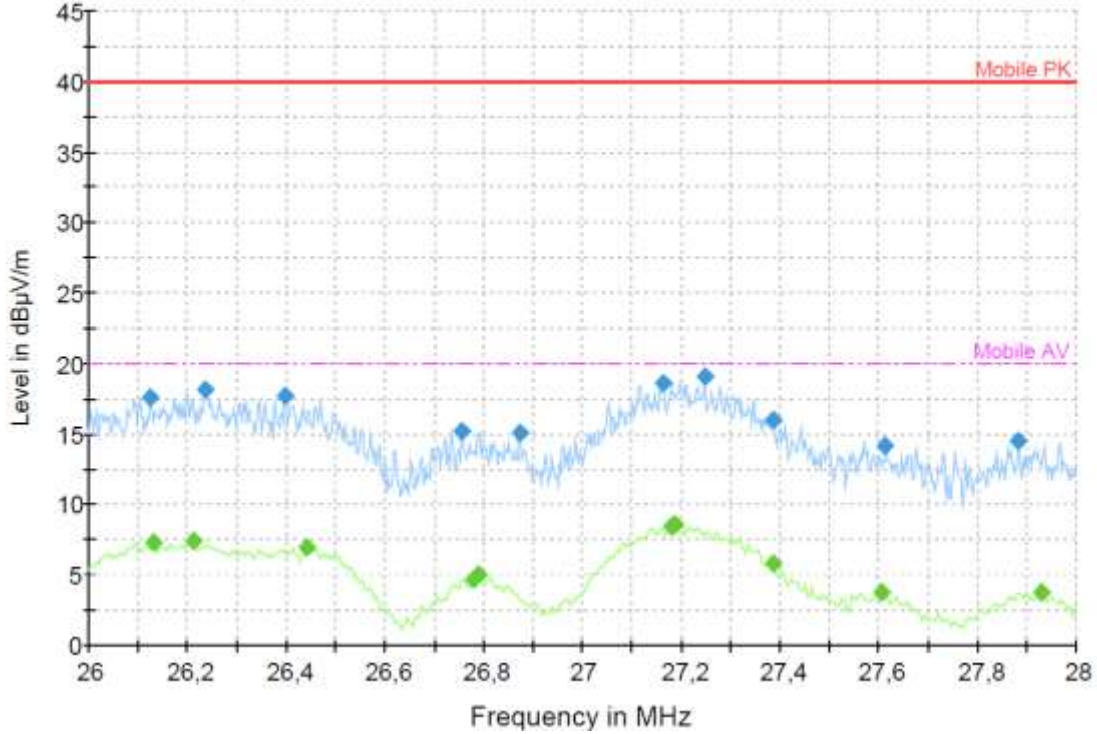
Broadcast

46.30

Razred 2

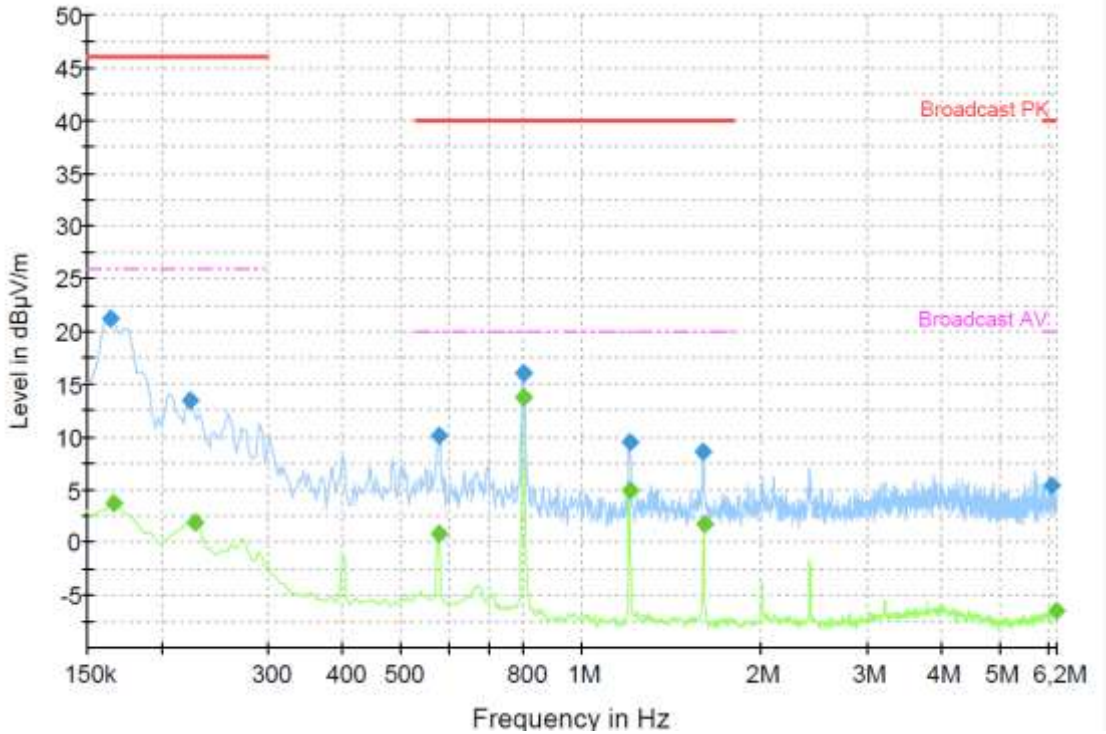


Mobile

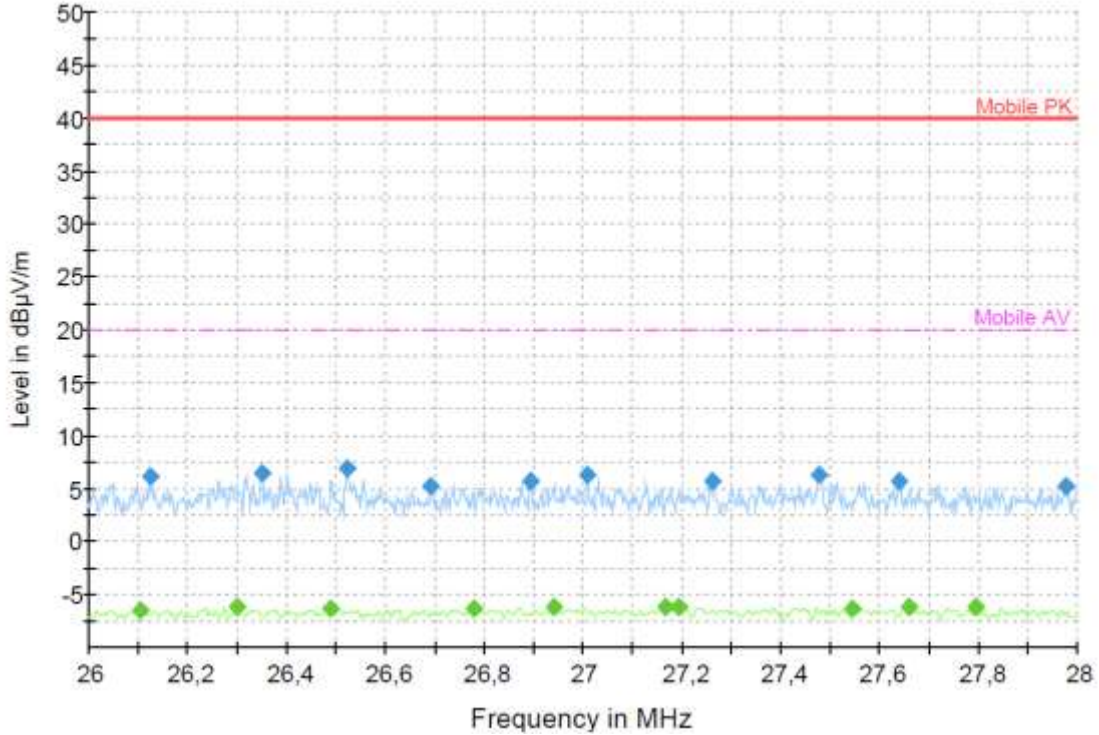


Čeferin #2: RE 150 kHz-30 MHz

Broadcast

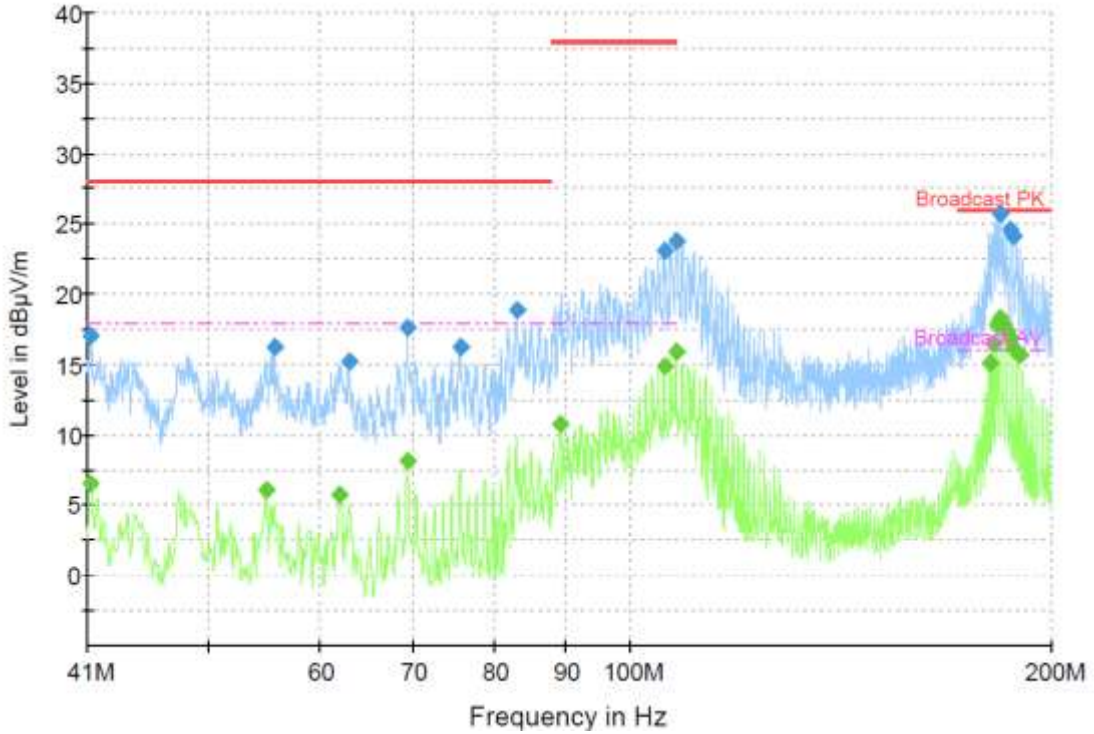


Mobile

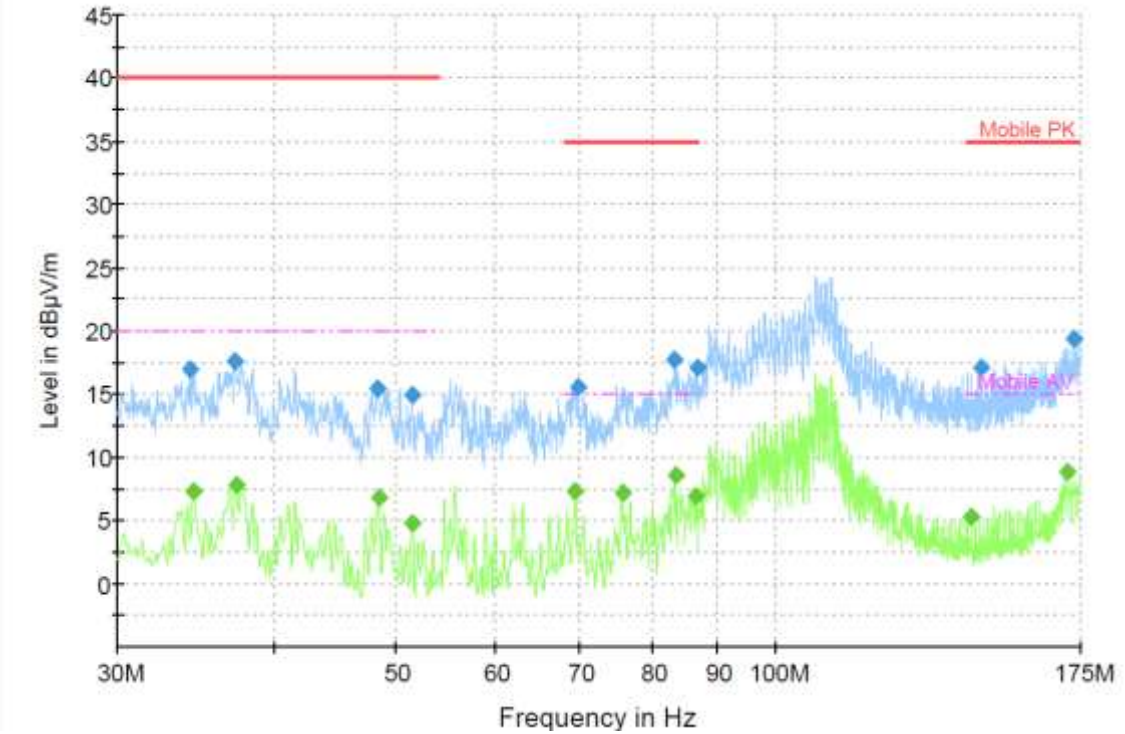


Čeferin #1: RE 30 MHz – 200 MHz

Broadcast



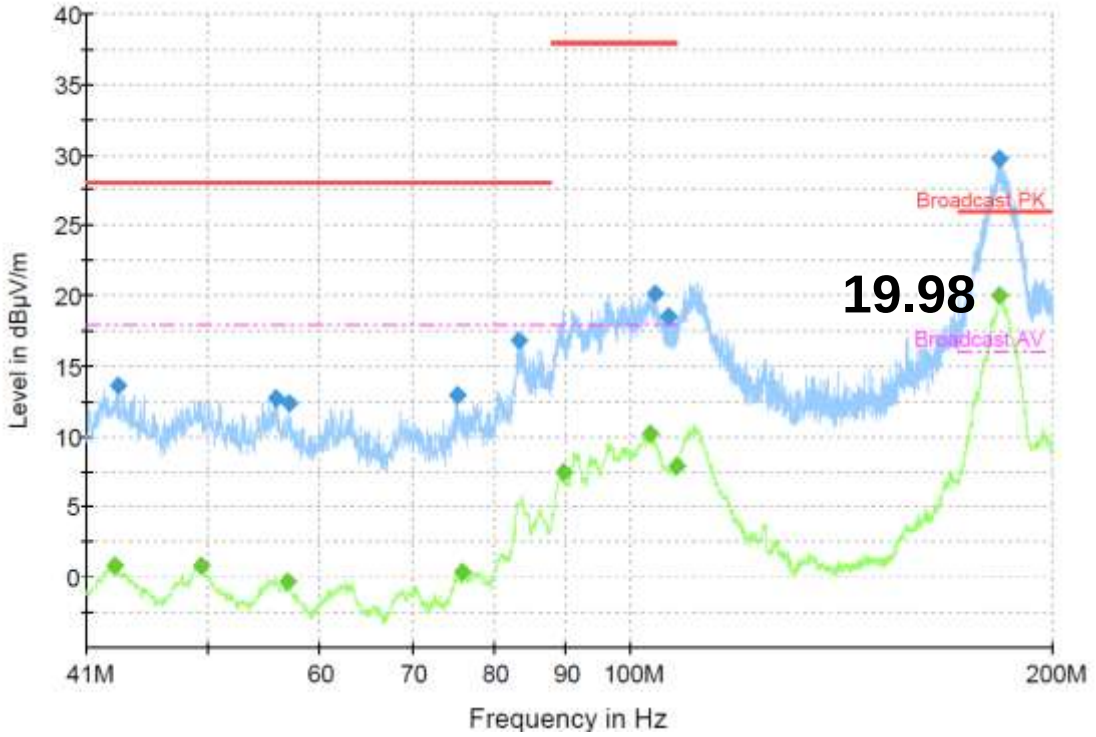
Mobile



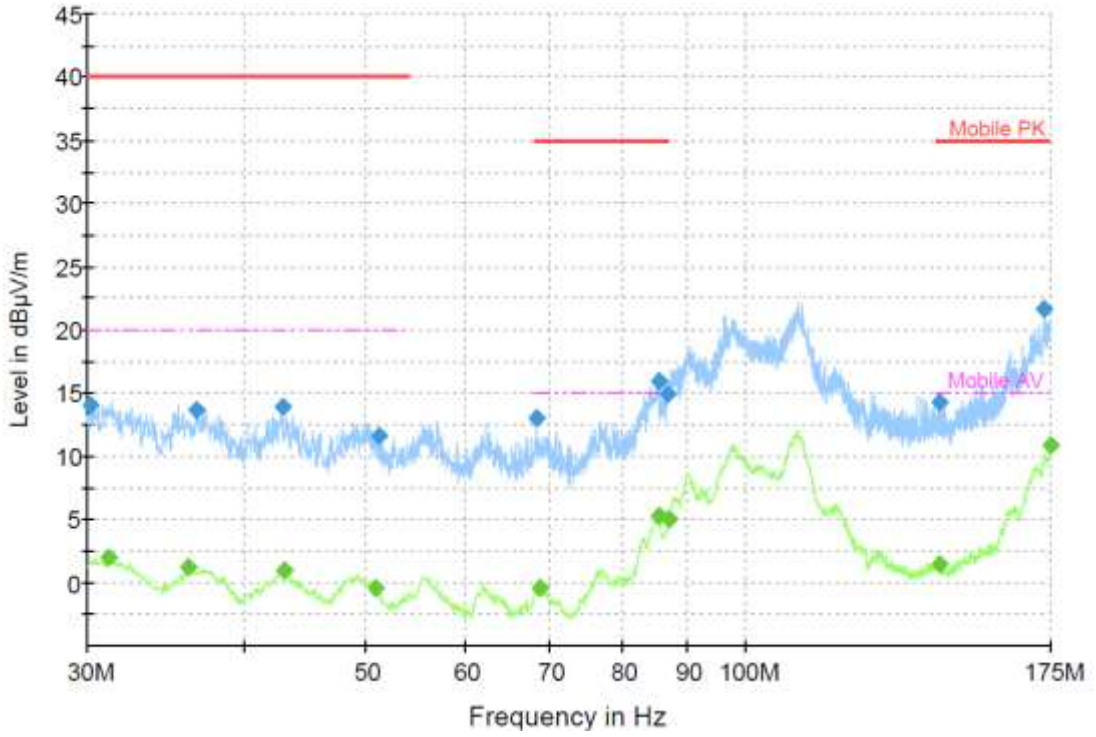
Čeferin #2 : RE 30 MHz – 200 MHz

Broadcast

Razred 4

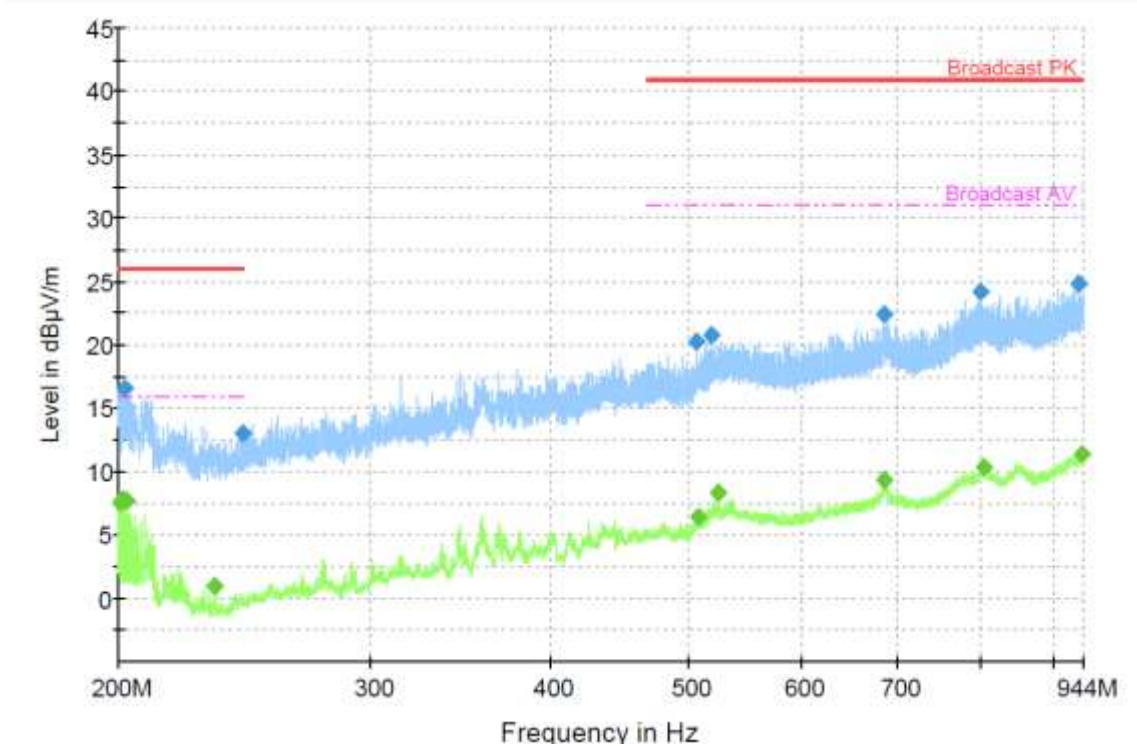


Mobile

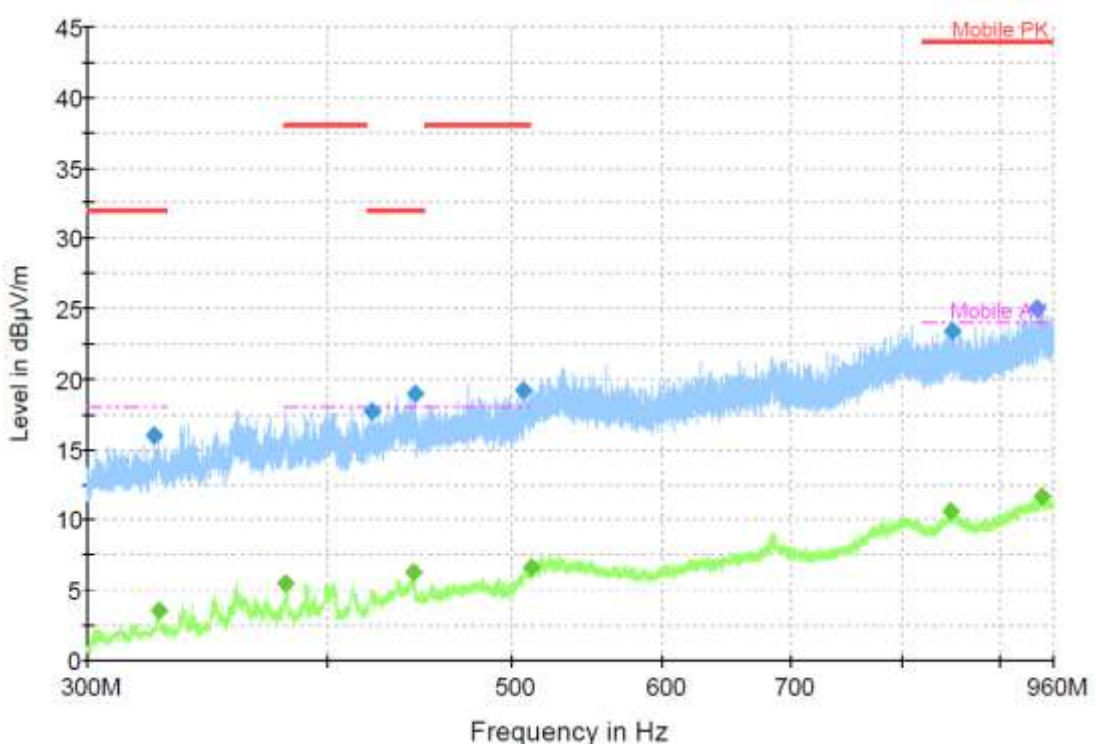


Čeferin #1: RE 200 MHz – 1 GHz

Broadcast

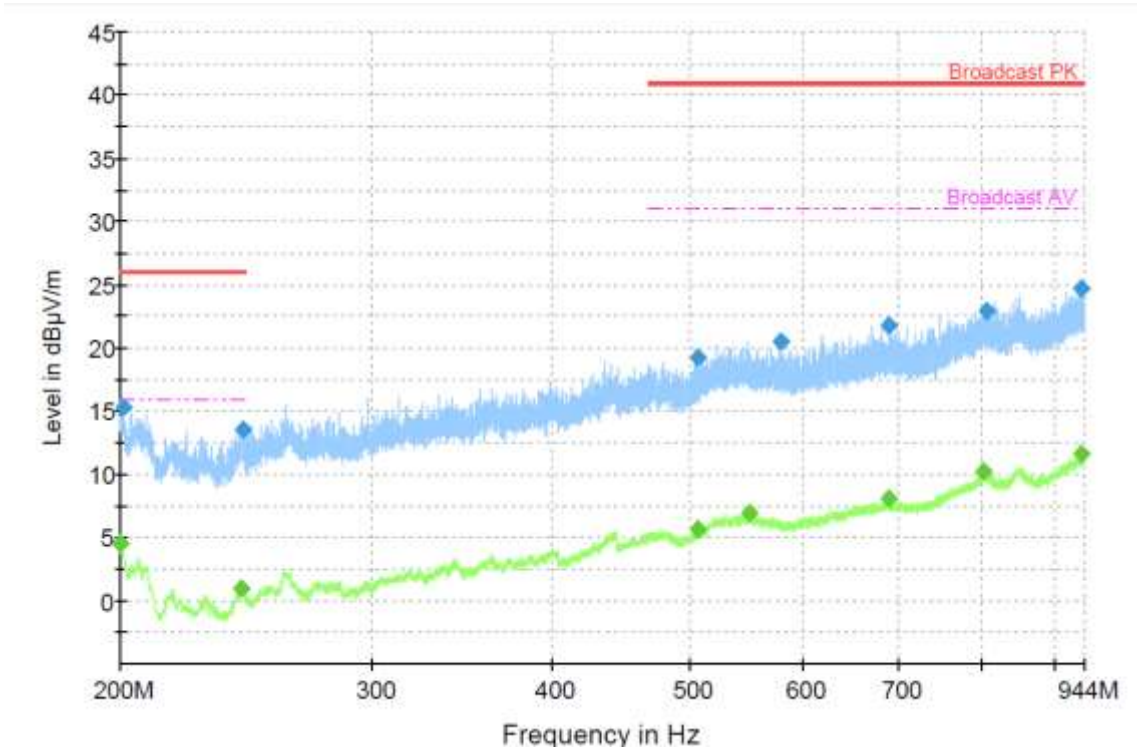


Mobile

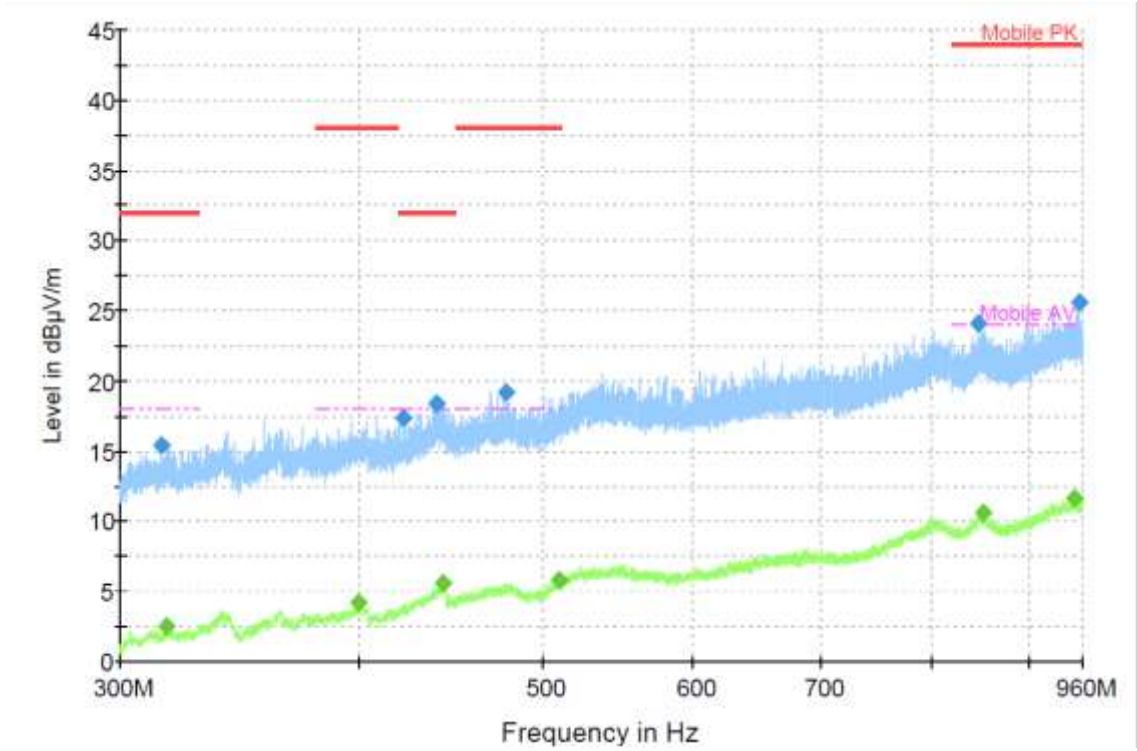


Čeferin #2 : RE 200 MHz – 1 GHz

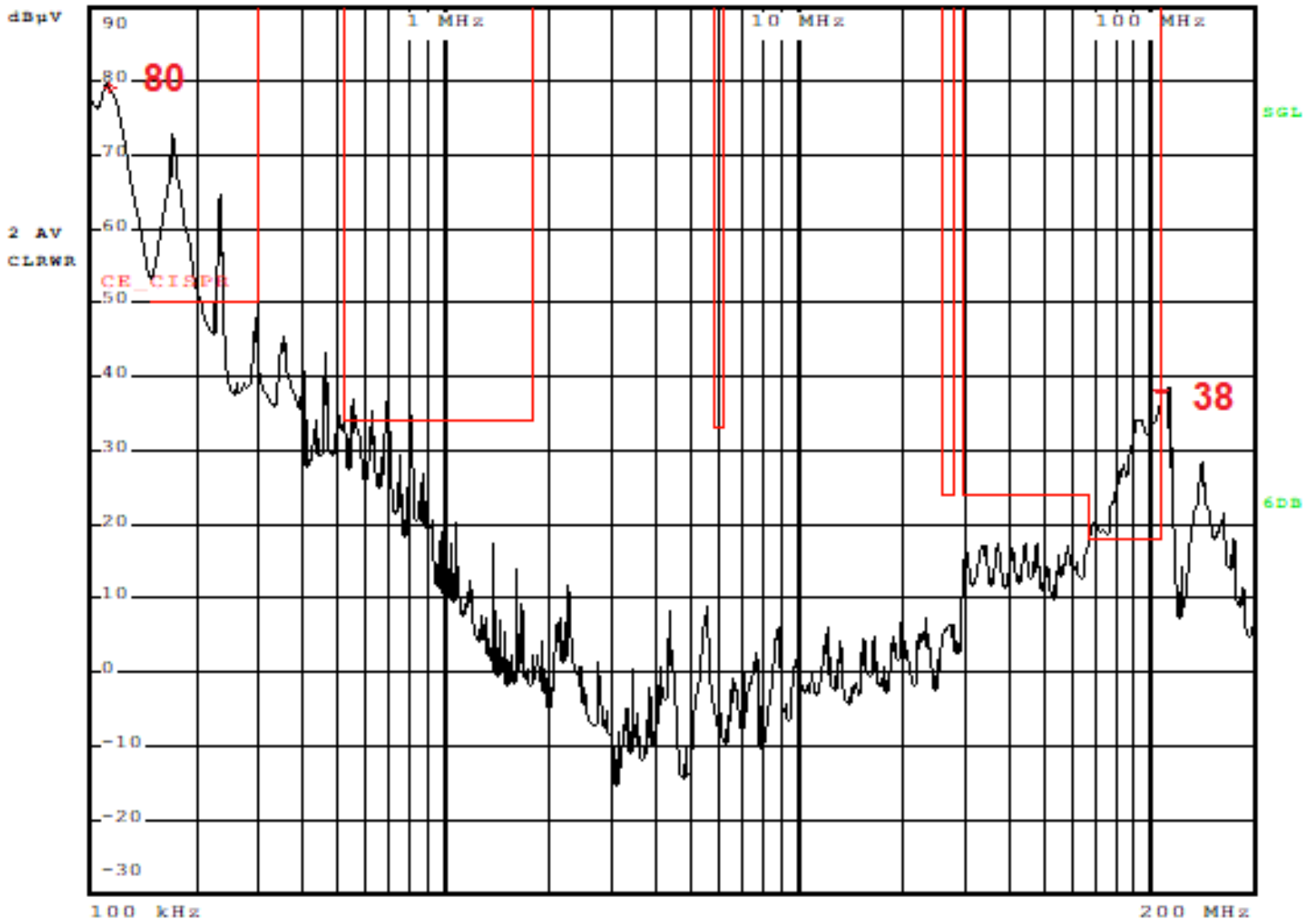
Broadcast



Mobile

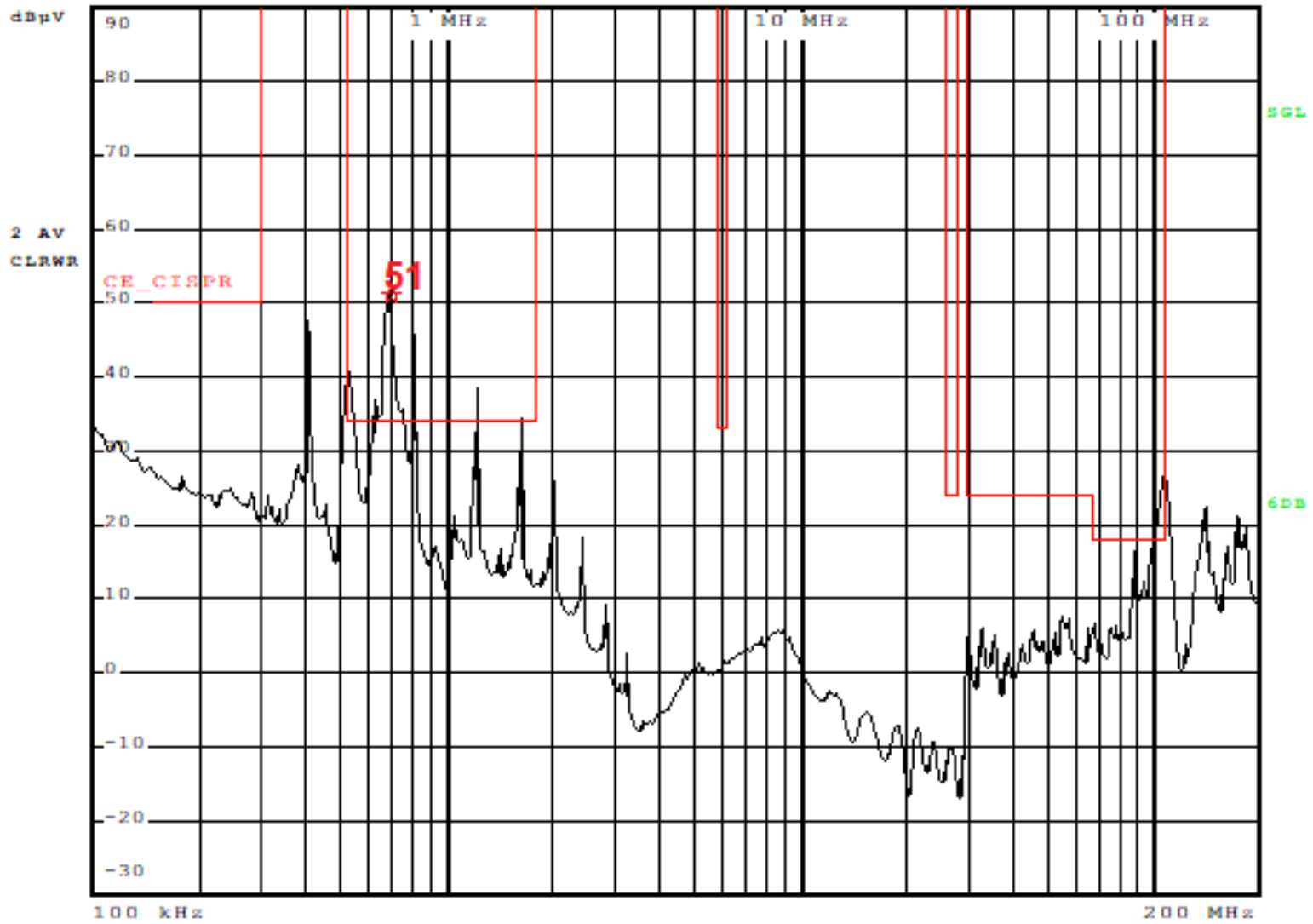


Čeferin #1: CE



Razred 2

Čeferin #2 : CE



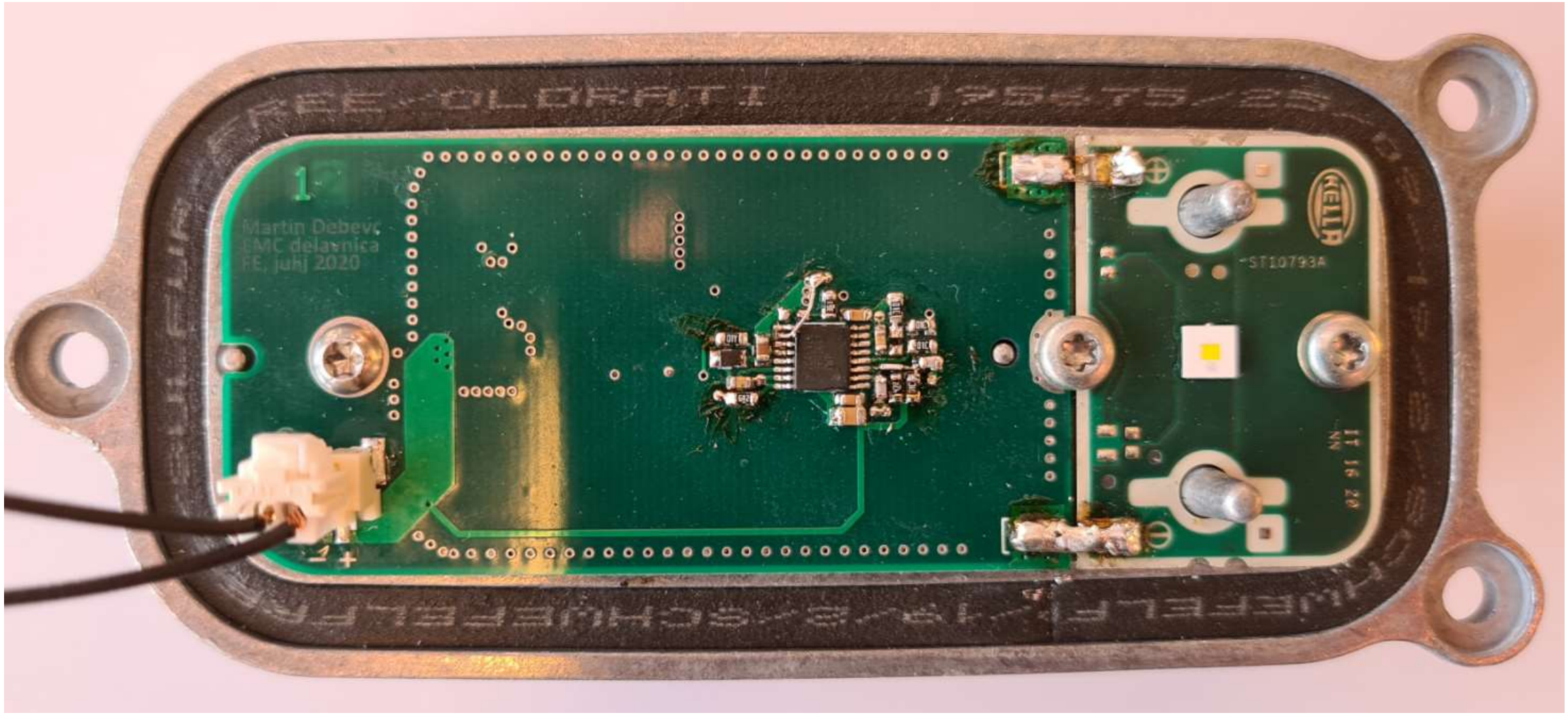
Razred 2

Čeferin: BOM

oznaka	opis	vrednost	količina	octopart cena/100	cena material
C4, C5, C6, C8, C14, C16	cer	10uF, 50V	6	0.15 €	0.87 €
FB1	742792114	50Ohm, 3A	1	0.16 €	0.16 €
L1	WE-PD2SA SMD Power Inductor, size 7850	2.7uH, 4.35A	1	1.26 €	1.26 €
L2	7427932	98Ohm, 18A	1	0.51 €	0.51 €
L3	SMT Flat Wire High Current Inductor WE-HCI	82 uH, 7 A	1	4.68 €	4.68 €
Q1, Q2	nmos	IRLR8726TRPBF	2	0.13 €	0.26 €
Q3	pmos	DMP3028LK3-13	1	0.18 €	0.18 €
/	elko	100u, 25V	2	0.02 €	0.03 €
Total					**7.95 €**

oznaka	opis	vrednost	količina	octopart cena/100	cena material
C4, C5, C6, C8, C14, C16	cer	4.7uF, 50V	6	0.10 €	0.58 €
FB1	742792114	50Ohm, 3A	1	0.16 €	0.16 €
FB2	7427932	98Ohm, 18A	1	0.51 €	0.51 €
L1	7443551221	22uH, 6A	1	2.31 €	2.31 €
L3	744373965100	10uH, 8.8A	1	1.83 €	1.83 €
Q1, Q2	nmos	IRLR8726TRPBF	2	0.13 €	0.26 €
Q3	pmos	DMP3028LK3-13	1	0.18 €	0.18 €
/	elko	100u, 25V	1	0.02 €	0.02 €
Total					**5.84 €**

Martin Debevc



Debevc: Delovanje

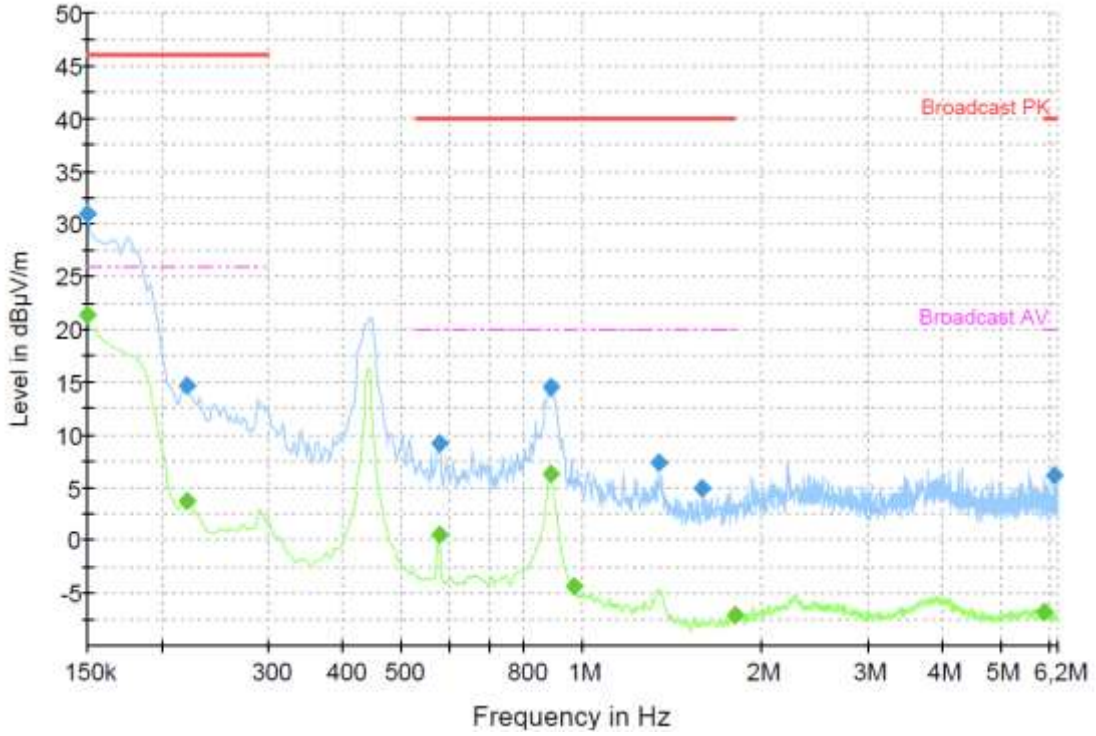
Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
6	18	1.78	13.5	24.03

Iout [A]	Uout [V]	Pout [W]	n [%]
6.44	3.56	22.9264	**95.4**

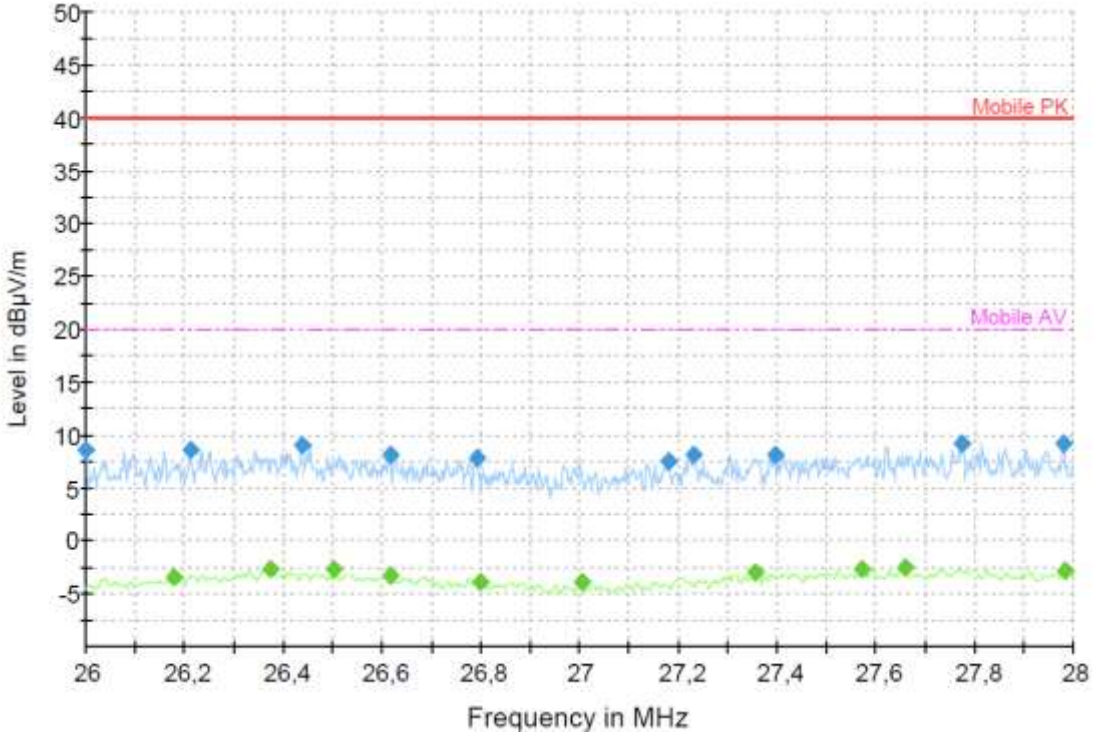
Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
140	**	**	30

Debevc: RE 150 kHz-30 MHz

Broadcast

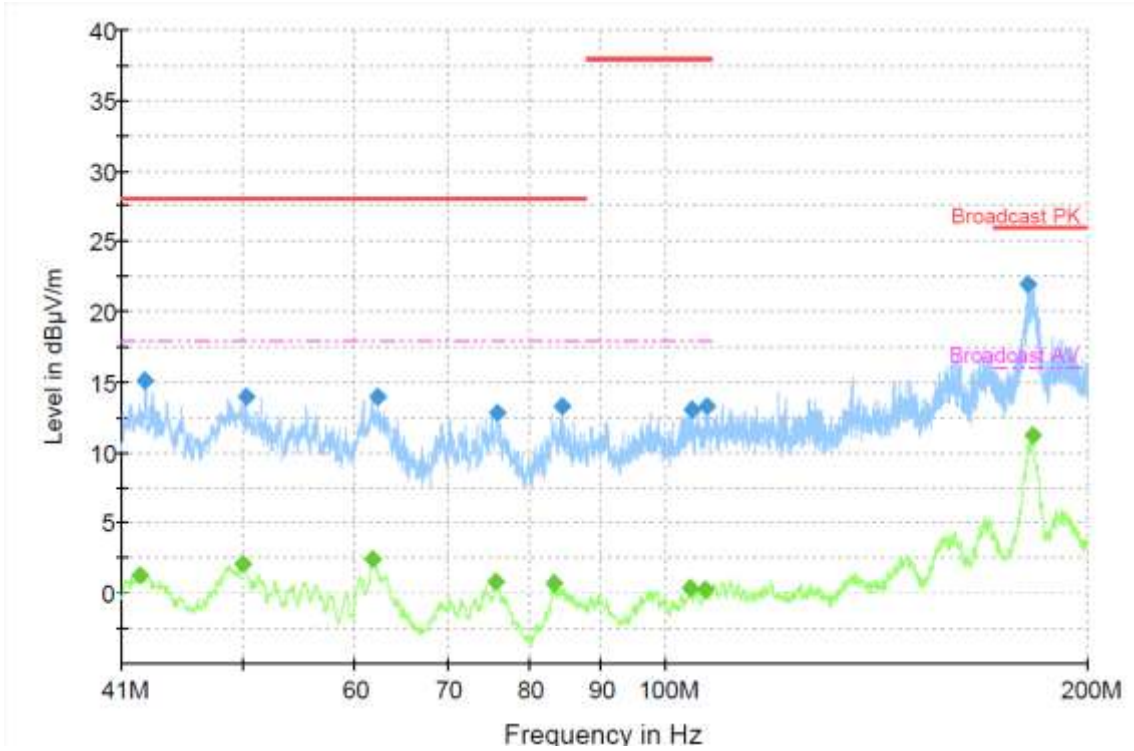


Mobile

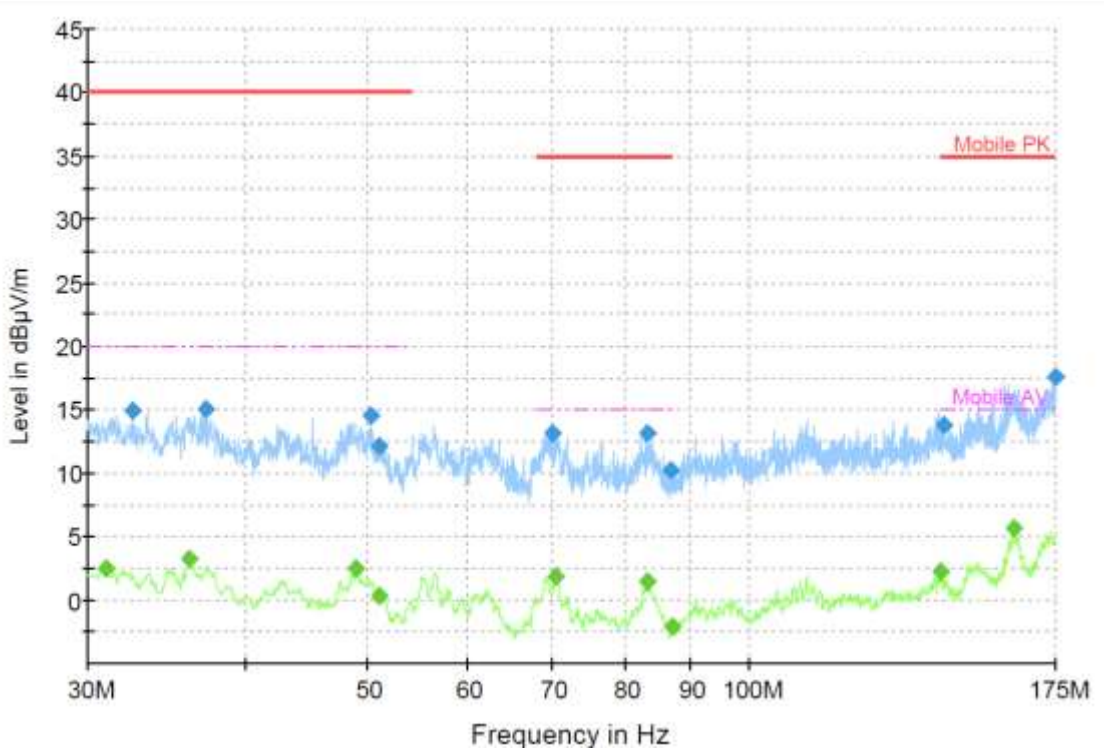


Debevc: RE 30 MHz – 200 MHz

Broadcast

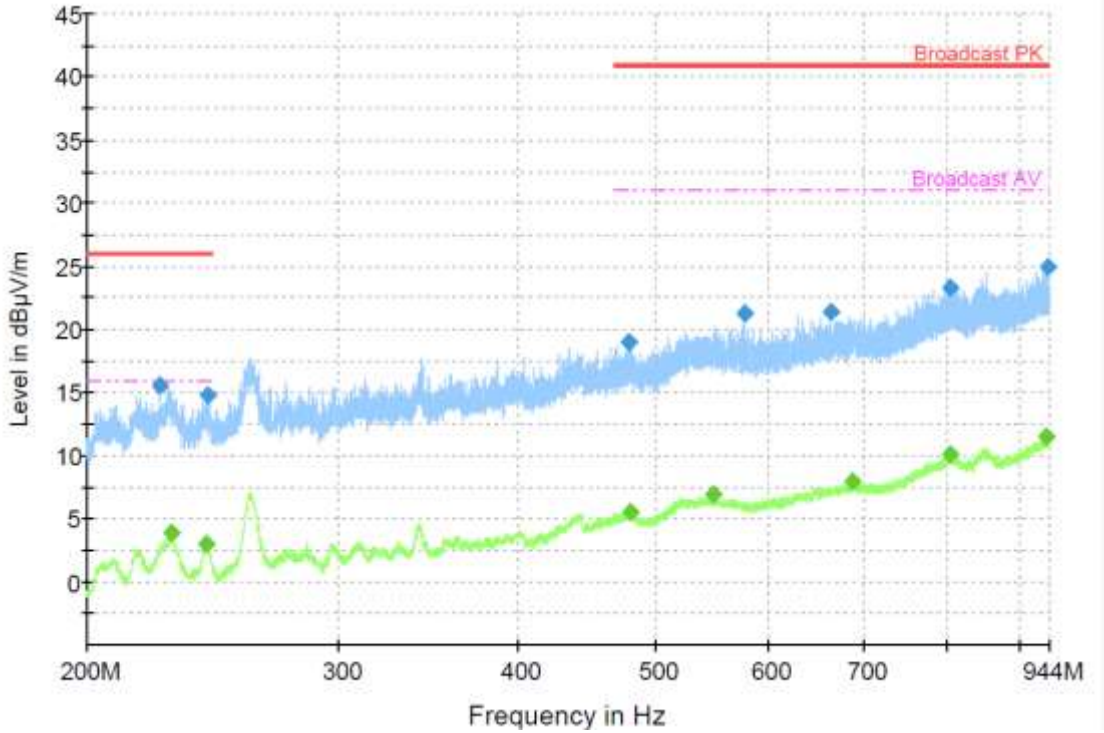


Mobile

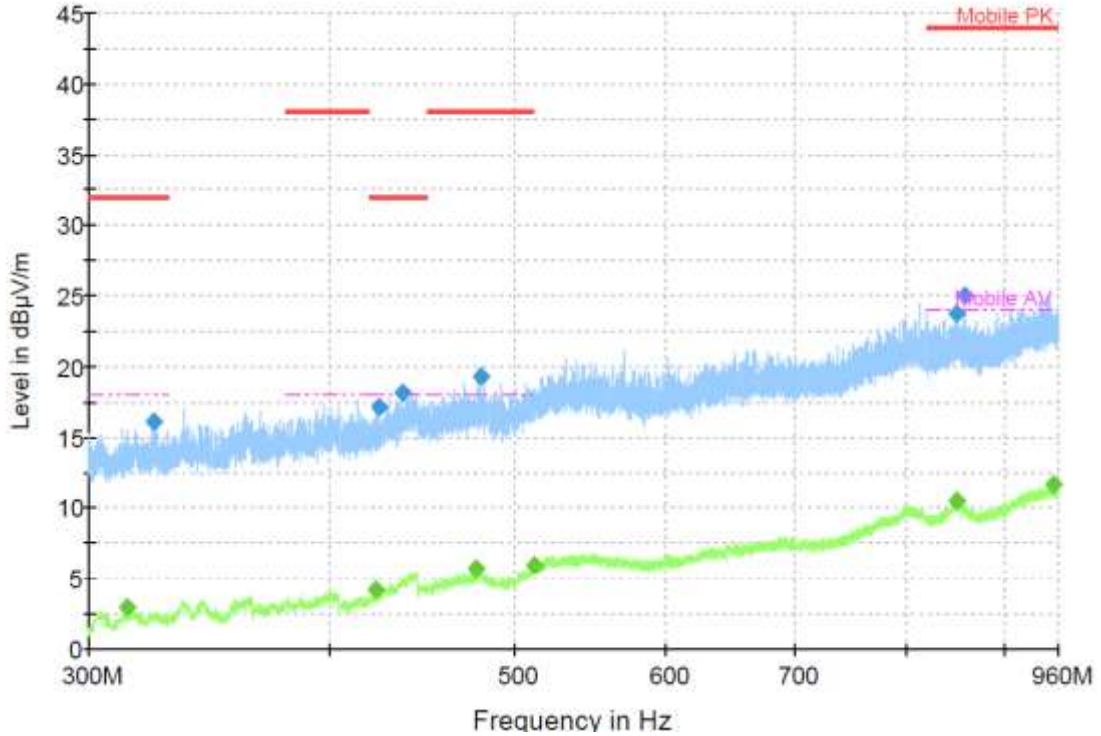


Debevc : RE 200 MHz – 1 GHz

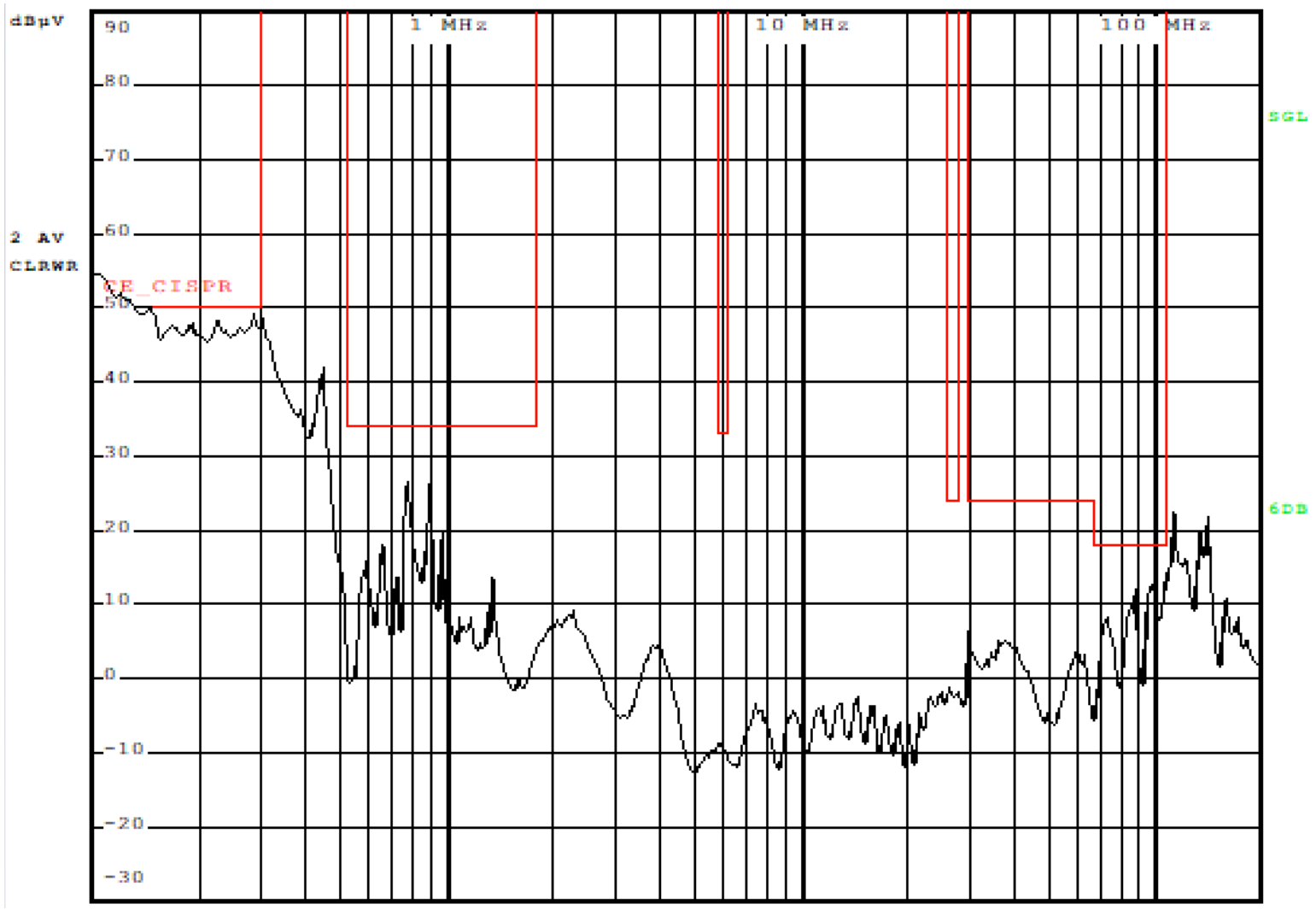
Broadcast



Mobile



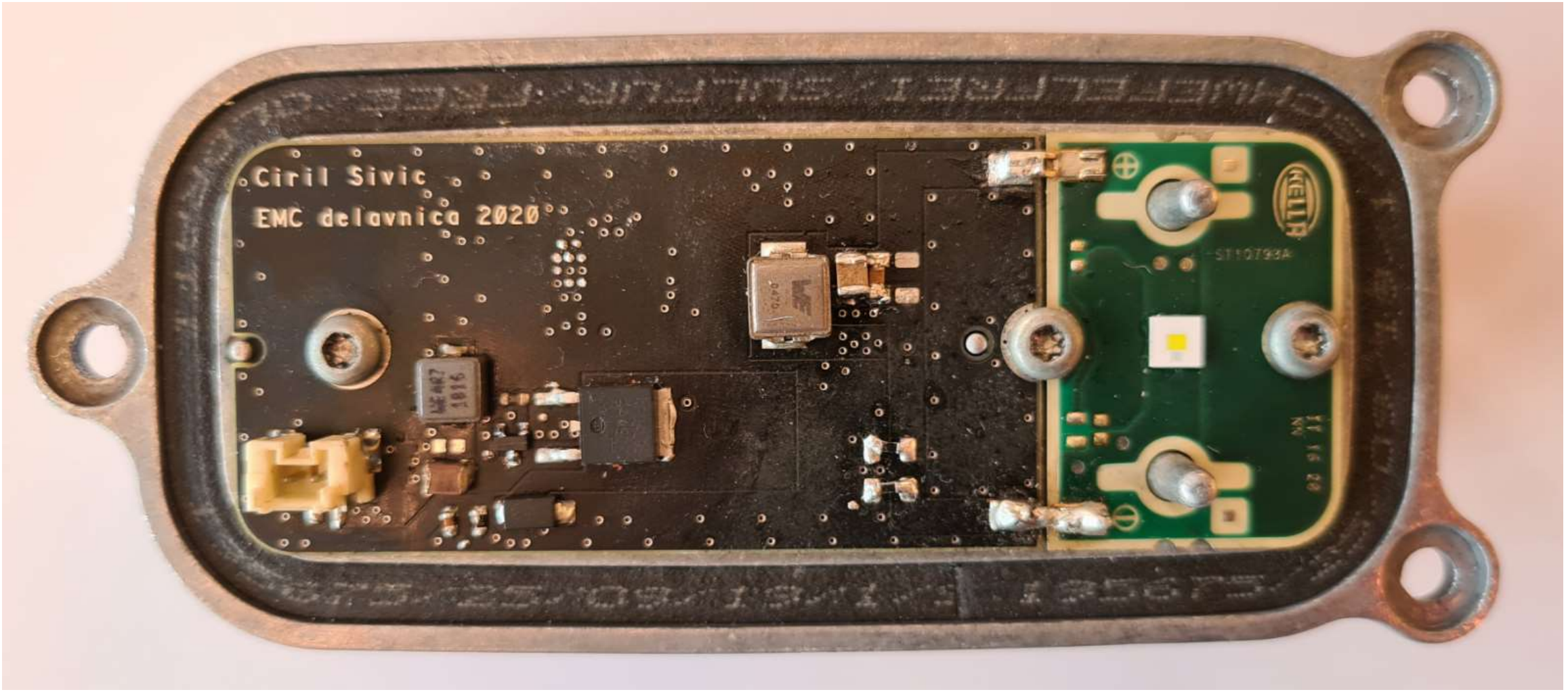
Debevc: CE


dBµV
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
1 MHz
10 MHz
100 MHz
2 AV
CLRWR
CE_CISPR
SGL
6DB

Debevc: BOM

designator	component	median octopart price per 1k pcs [USD]	#pcs	final price	Column1
FB1	742792515	0.108	1	0.108	
L1	744316150	1.774	1	1.774	
L2	744373965068	1.840	1	1.84	
Q1	BSC0921NDI	0.622	1	0.622	
C3, C4, C23	885012207103	0.127	3	0.381	1u
C5, C6	885012207098	0.032	2	0.064	100n
C24, C25	885012207074	0.076	2	0.152	470n
C2	885012209048	0.358	1	0.358	4u7
C20, C21, C15	885012209028	0.400	3	1.2	10u
C10, C11, C9	885012209028	0.400	3	1.2	10u izhodni
			SUM	7.699	USD
				6.52	EUR

Ciril Šivic



Šivic: Delovanje

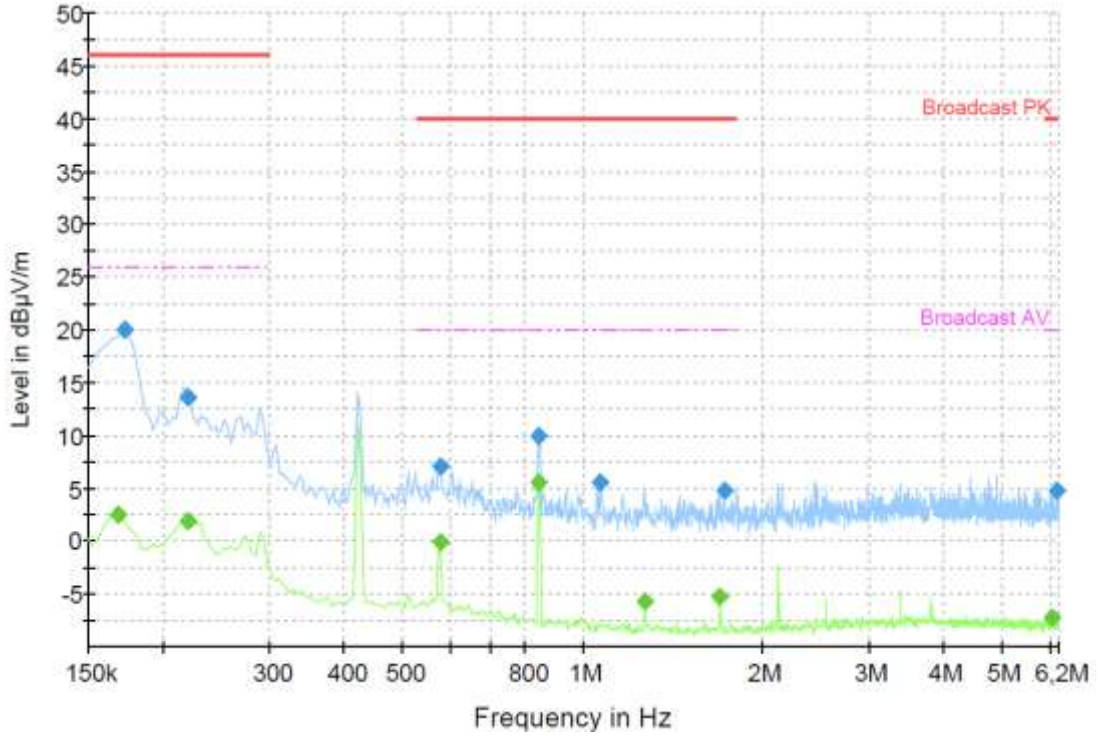
Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
8	18	1.74	13.5	23.49

Iout [A]	Uout [V]	Pout [W]	n [%]
5.98	3.44	20.5712	**87.6**

Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
140	**	**	30

Šivic: RE 150 kHz-30 MHz

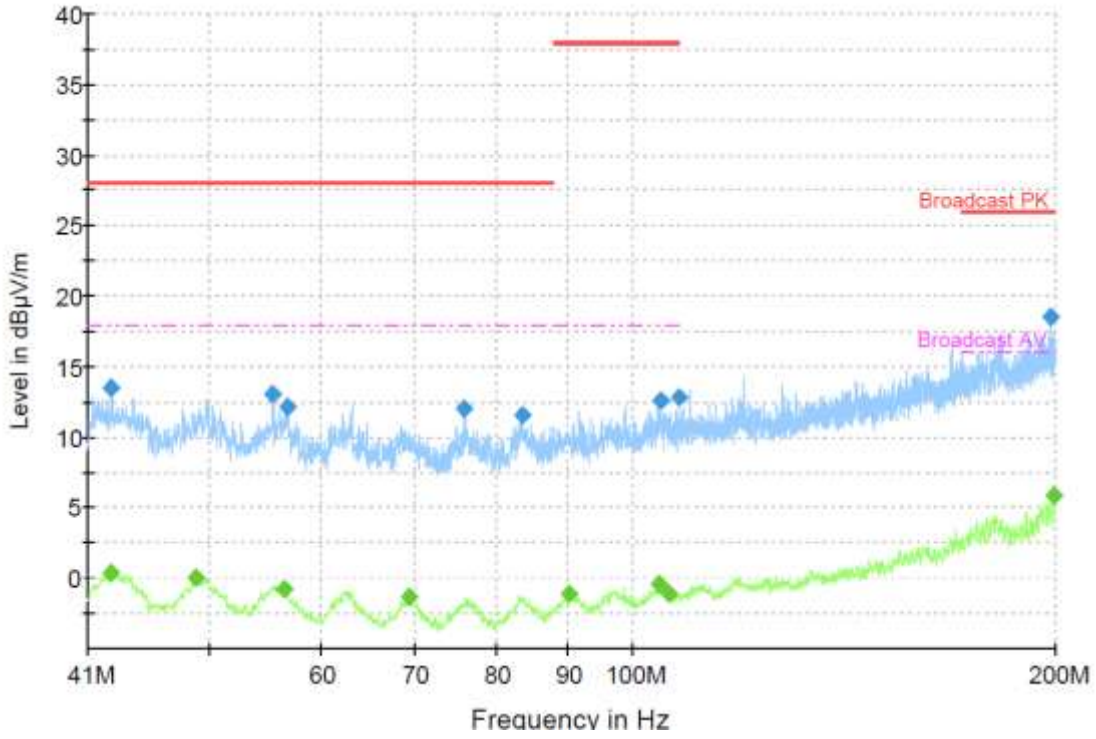
Broadcast



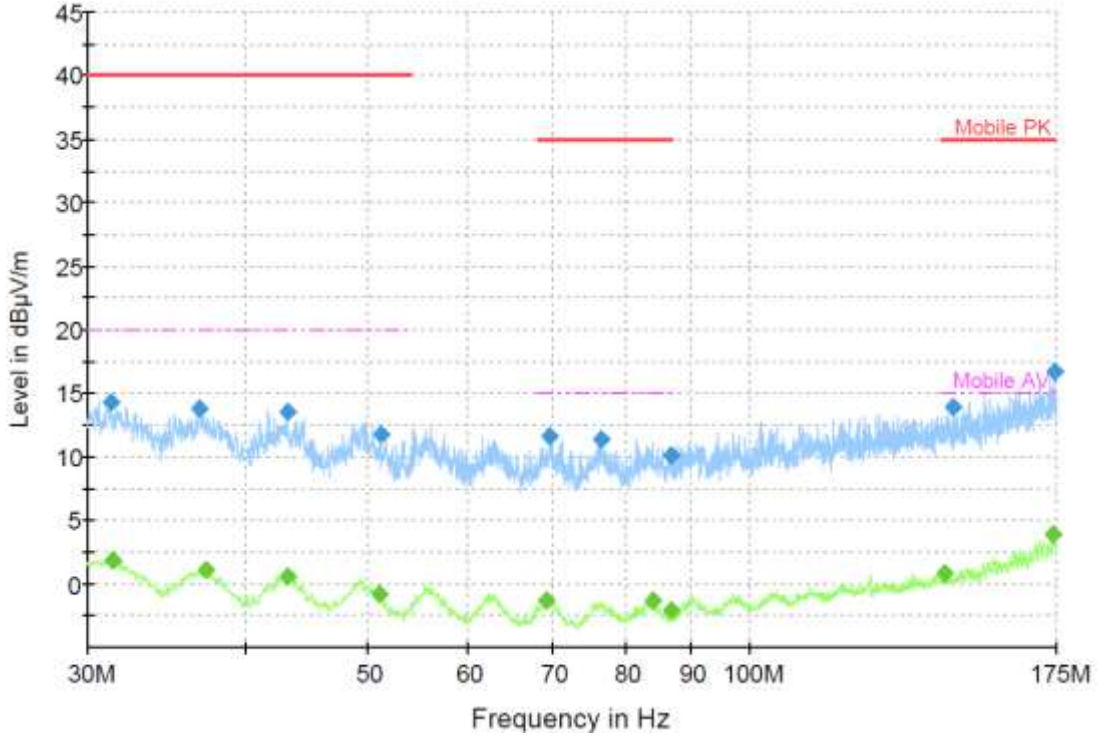
Mobile

Šivic: RE 30 MHz – 200 MHz

Broadcast

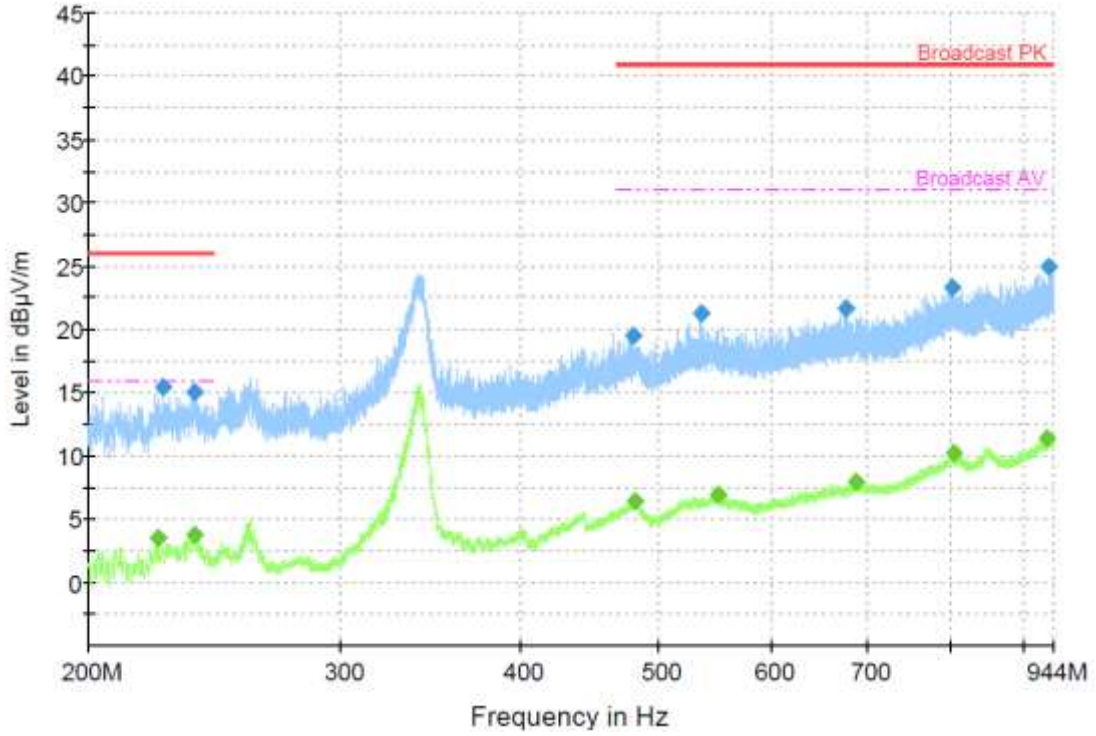


Mobile

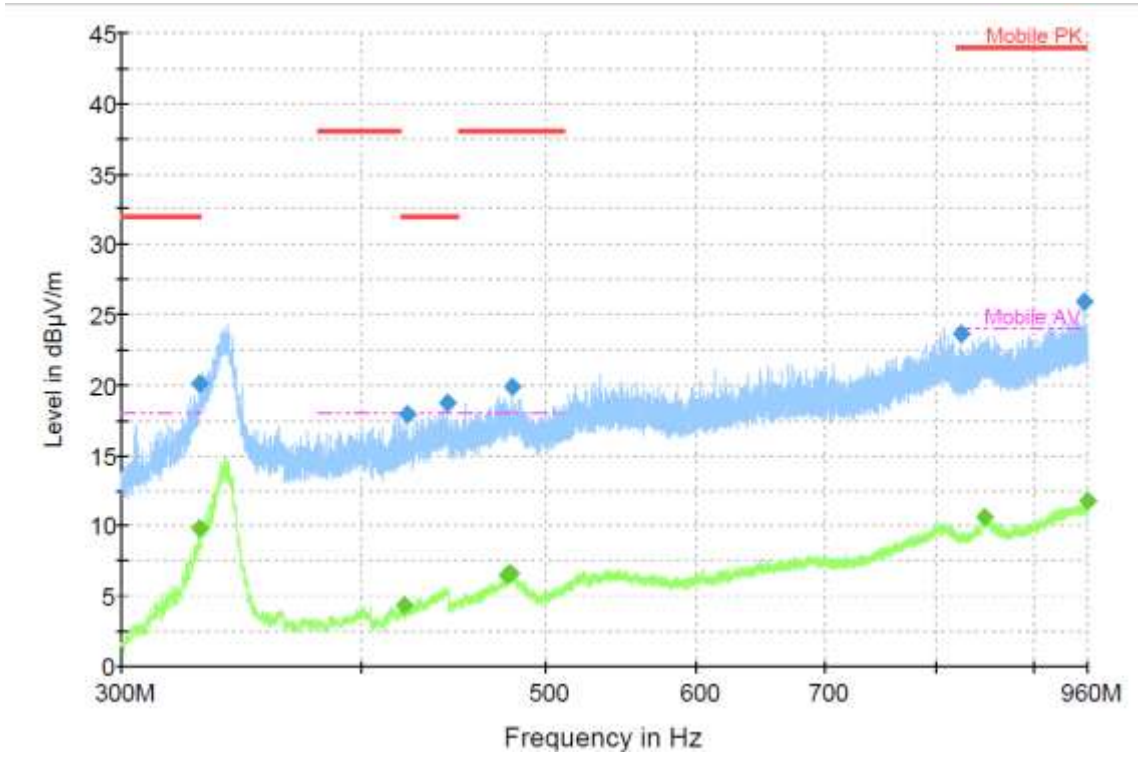


Šivic: RE 200 MHz – 1 GHz

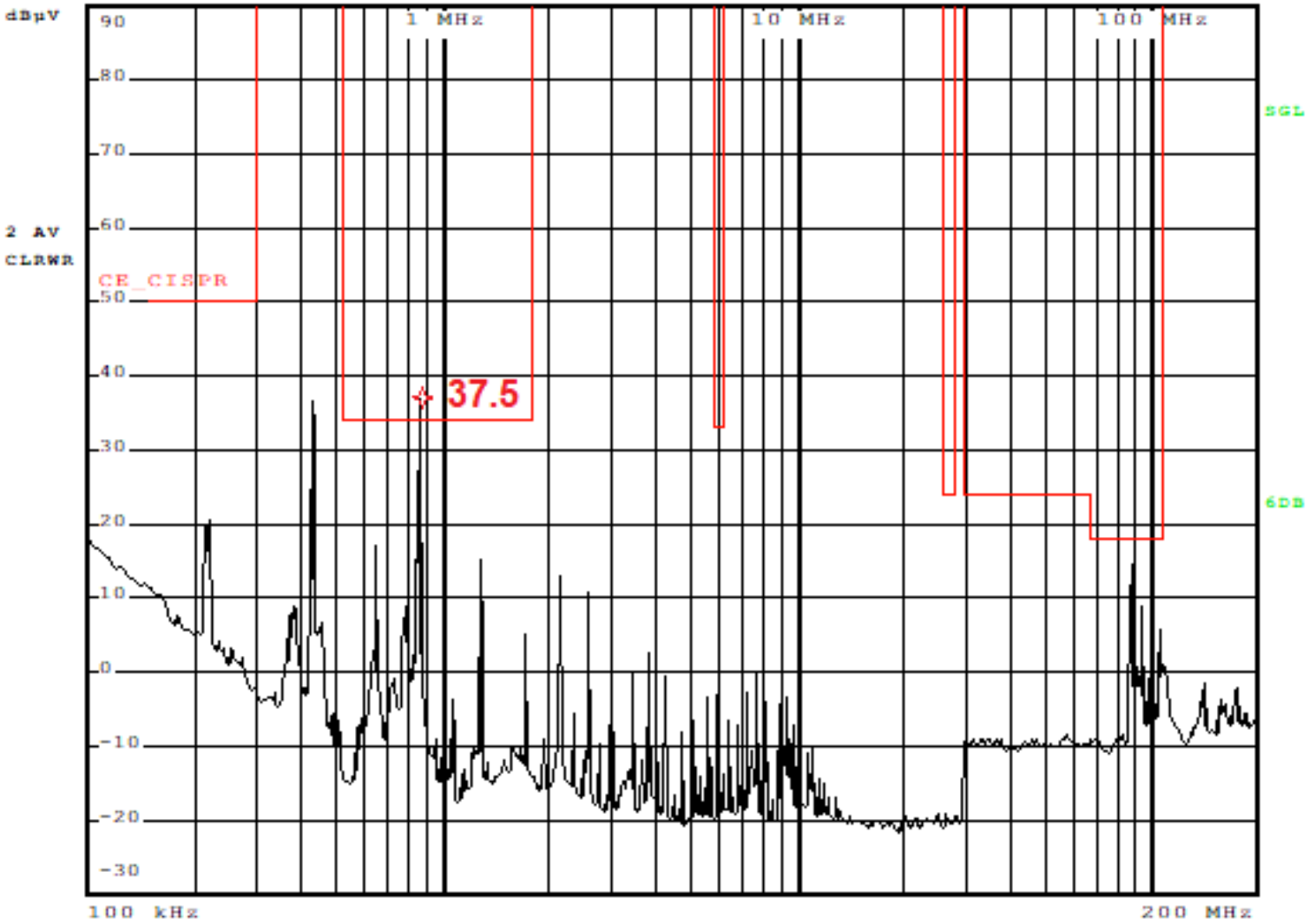
Broadcast



Mobile



Šivic: CE



Razred 4

Šivic: BOM

COMPONENT	No	VALUE	COMMENT	MANUFACTURER	MANUFACTURER No	SUPPLYER	SUPPLYER NO	PRICE PER 1000 [USD]	
D1	1		Diode supp SMA P4SMA36CA	Littelfuse Inc	P4SMA36CA	digi-key	P4SMA36CACT-ND	0,121	
D2	1		DIODE-Z SOT23 0,25W BZX84/C18	Nexperia USA Inc.	BZX84-C18,235	digi-key	1727-6254-2-ND	0,014	
D3	1		DIODE SCHOT SOD323 NSR1020MW2	ON SEMICONDUCTOR	NSR1020MW2T3G	Farnell	2533247	0,055	
L1	1	4,7uF	WE-LHMI 5030	Würth Elektronik	74437336012	Würth Elektronik	74437336012	1,795	
L2	1	4,7uF	WE-LHMI 1365	Würth Elektronik	74437356047	Würth Elektronik	74437356047	1,826	
L3	1	0,47uF	WE-LHMI 7030	Würth Elektronik	7443734615	Würth Elektronik	7443734615	1,038	
T1	1		TRAN TO252/3 NP15P04SLG	INFINEON	IPD85P04P4L06ATMA1	Farnell	2839465	0,607	
T2, T3	2		BSZ0506NSATMA1	INFINEON	BSZ0506NSATMA1	Farnell	2725823	0,364	
TOTAL	9							5,82	USD
								4,97	€

Žiga Šmelcer

Žiga Šmelcer

Šmelcer: Delovanje

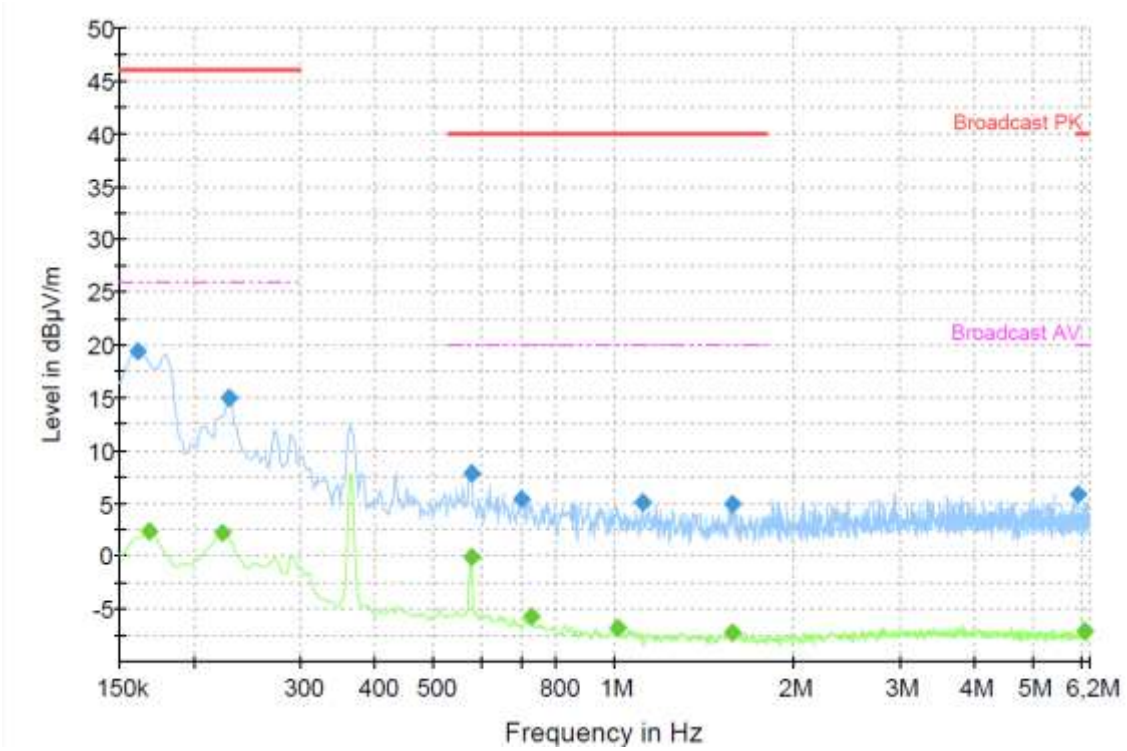
Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
7	18	1.8	13.5	24.3
7	18	1.75	13.5	23.625
7	18	1.81	13.5	24.435

Iout [A]	Uout [V]	Pout [W]	n [%]
5.88	3.56	20.9328	**86.1**
5.8	3.46	20.068	**84.9**
5.9	3.46	20.414	**83.5**

Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
60	**	**	20
60	**	**	20
60	**	**	20

Šmelcer #1: RE 150 kHz-30 MHz

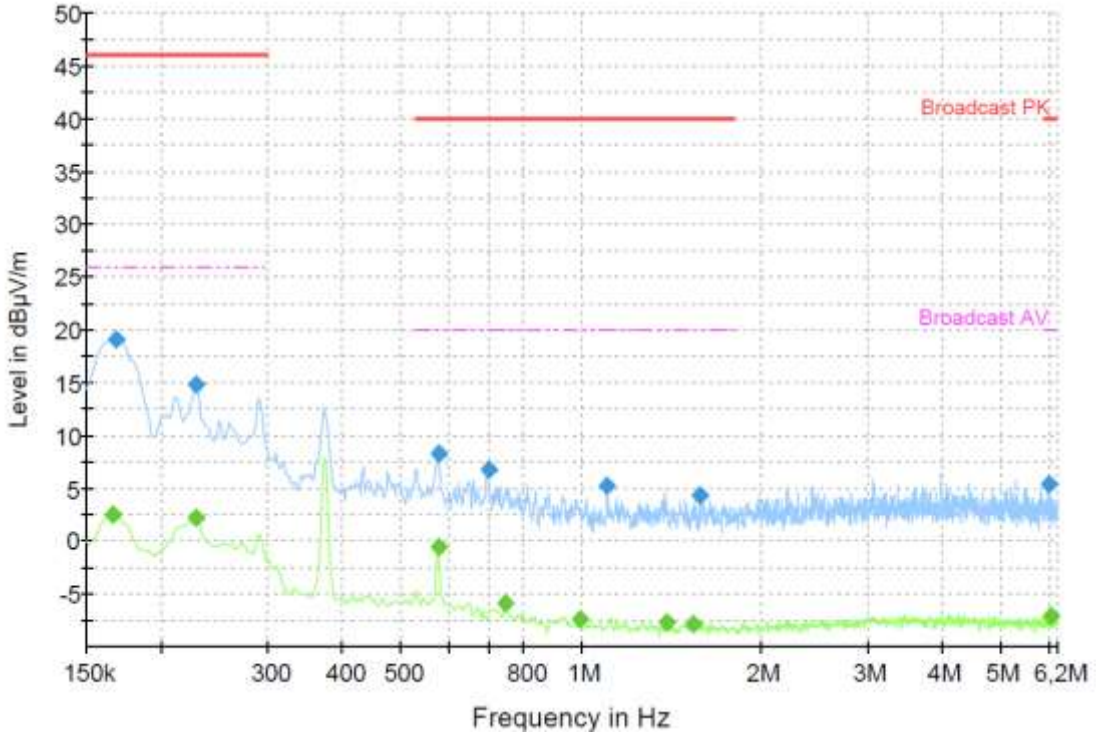
Broadcast



Mobile

Šmelcer #2: RE 150 kHz-30 MHz

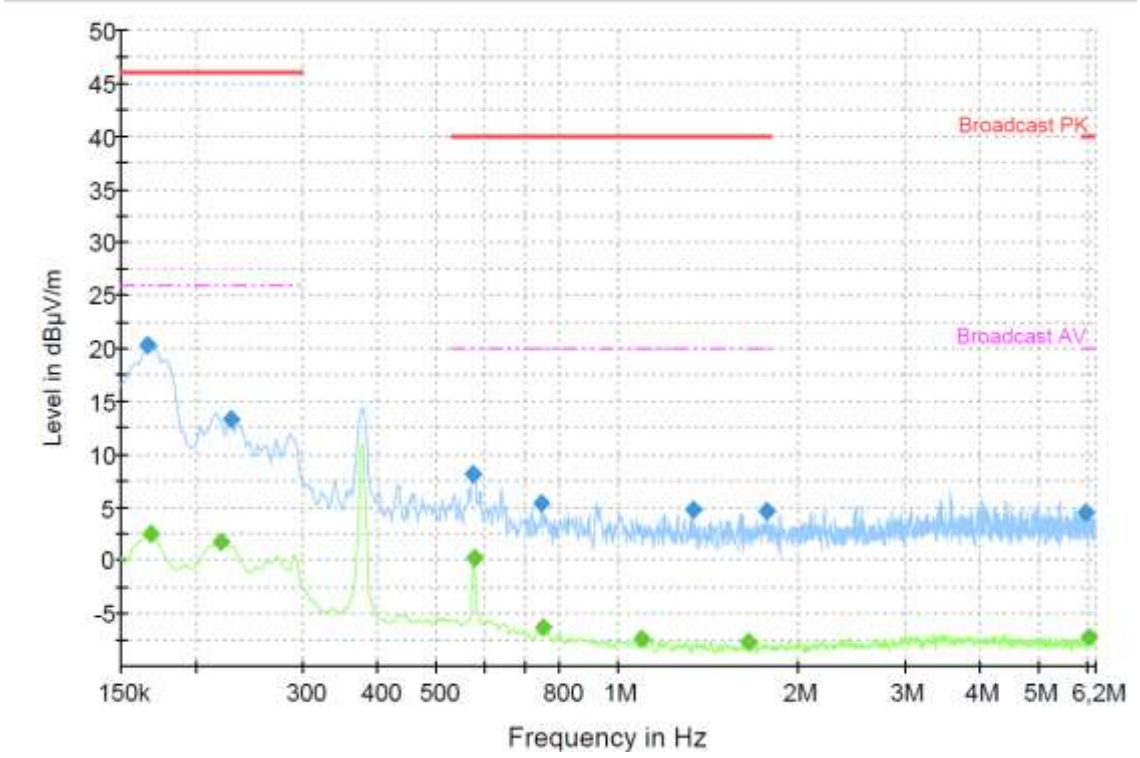
Broadcast



Mobile

Šmelcer #3: RE 150 kHz-30 MHz

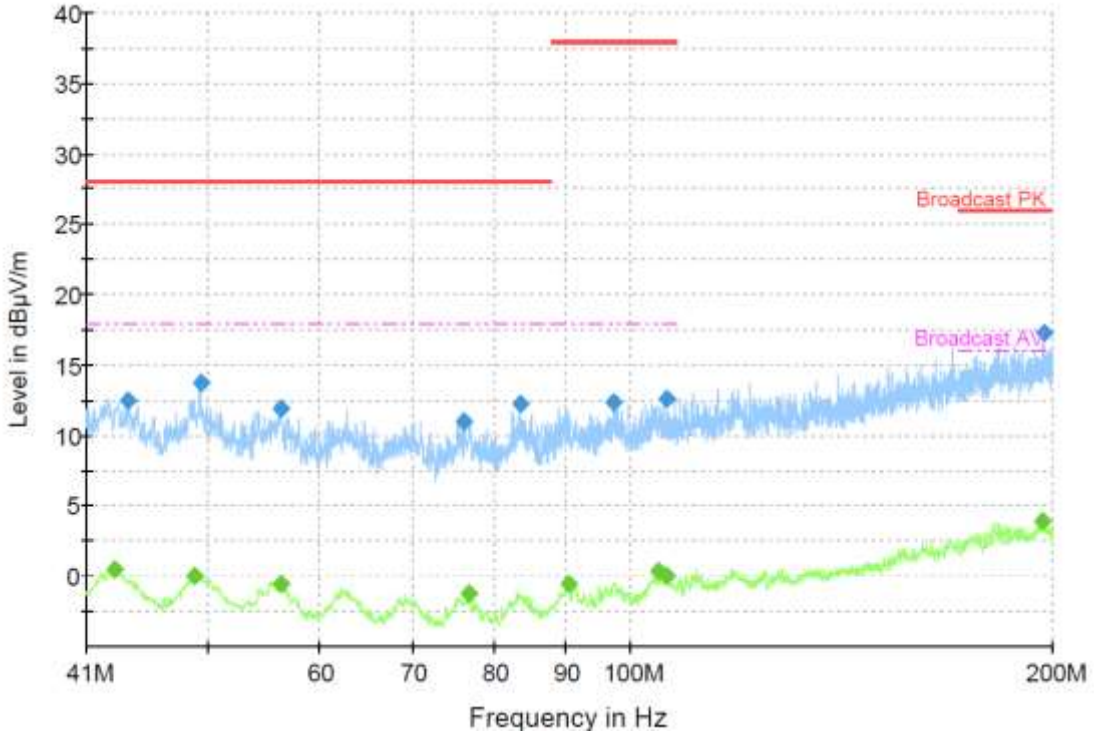
Broadcast



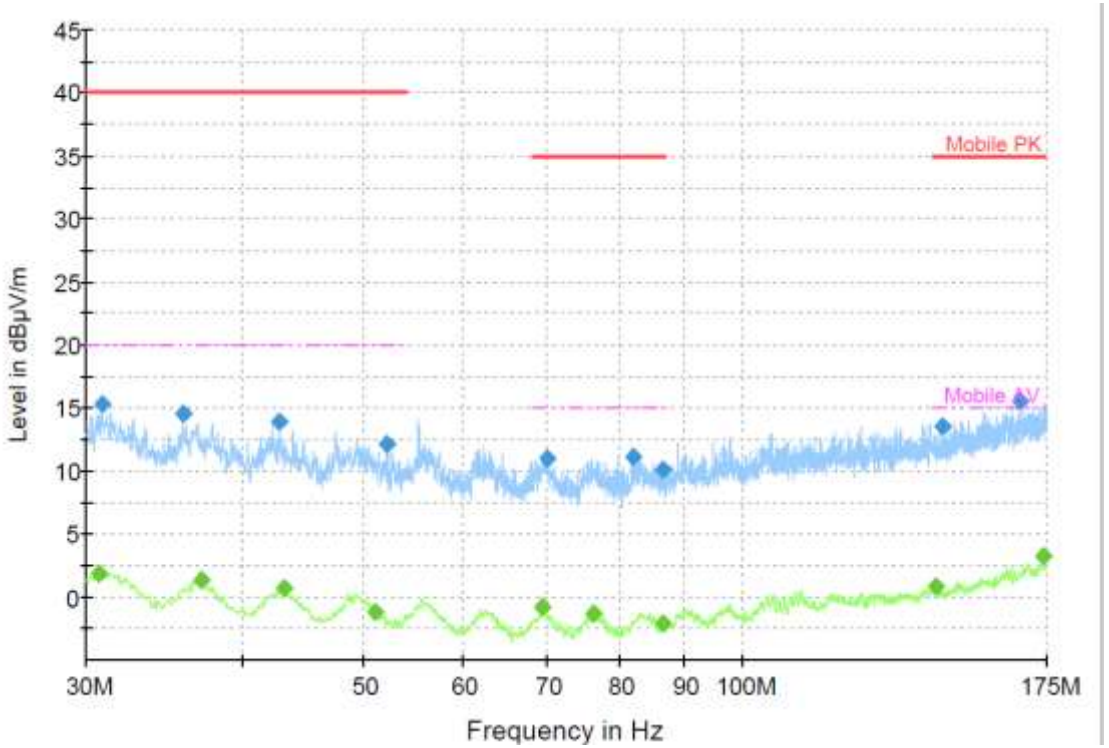
Mobile

Šmelcer #1: RE 30 MHz – 200 MHz

Broadcast

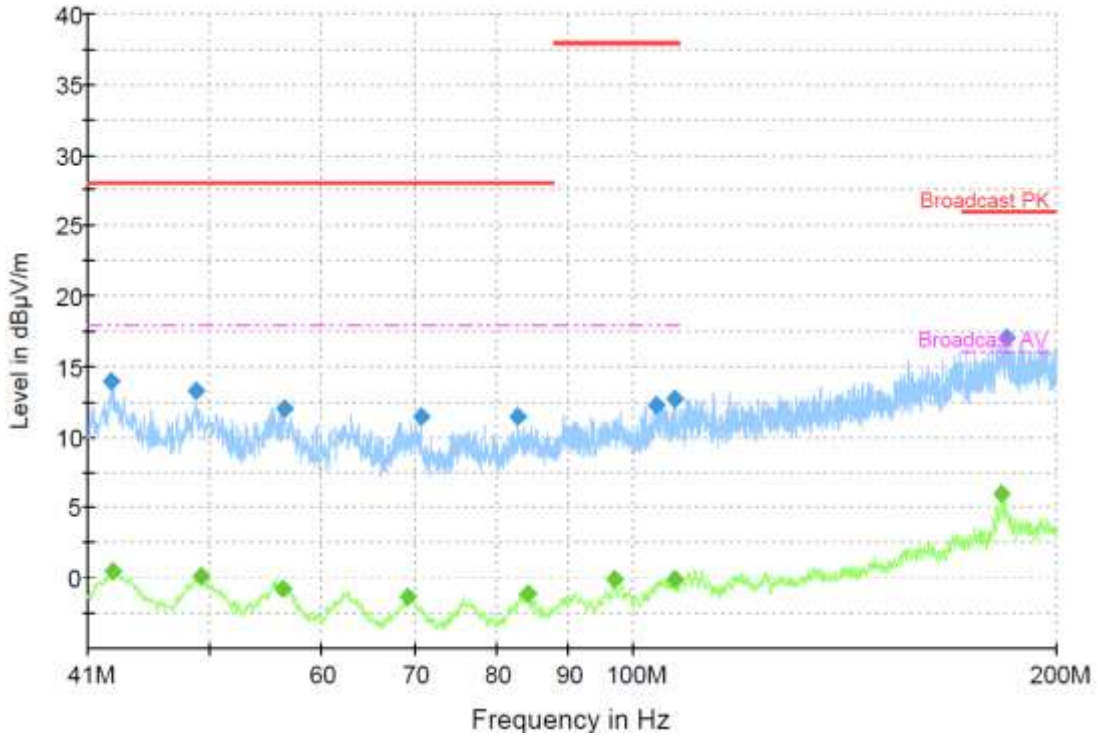


Mobile

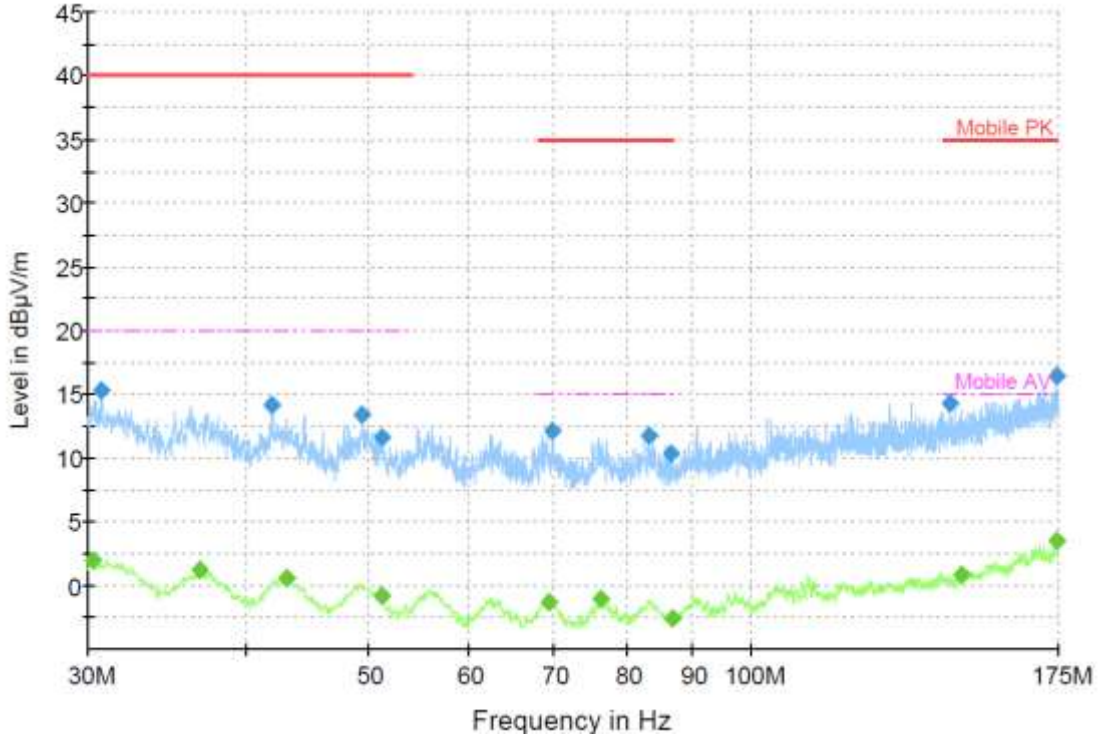


Šmelcer #2: RE 30 MHz – 200 MHz

Broadcast

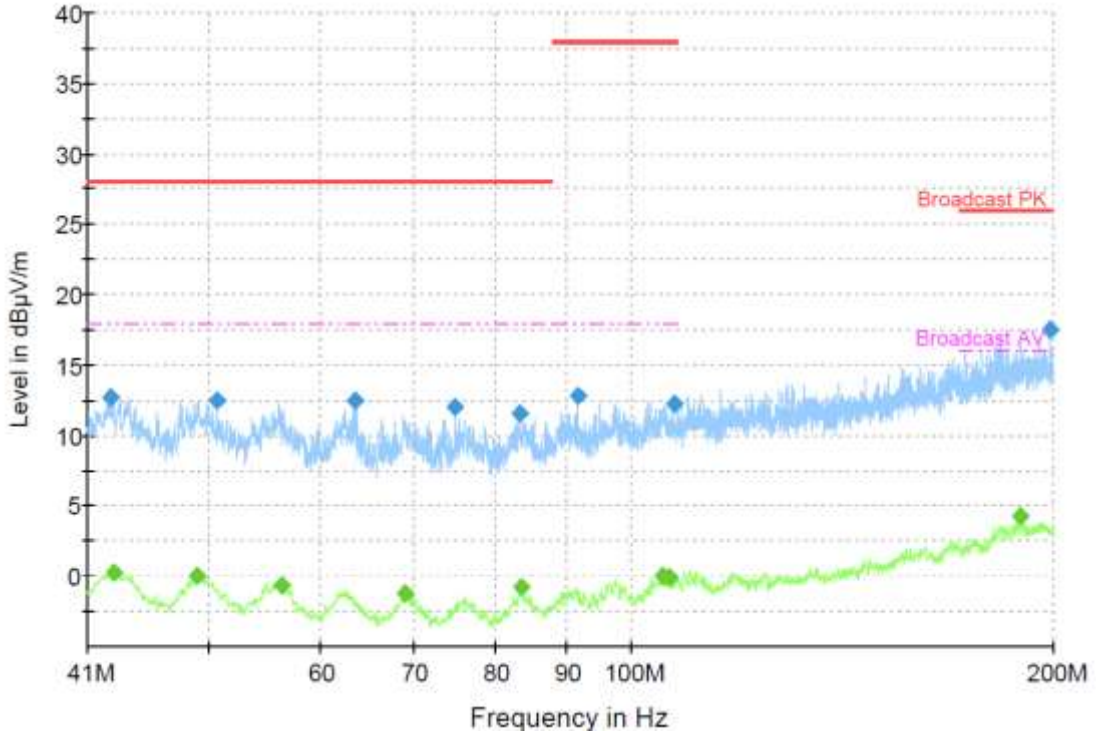


Mobile

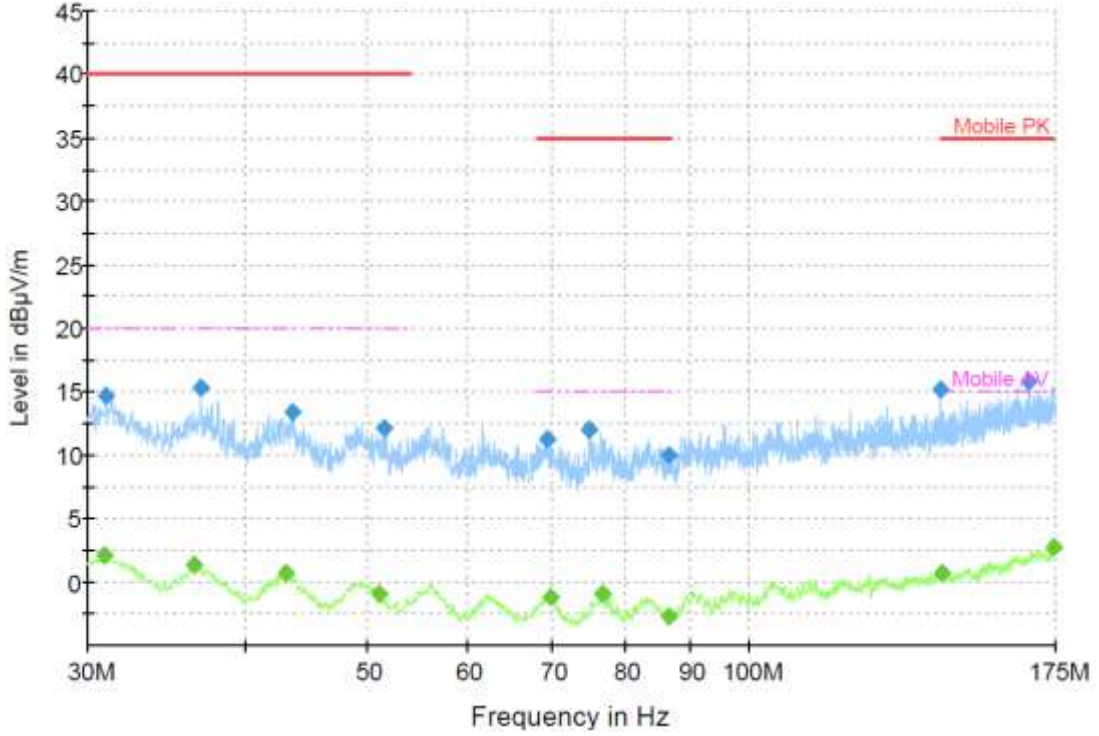


Šmelcer #3: RE 30 MHz – 200 MHz

Broadcast

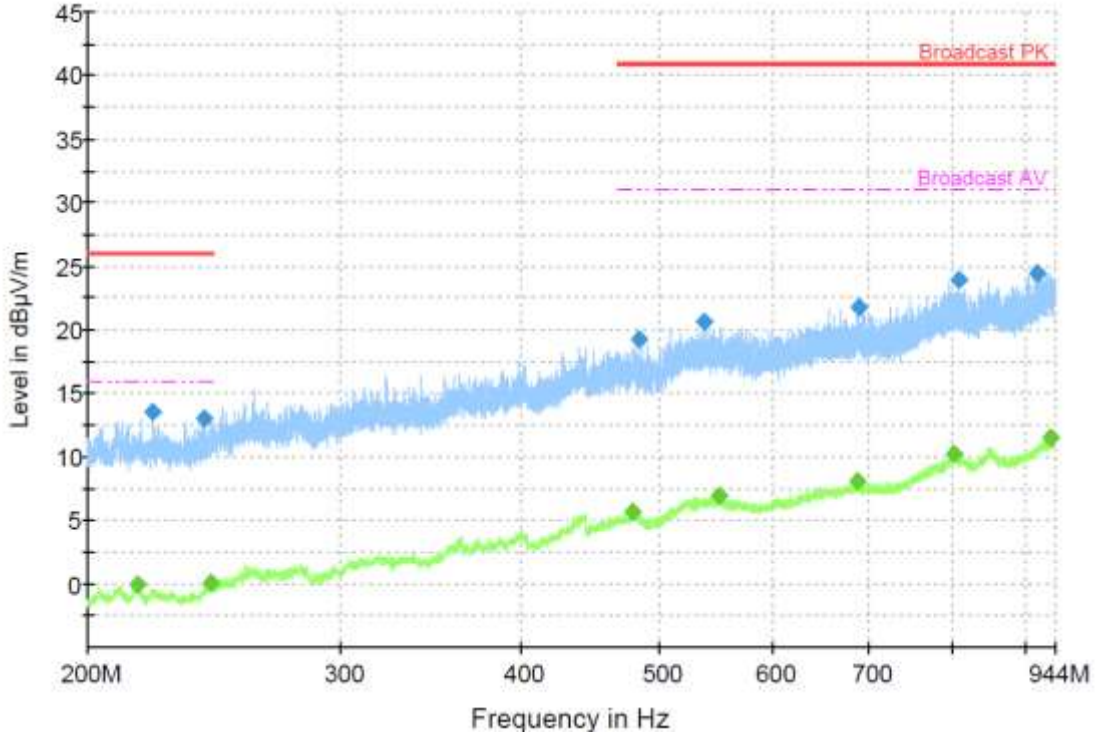


Mobile

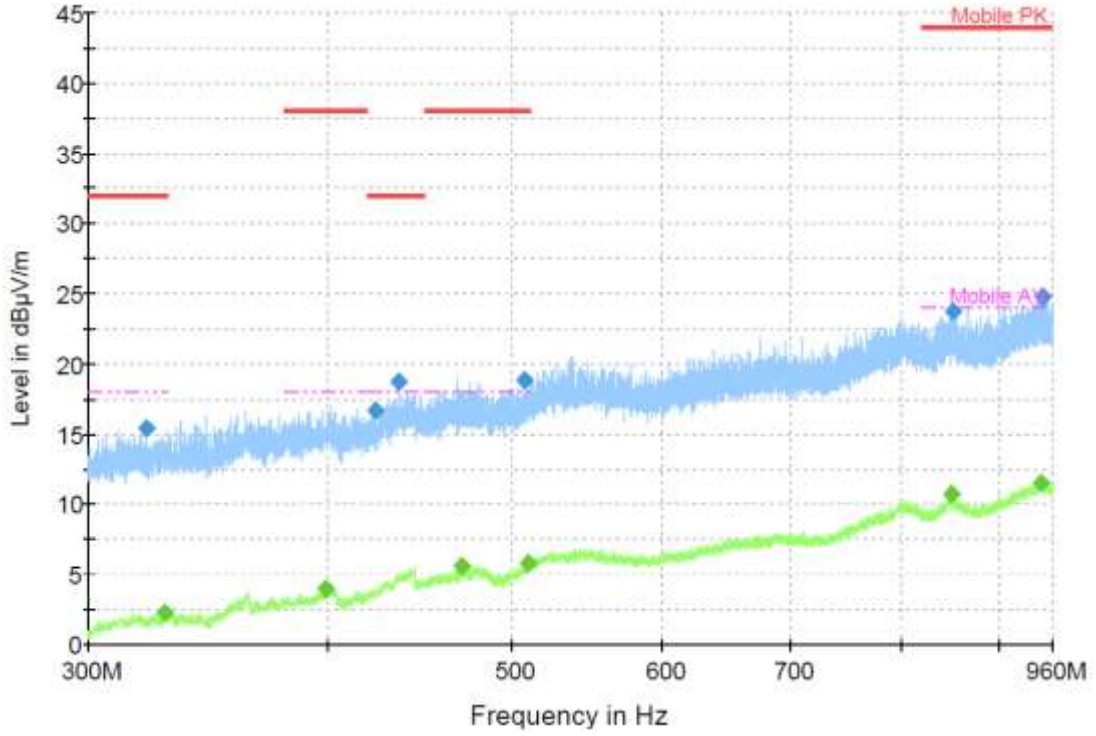


Šmelcer #1: RE 200 MHz – 1 GHz

Broadcast

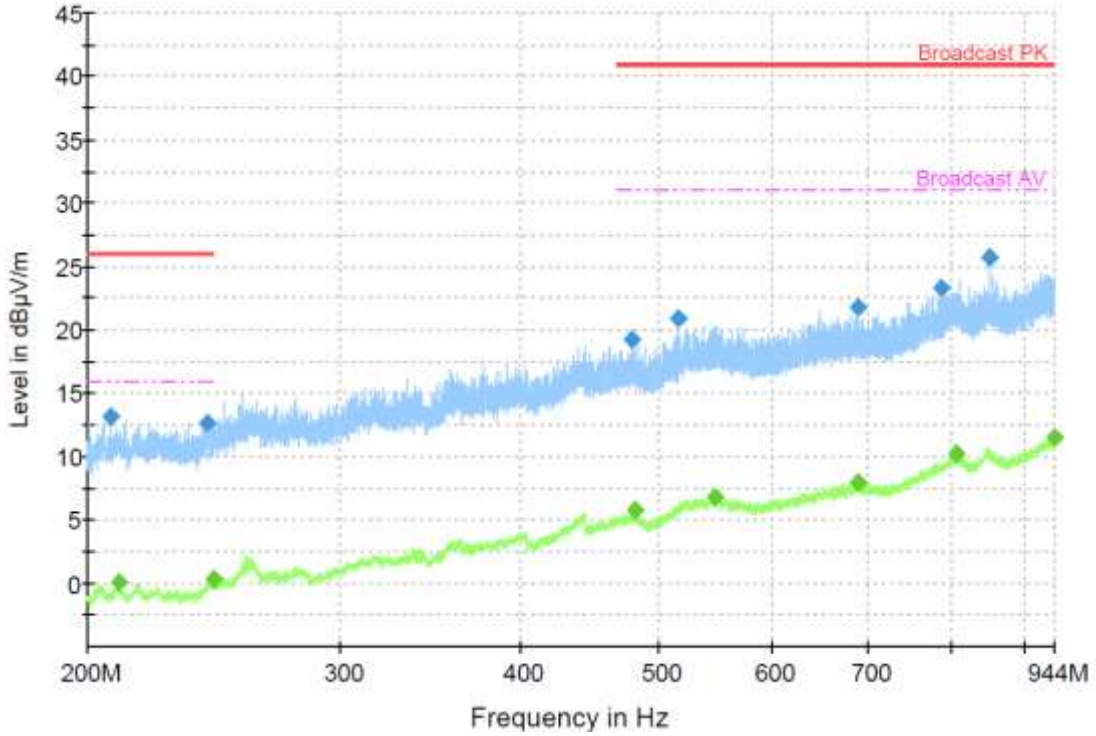


Mobile

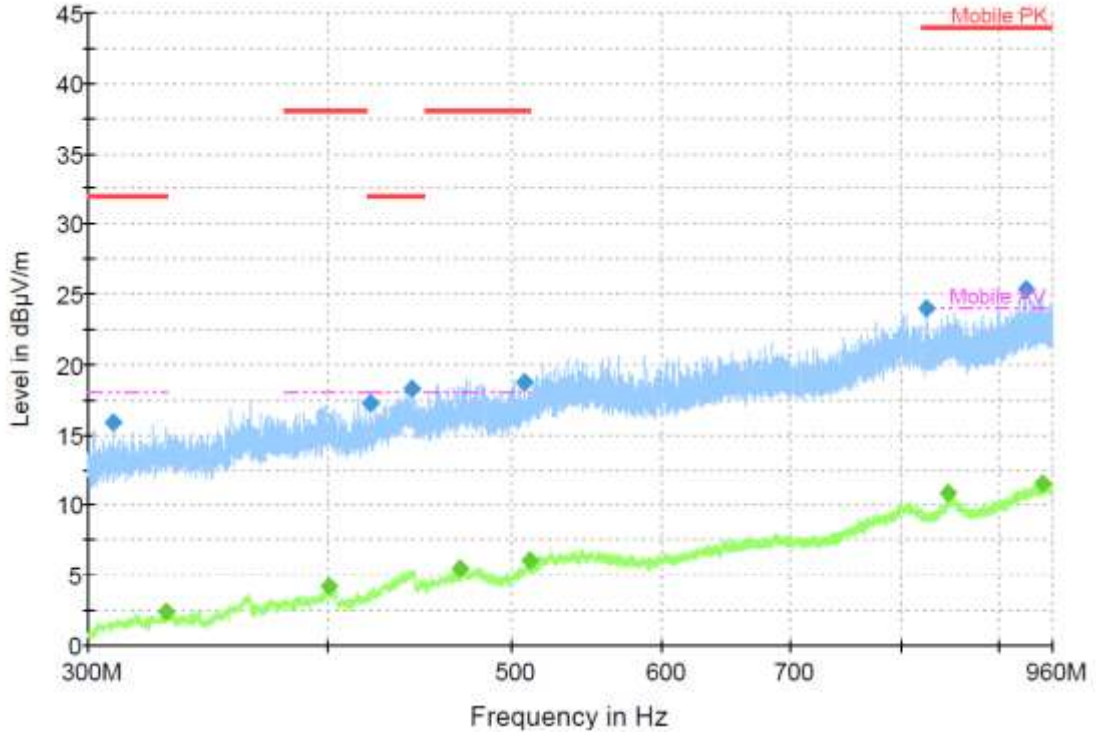


Šmelcer #2: RE 200 MHz – 1 GHz

Broadcast

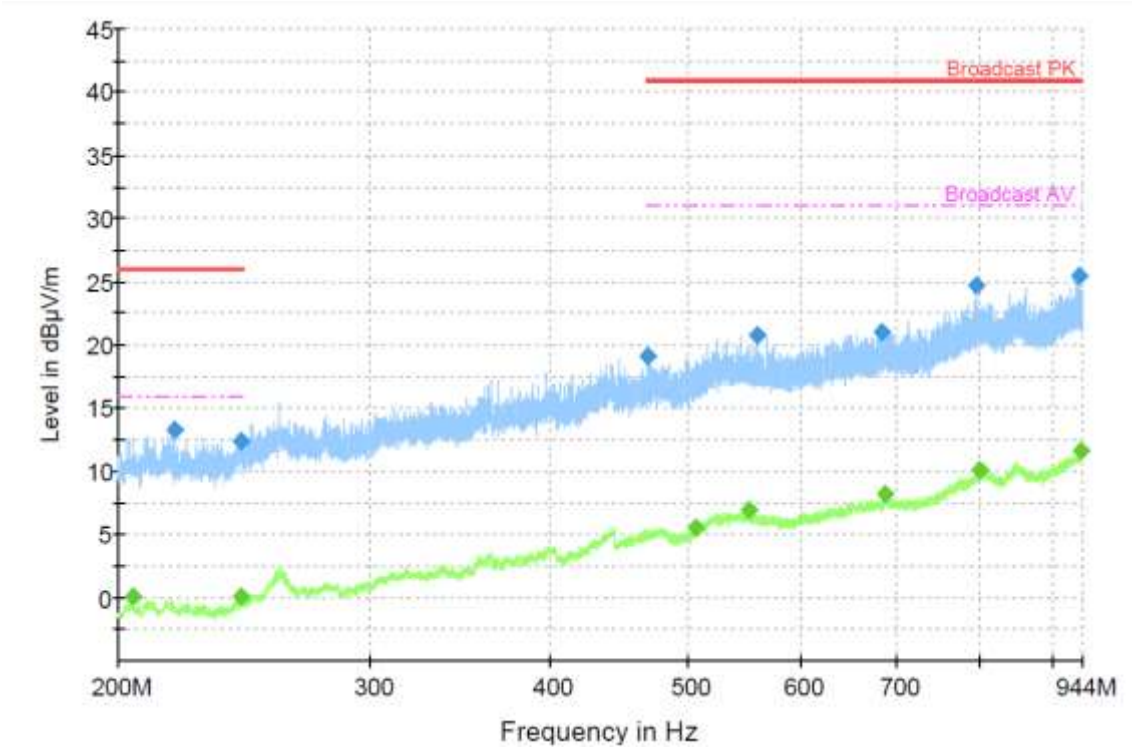


Mobile

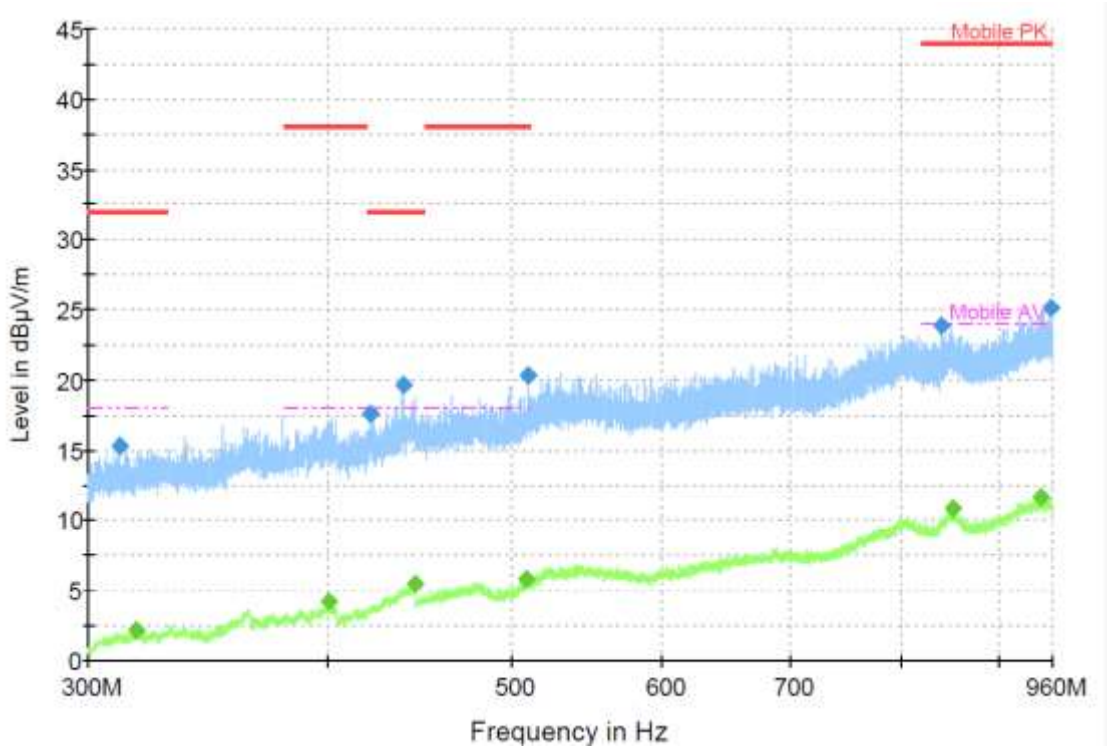


Šmelcer #3: RE 200 MHz – 1 GHz

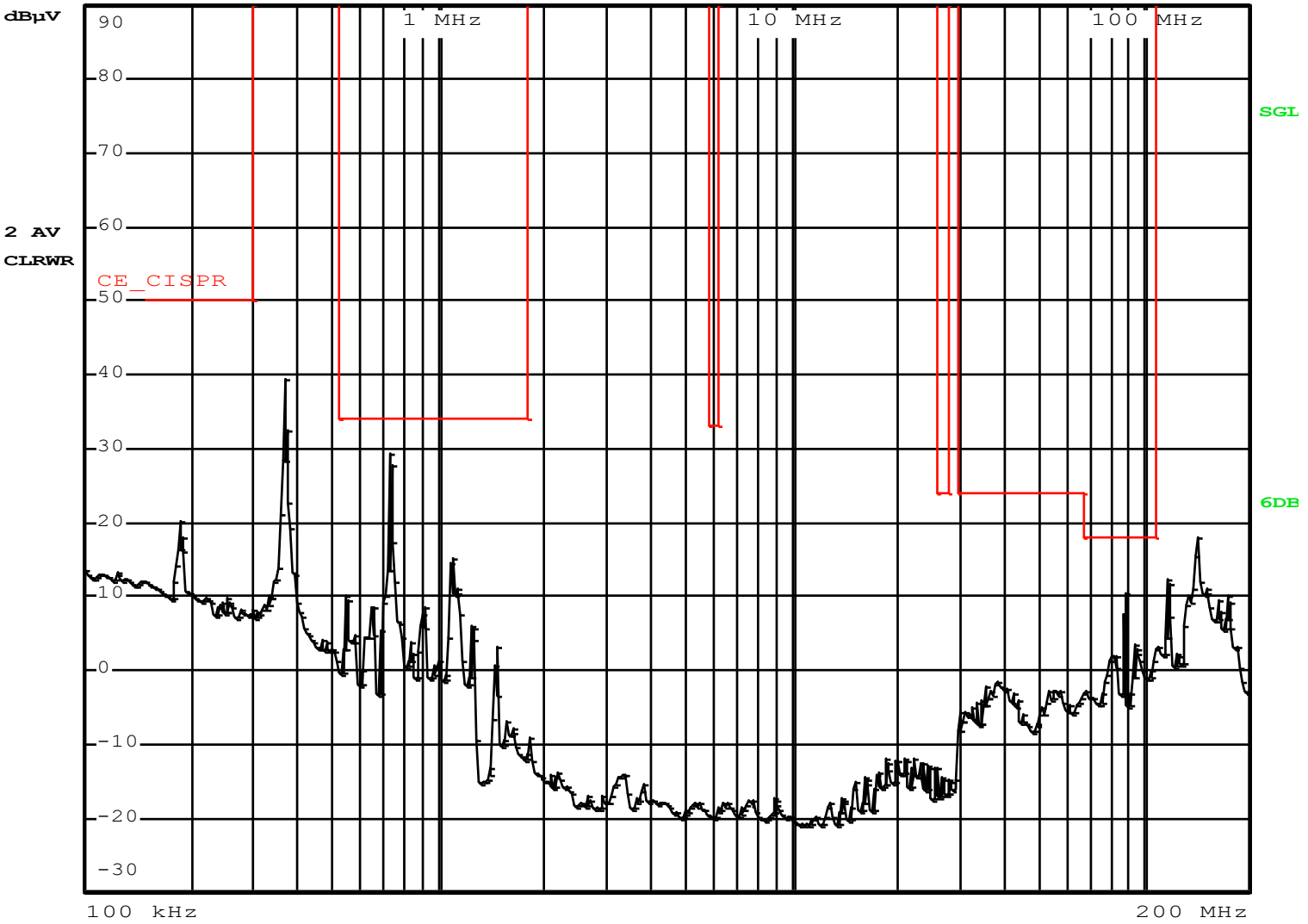
Broadcast



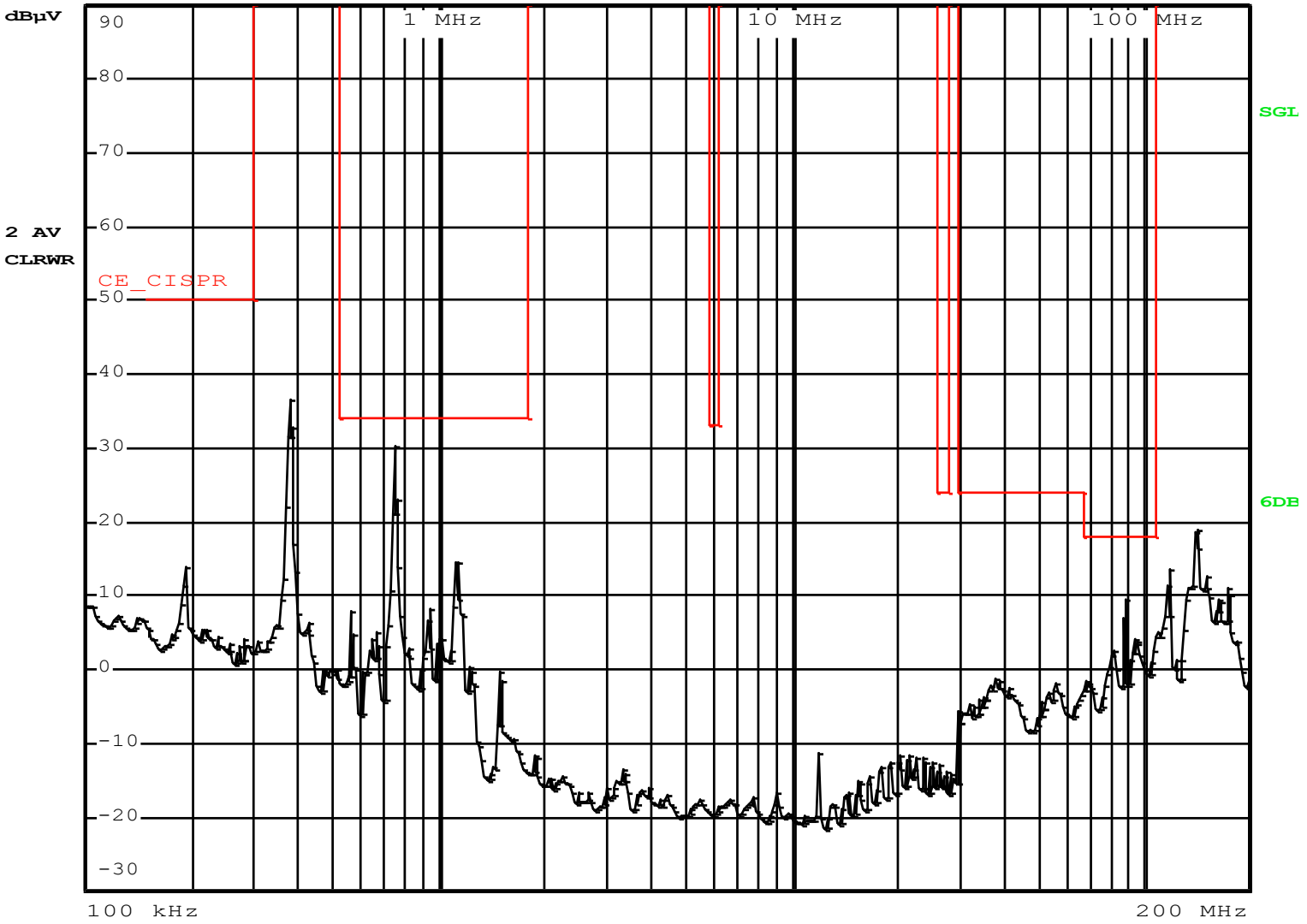
Mobile



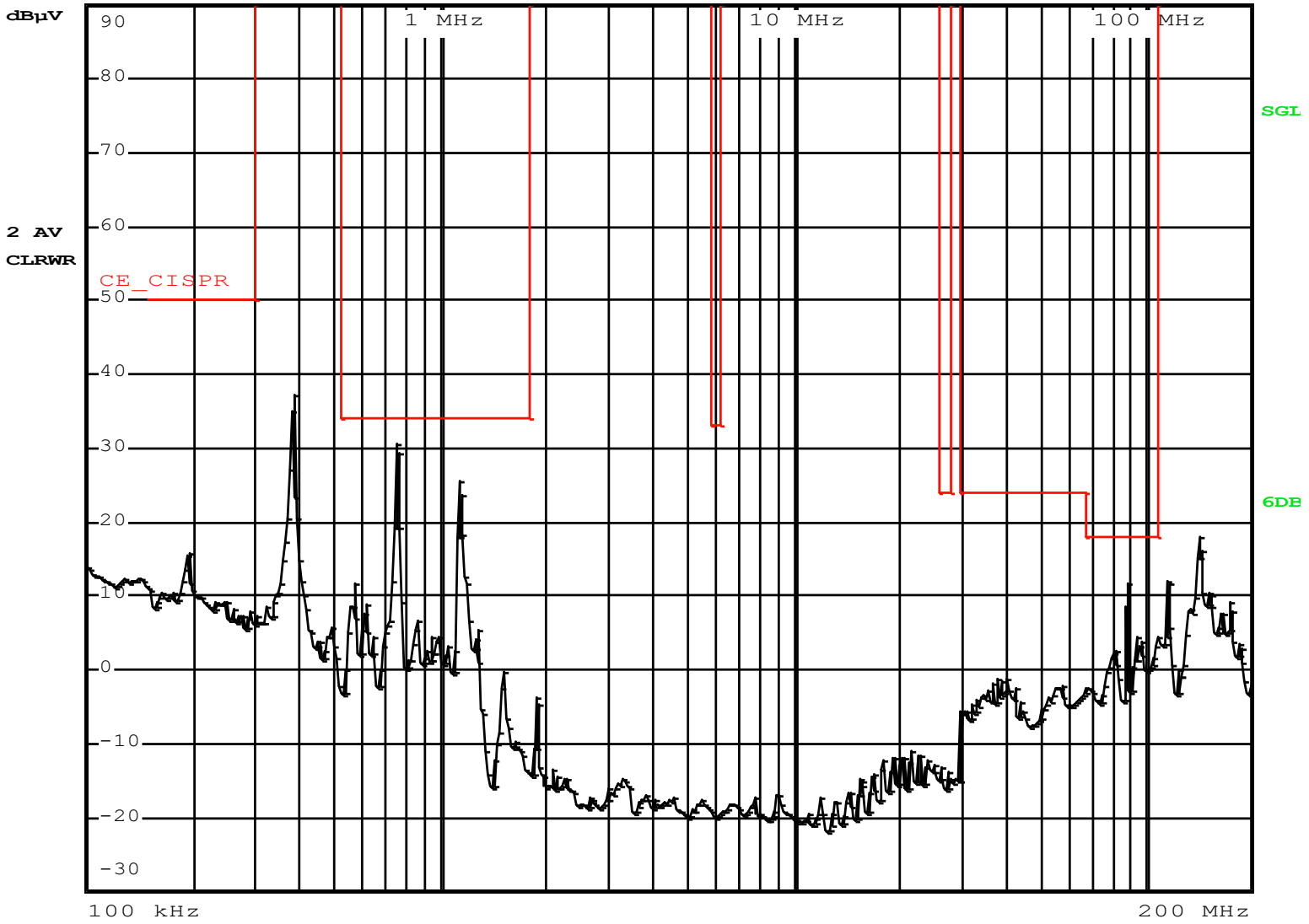
Šmelcer #1: CE


dBµV
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
1 MHz
10 MHz
100 MHz
2 AV
CLRWR
CE_CISPR
SGL
6DB
100 kHz
200 MHz

Šmelcer #2: CE


dBµV
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
1 MHz
10 MHz
100 MHz
SGL
6DB
2 AV
CLRWR
CE_CISPR
100 kHz
200 MHz

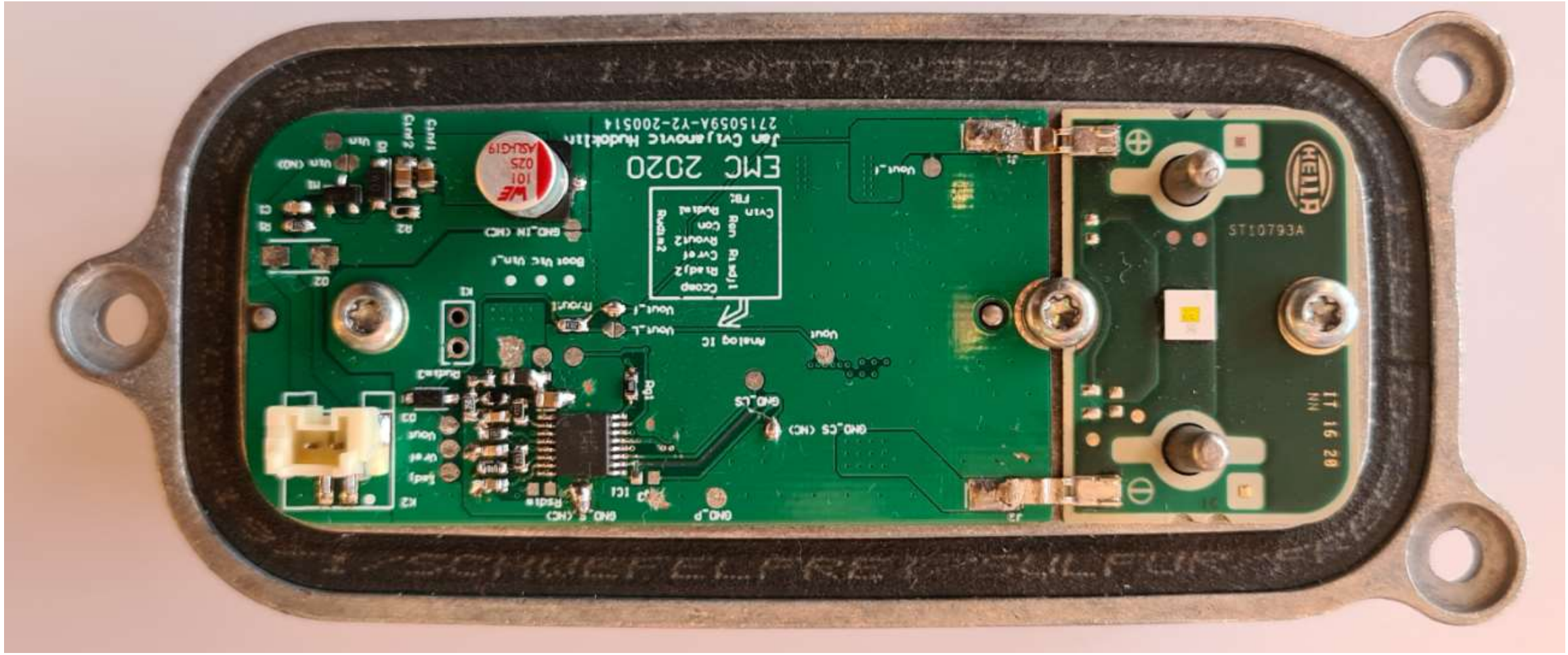
Šmelcer #3: CE


dBµV
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
1 MHz
10 MHz
100 MHz
SGL
6DB
2 AV
CLRWR
CE_CISPR
100 kHz
200 MHz

Šmelcer: BOM

Comment	Description	Designator	Footprint	LibRef	Quantit	CENA Mouser za 100(	SUMA	Proizvajal	ŠIFRA
1.6m	Elektrolitski/polariz	C1	C_el_10mm	C el	1	0.227	0.227	PHILIPS	EEU-FS1E122B
10µ	Kondenzator	C2, C3, C4, C5, C6, C7	C_1206	C	14	0.182	2.548	TDK	C3216X7R1E106M160A
100n	Kondenzator	C12	C_1206	C	1	0.157	0.157	Murata	GRM31C5C2A104JA01L
4.7mF	Elektrolitski/polariz	C13	C_el_10mm	C el	1	0.25	0.25	Rubycon	6.3ZLQ4700MEFC10X25
470p	Kondenzator	C21, C22	C_1206	C	2	0.051	0.102	Kemet	C1206C471J5GAC
100n	Kondenzator	C32	C_0603	C	1	0.007	0.007	Kemet	C0603C104M4RAC
100p	Kondenzator	C31, C34	C_0603	C	2	Drobiž		China	
470n	Kondenzator	C33	C_0603	C	1	Drobiž		China	
10n	Kondenzator	C35	C_0603	C	1	Drobiž		China	
6.8p	Kondenzator	C40, C41	C_0603	C	2	Drobiž		China	
L_FB	Ferrite bead	FB1, FB2	L_1806	L_FB	2	0.048	0.096	Taiyo Yunder	FBMJ4516HS720NT
Cfeedth	HF filterski kondenz	Cf1, Cf2	C_1206_ft	C feedth	2	0.19	0.38	TDK	YFF31HC2A105MT000N
ZENER	Zener diode	D1	D_MELF_0102	D_ZENER	1	0.037	0.037	Vishay	BZM55C16-TR
SHOTKY	Shottky diode	D3	SOD-123	D_SHOTKY	1	0.086	0.086	NEXPERIA	PMEG4030ER/8X
L_uni	Inductor	Lfin, Lsw	L_13x13mm_uni	L	2	0.549	1.098	Bourns	SRP1265A-100M
DMP3013	Power switch P-MO	Q1	DIODES_PowerDI333	MOS_P_DMP3013	1	0.167	0.167	Diodes	DMP3018SFV-7
IRF8327	Power N-MOSFET 30	Q2, Q3	IRF_DirectFET SQ	MOS_N_IRF8327	2	0.432	0.864	Infineon	IRF8327STRPBF
1k	Upor	R1	R_0805	R	1	Drobiž		China	
200	Upor	R2, R4	R_0603	R	2	Drobiž		China	
9.1M	Upor	R3, R5	R_0603	R	2	Drobiž		China	
1	Upor	R8, R41, R42	R_1206	R	3	Drobiž		China	
51k	Upor	R10	R_0603	R	1	Drobiž		China	
47k	Upor	R11	R_0603	R	1	Drobiž		China	
10k	Upor	R12, R13, R14	R_0603	R	3	Drobiž		China	
1k	Upor	R15	R_0603	R	1	Drobiž		China	
3.3k	Upor	R16	R_0603	R	1	Drobiž		China	
100k	Upor	R17	R_0603	R	1	Drobiž		China	
20k	Upor	R22	R_0805	R	1	Drobiž		China	
9.1M	Upor	R23	R_0805	R	1	Drobiž		China	
15k	Upor	R24	R_0603	R	1	Drobiž		China	
2.2k	Upor	R25	R_0603	R	1	Drobiž		China	
10	Upor	R30, R31	R_1206	R	2	Drobiž		China	
10m	Upor	Rs	R_1206	R	1	0.039	0.039	OHMITE	PCS1206DR0100ET
						SUMA VSE	**6.058**	€	

Jan Cvijanovič Hudoklin



Cvijanovič Hudoklin: Delovanje

Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
7.5	18	1.82	13.5	24.57

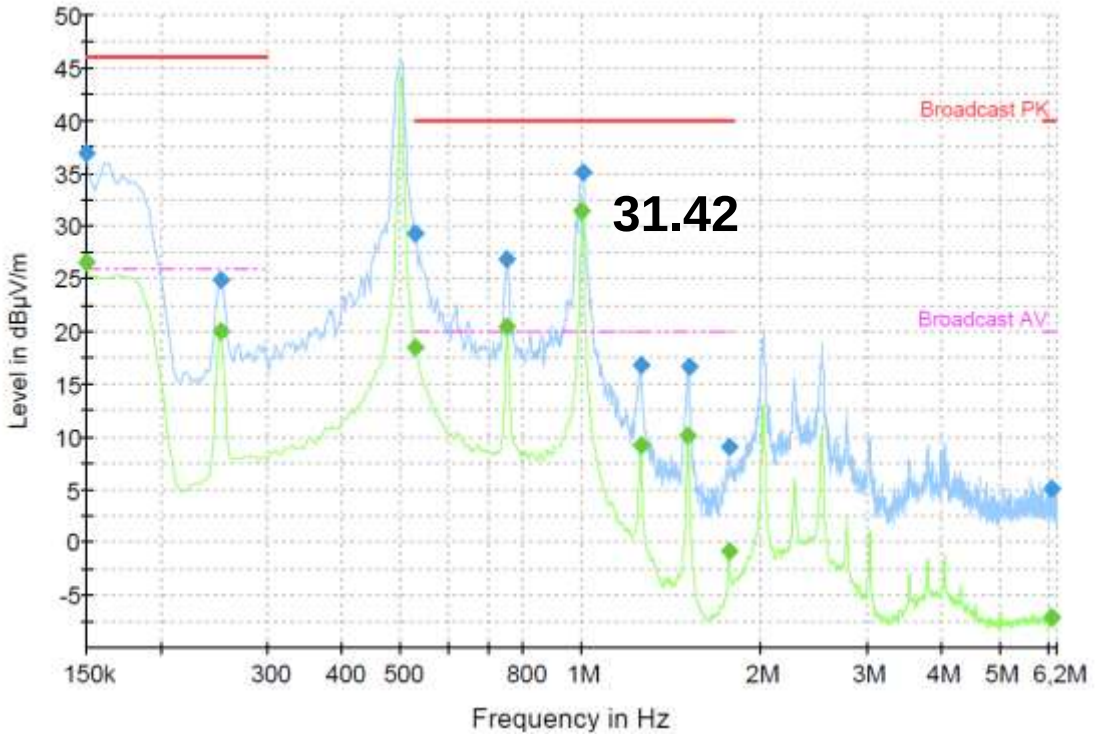
Iout [A]	Uout [V]	Pout [W]	n [%]
5.9	3.62	21.358	**86.9**

Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
200	**	**	100

Cvijanovič Hudoklin: RE 150 kHz-30 MHz

Broadcast

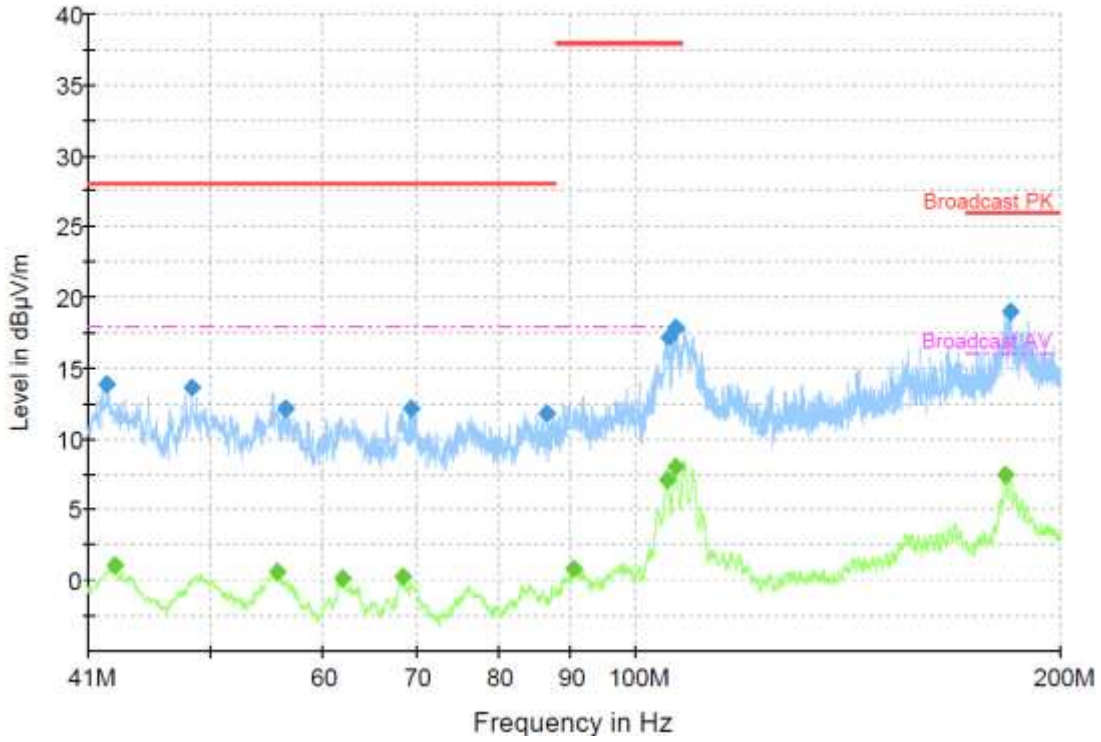
Razred 3



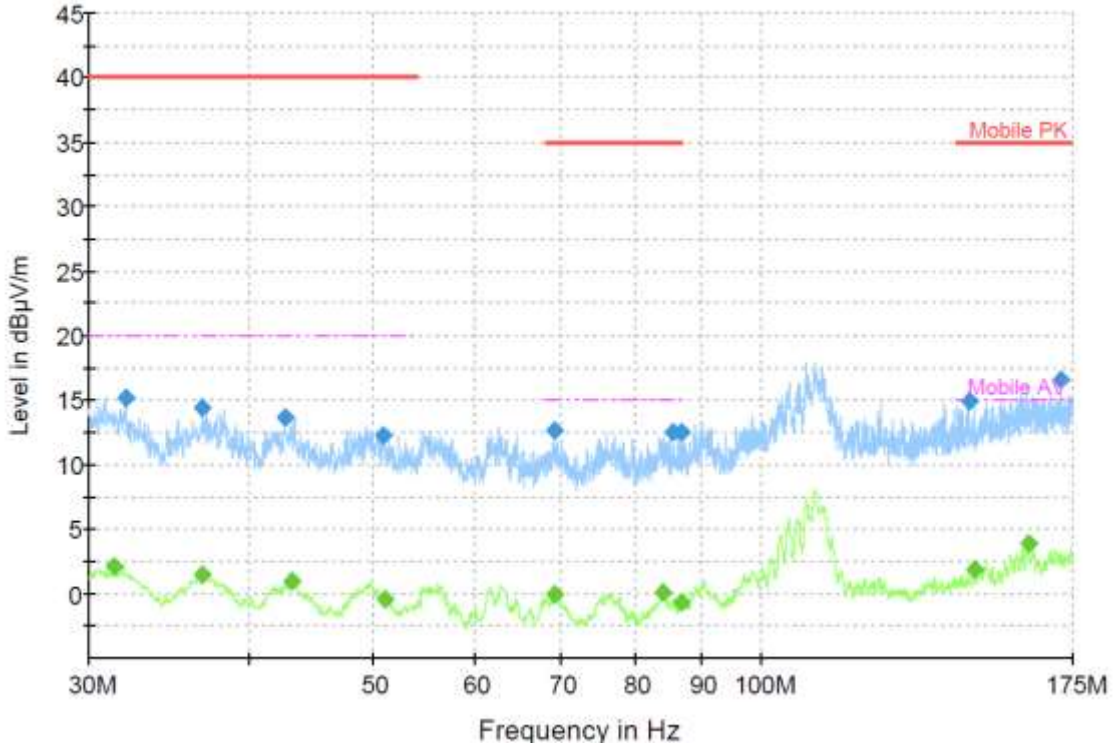
Mobile

Cvijanovič Hudoklin: RE 30 MHz – 200 MHz

Broadcast

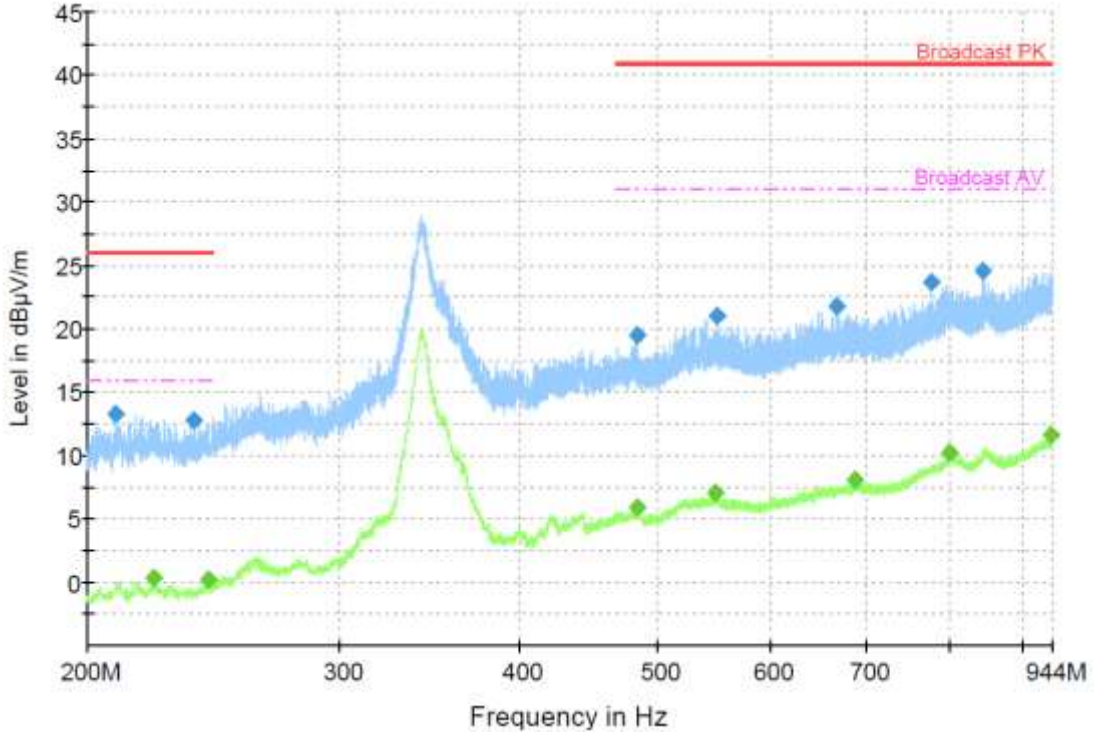


Mobile

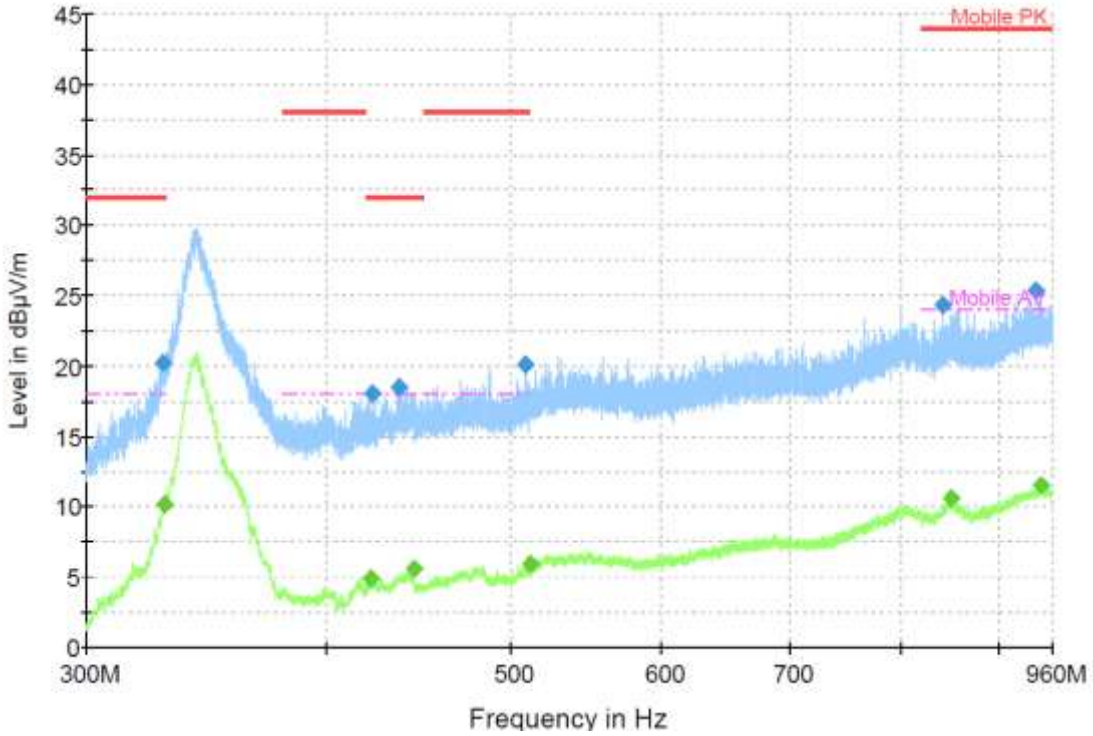


Cvijanovič Hudoklin: RE 200 MHz – 1 GHz

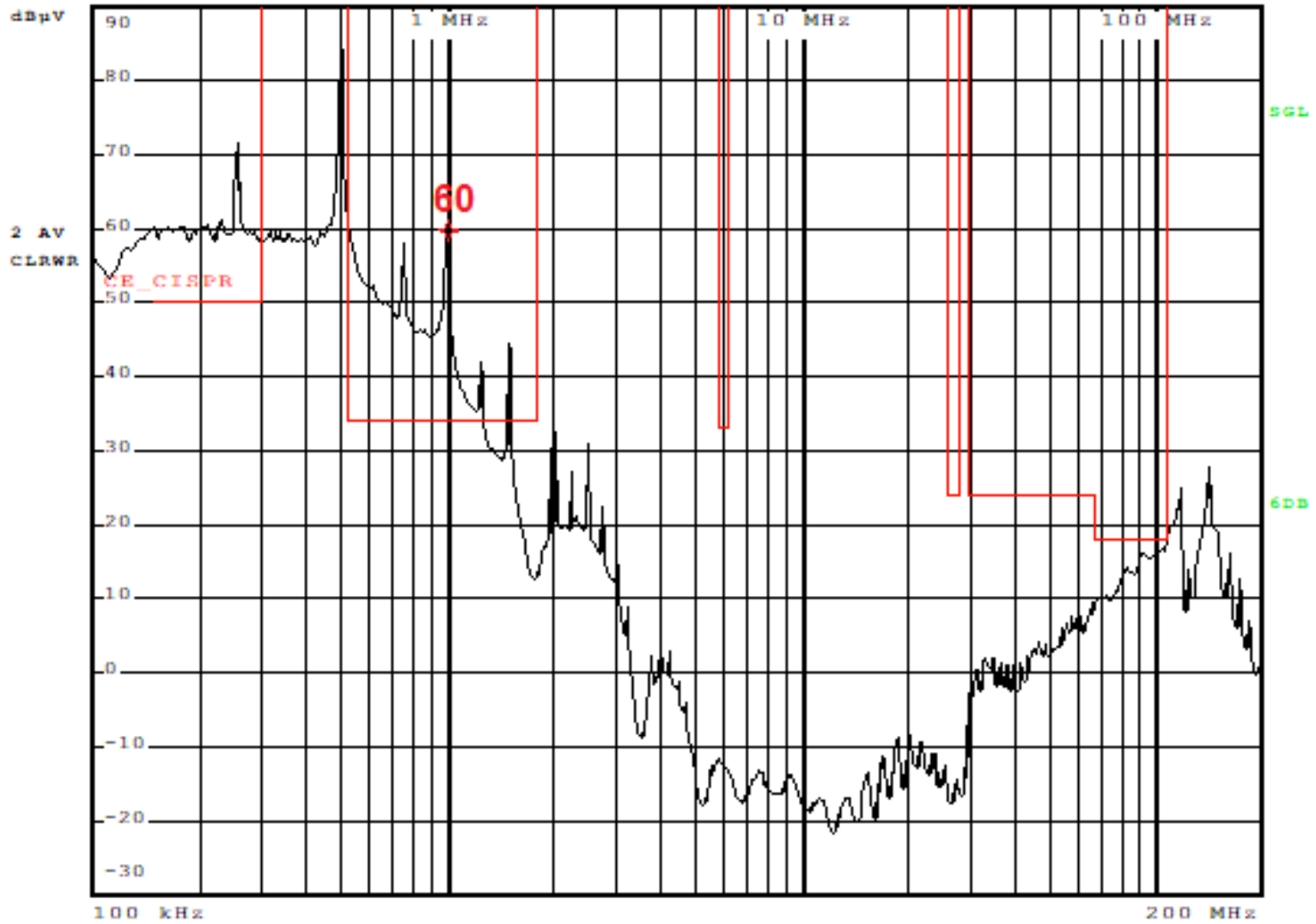
Broadcast



Mobile



Cvijanovič Hudoklin: CE

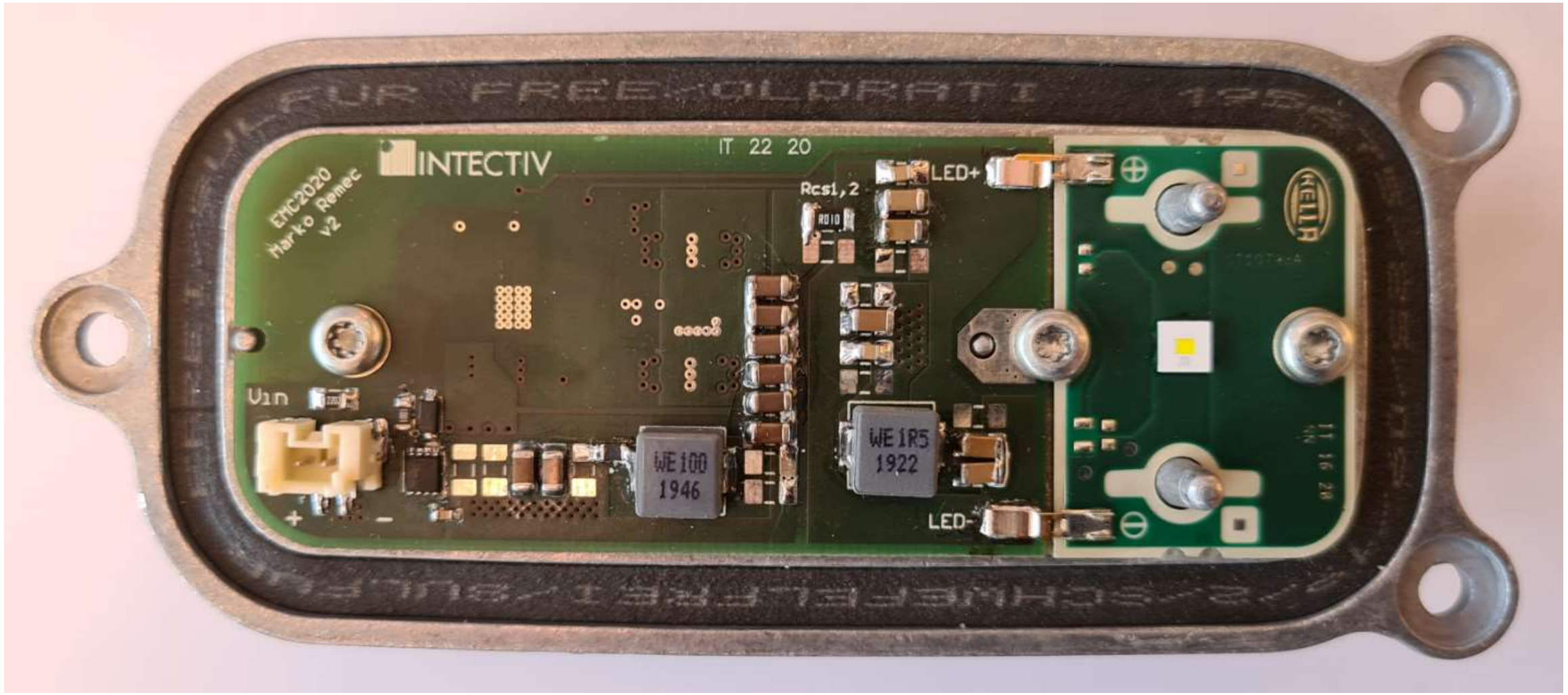


Razred 1

Cvijanovič Hudoklin: BOM

Comment	Description	Designator	Quantity	Price per 1000	Total
NTS260SFT3G	Schottky Diode	D4	1	0,05 €	0,05 €
BZT52C24	Zener Diode	D1	1	0,01 €	0,01 €
865080449011	WCAP-ASLI Aluminum Electrolytic Capacitors, 100uF, 25V	C2	1	0,22 €	0,22 €
EEE-FN1E101UP	Aluminium Electrolytic Capacitors - SMD 25VDC 100uF 20% 240mA AEC-Q200	C3	1	0,10 €	0,10 €
EEE-FN1A101UR	Aluminium Electrolytic Capacitors - SMD 10VDC 100uF 20% 160mA AEC-Q200	C4	1	0,10 €	0,10 €
744373965100	Inductor 10uH	L3	1	1,20 €	1,20 €
744273501	WE-SL5 HC SMT Common Mode Line Filter, 5uH, 5A	L4	1	1,60 €	1,60 €
FDN360P	PMOS	M1	1	0,08 €	0,08 €
782853701	Ferrite Bead, 700 Ohm, 1.5A	FB1	1	0,06 €	0,06 €
BSZ060NE2LSATMA1	MOSFET (N-Channel)	Q1, Q2	2	0,27 €	0,53 €
PE2512FKE7W0R01Z	Resistor	Rcs	1	0,14 €	0,14 €
					4,11 €

Marko Remec


INTECTIV
IT 22 20
EMC2020
Marko Remec
V2
Rcs1,2
R010
LED+
LED-
Vin
+
-
WE 100
1946
WE IR5
1922
HELLA

Marko Remec: Delovanje

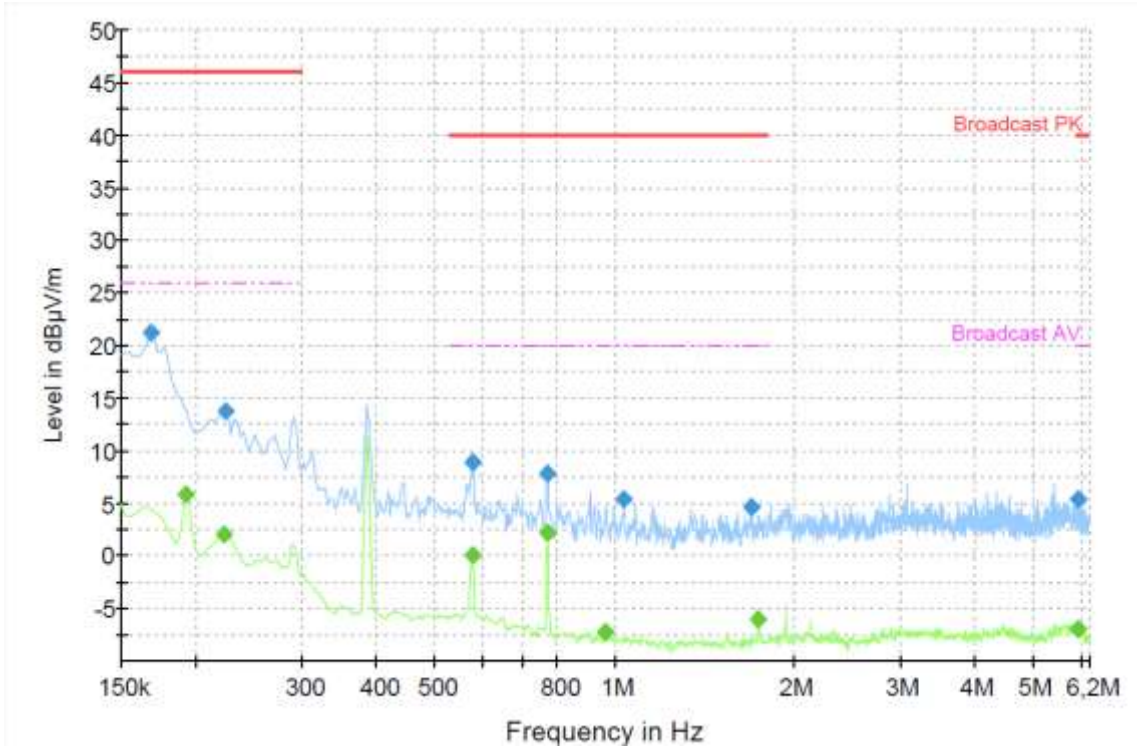
Iout [A]	Uout [V]	Pout [W]	n [%]
6	3.46	20.76	**85.9**

Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
8	18	1.79	13.5	24.165

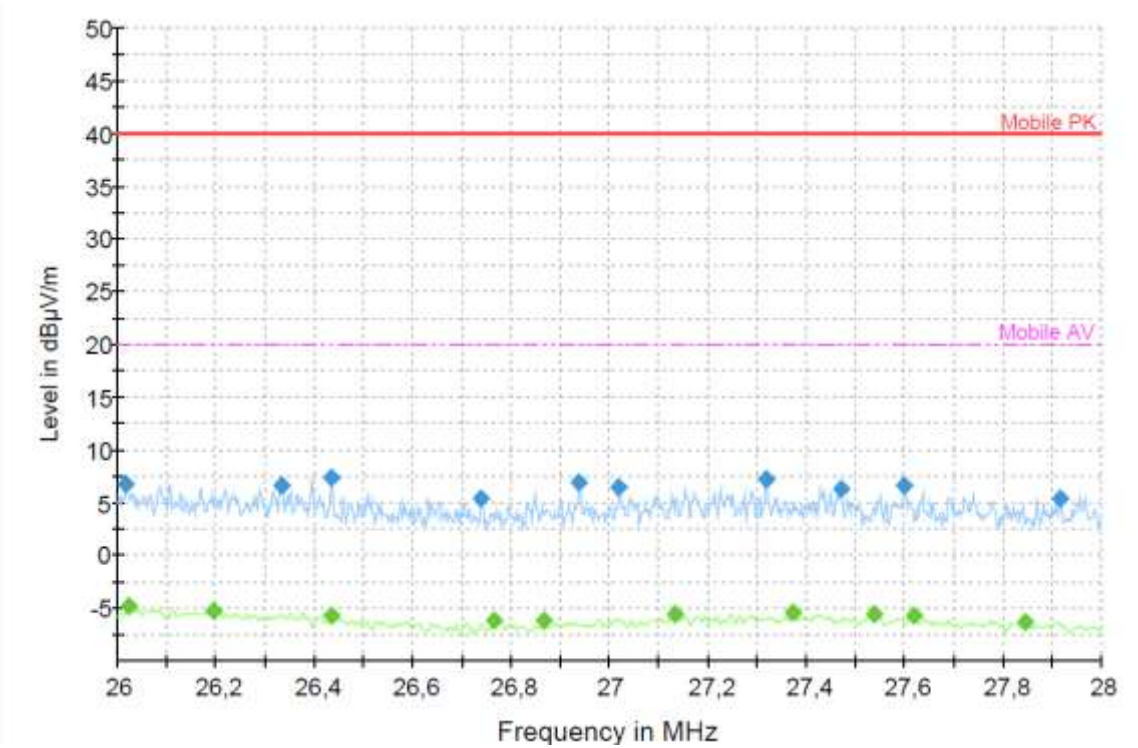
Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
100	**	**	20

Remec: RE 150 kHz-30 MHz

Broadcast

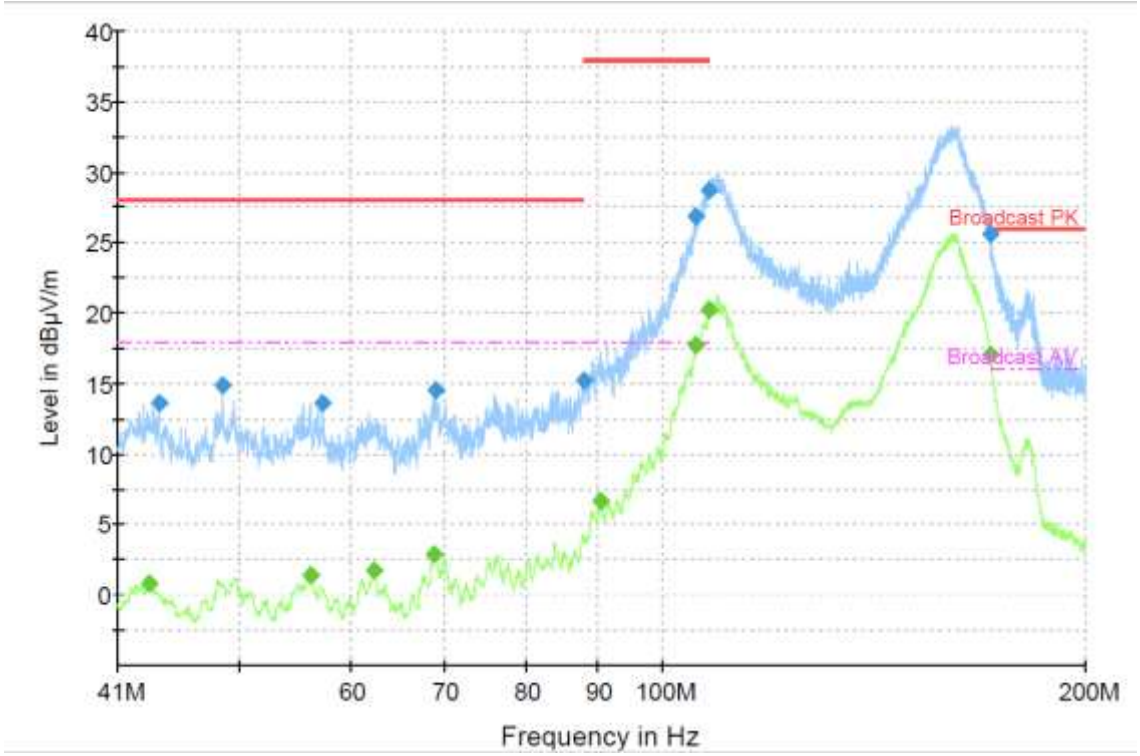


Mobile



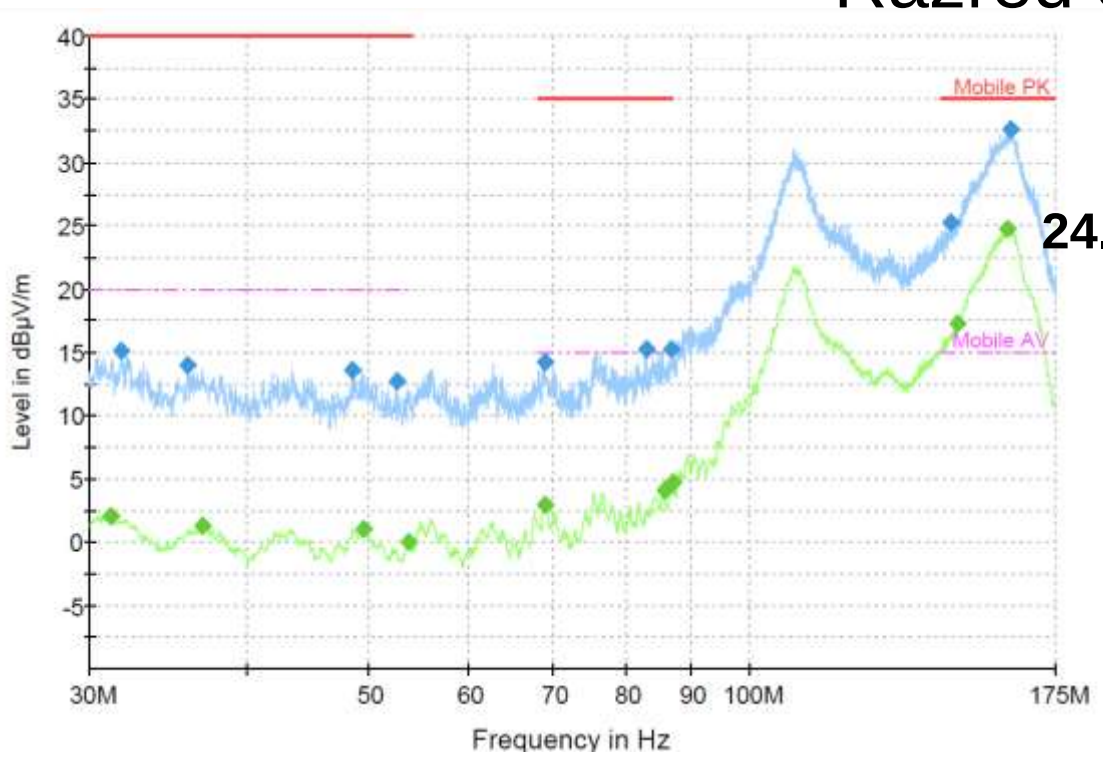
Remec: RE 30 MHz – 200 MHz

Broadcast



Mobile

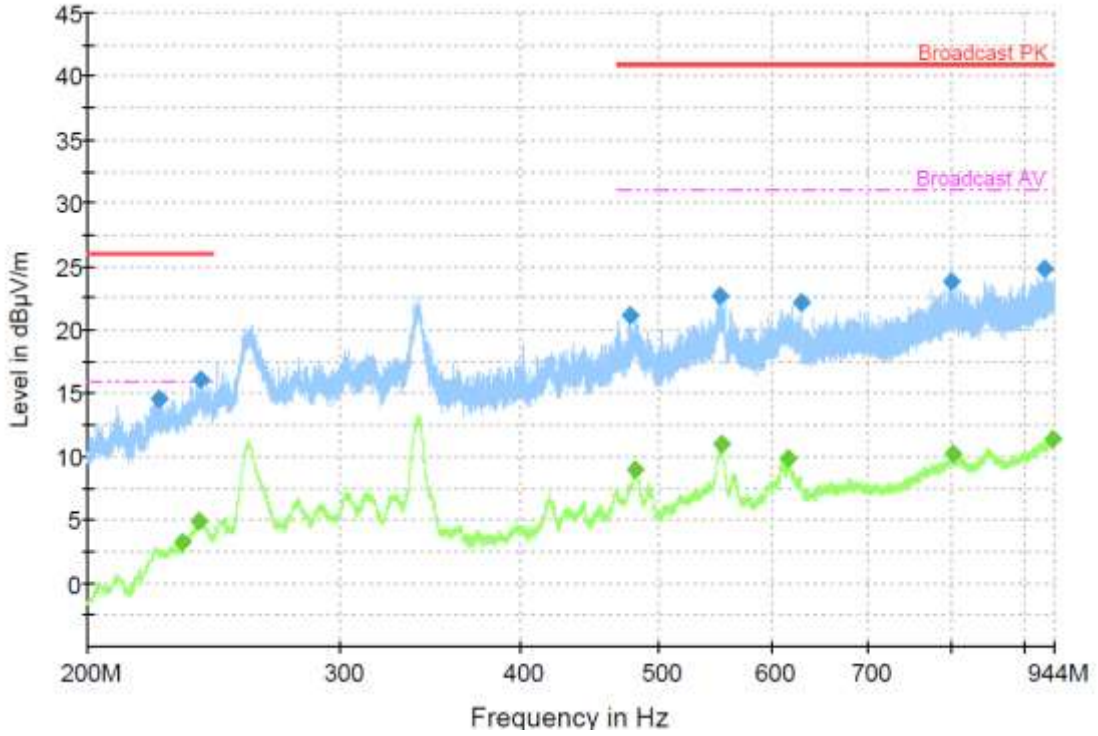
Razred 3



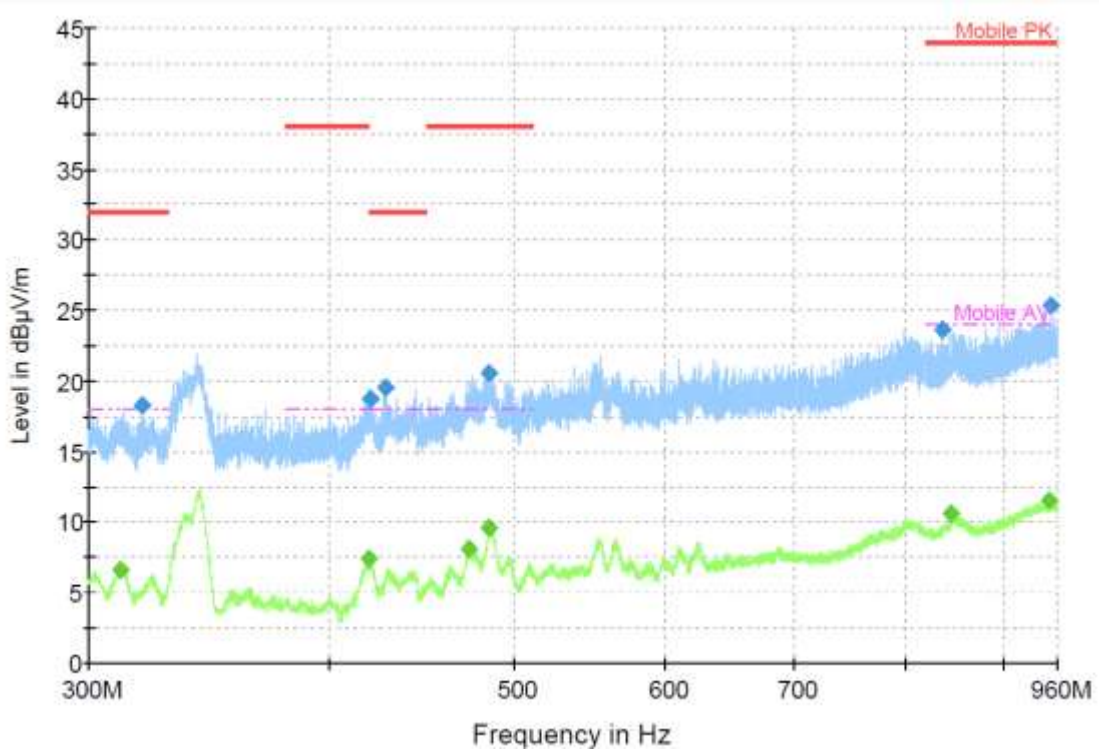
24.78

Remec: RE 200 MHz – 1 GHz

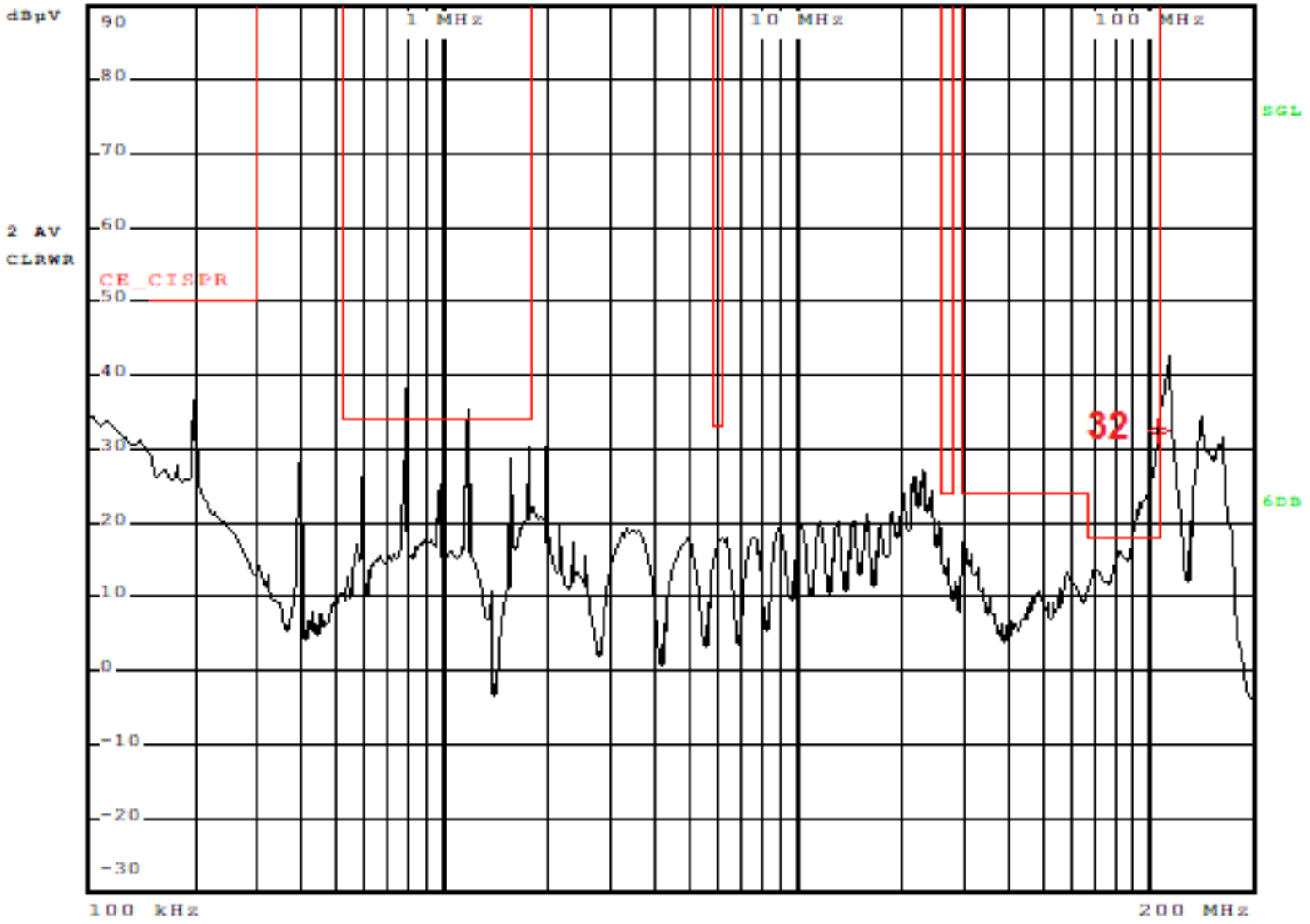
Broadcast



Mobile



Remec: CE

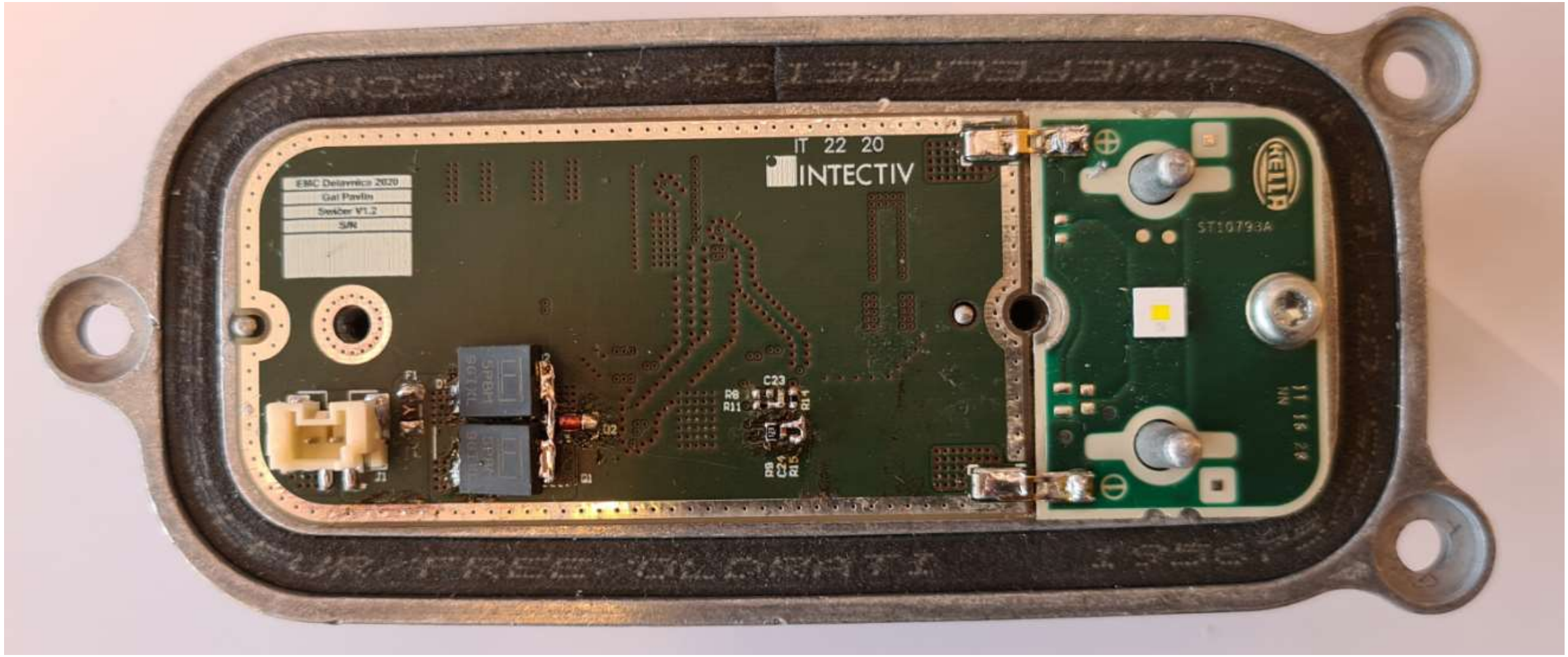


Razred 2

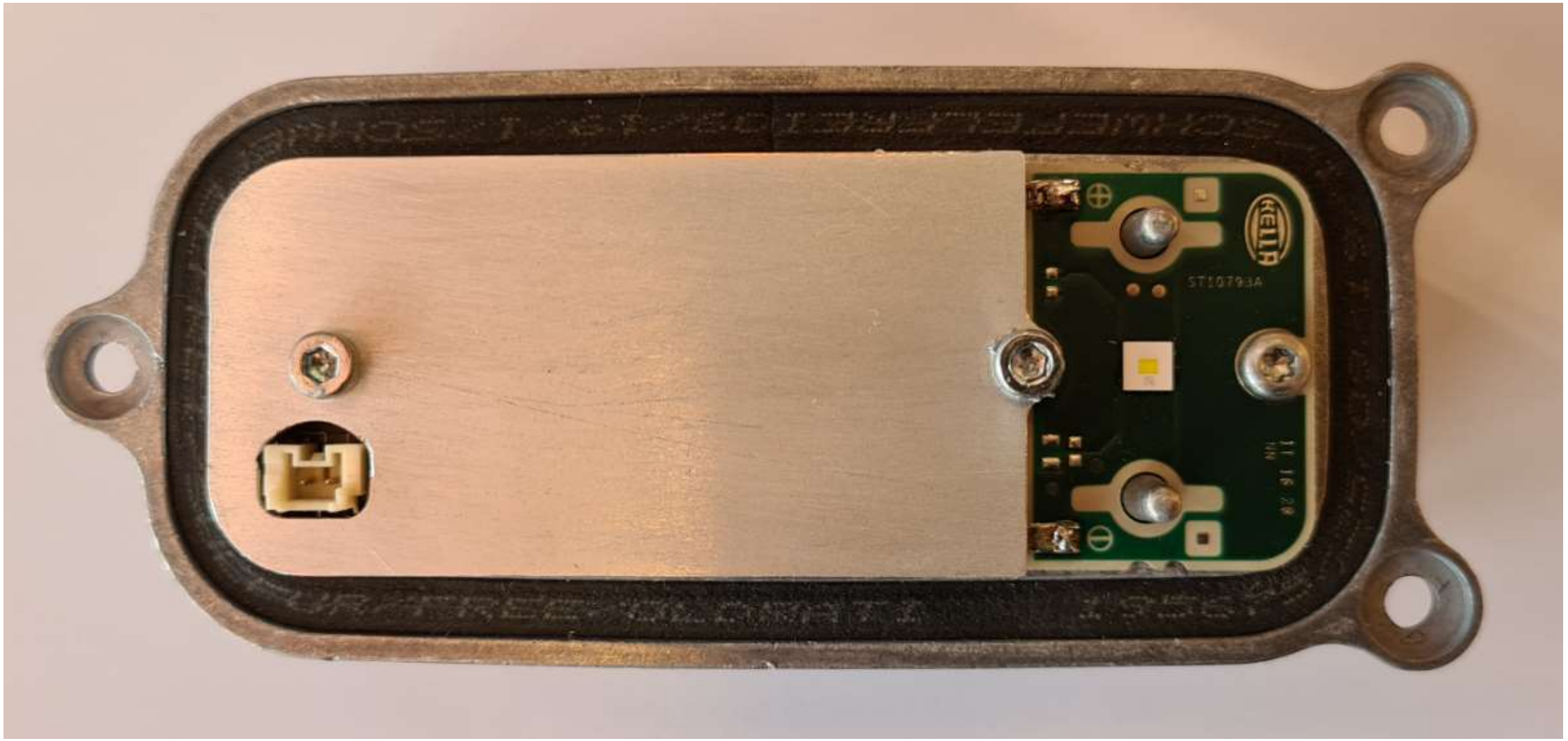
Remec: BOM

Comment	Description	Designator	Footprint	LibRef	Quantity	Price 1pc/1000pc	Price total
Cvh_a	Capacitor	C1, C3	C3216_1206I_N	C	2	0.247	0.494
Cvh_tranz	Capacitor 100n	C2, C24, C25, C26	C2012_0805I_N	C	4	0.069	0.276
Cizh_a	Capacitor 22u	C4, C21, C22, C23	C3216_1206I_N	C	1	0.101	0.101
Cizh_b	EMK325ABJ476KMHP	C5, C6, C7, C8, C20	C3216_1206I_N	C	4	0.28	1.12
Cvh_b	Capacitor 22u 25V x5r TM	C12, C13, C14, C15, C1	C3216_1206I_N	C	6	0.115	0.69
2u2	Capacitor	Cvcc, Cvin	C2012_0805I_N	C	2	0.078	0.156
MMSZ4703T1G	Zener	D1	SOD-123F_N	D	1	0.027	0.027
RB160M-40	Schottky 1A, 40V	Dboot	SOD-123F_N	RB160M-40	1	0.076	0.076
10 uH, 8.8 A	WE-LHMI, size 1365, 10 ul	L1	WE-LHMI_1365	744373965100	1	1.56	1.56
1R5	74437349015	L2	WE-LHMI_7050		2	1.31	2.62
10uH	WE-LHMI	L3	WE-LHMI_7050		2	2.01	4.02
SQJ940EP-T1_GE3	MOSFET (N-Channel)	Q1	SQJ940EPT1_GE3	SQJ940EP-T1_GE3	1	0.38	0.38
DMP3018SFVQ-13	MOSFET (P-Channel)	Q2	DMP3007SFG7	DMP3018SFVQ-13	1	0.178	0.178
ferite bead	782853131	R_FB	R1608_0603I_N-equic	R	1	0.039	0.039
10m	R	Rcs1	R3216_1206I_N	R	1	0.069	0.069
						Skupaj:	**11.806**

Gal Pavlin


IT 22 20
INTECTIV
EMC Delavnica 2020
Gal Pavlin
Senčer V1.2
S/N
HELLA
ST10793A

Gal Pavlin



Pavlin:Delovanje

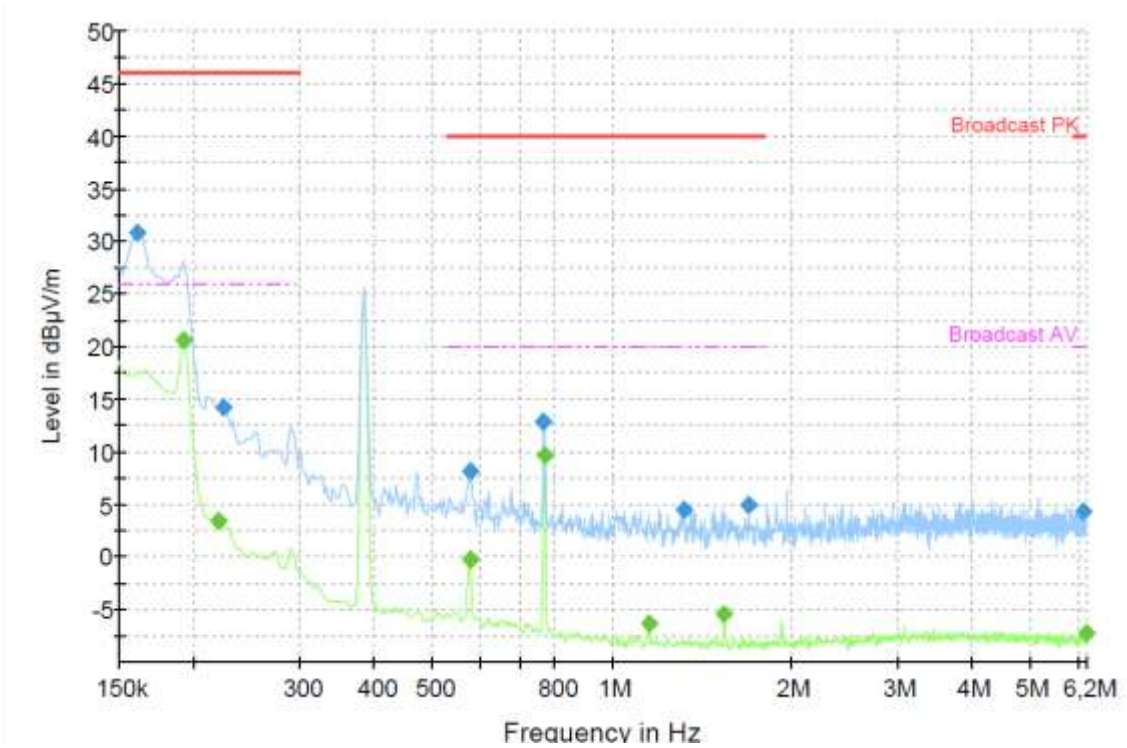
Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
7	18	1.8	13.5	24.3

Iout [A]	Uout [V]	Pout [W]	n [%]
5.8	3.64	21.112	**86.9**

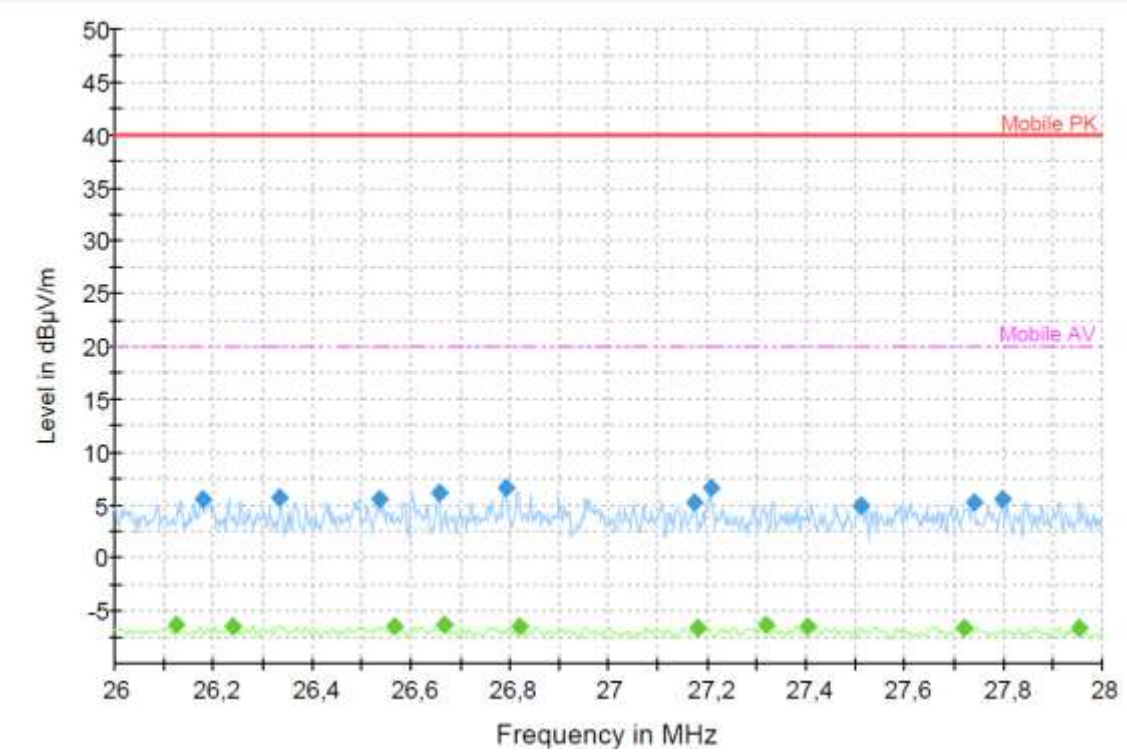
Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
140	**	**	40

Pavlin: RE 150 kHz-30 MHz

Broadcast

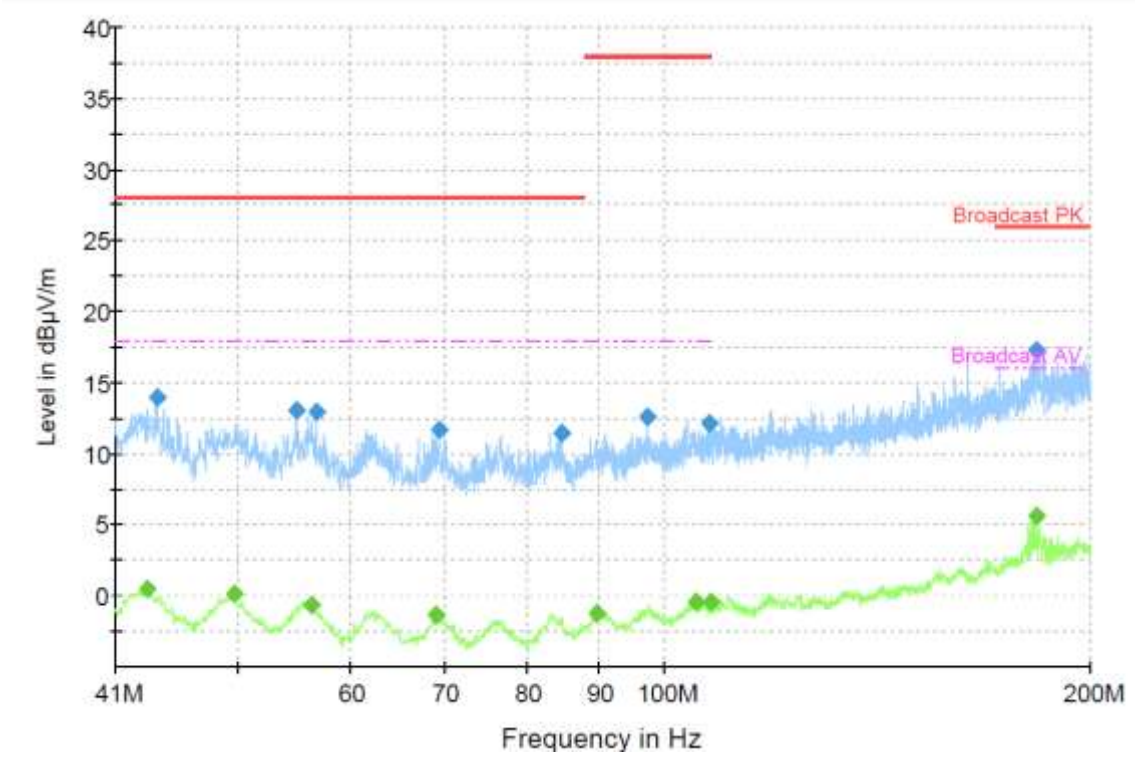


Mobile

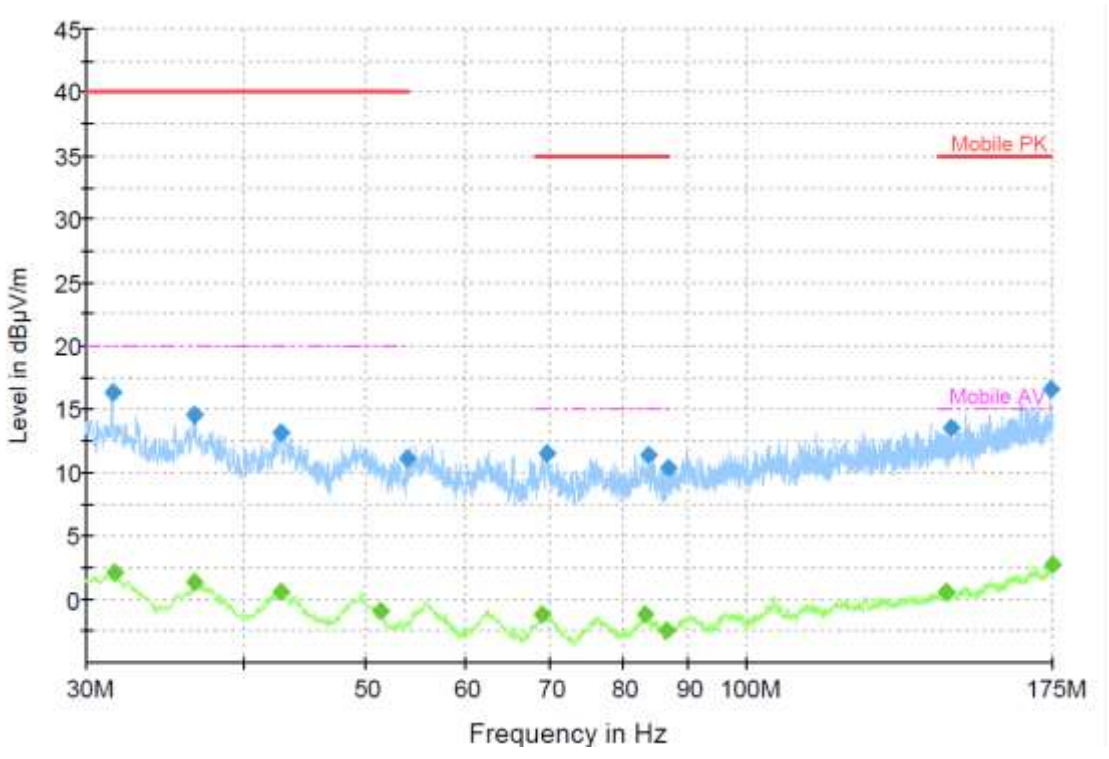


Pavlin: RE 30 MHz – 200 MHz

Broadcast

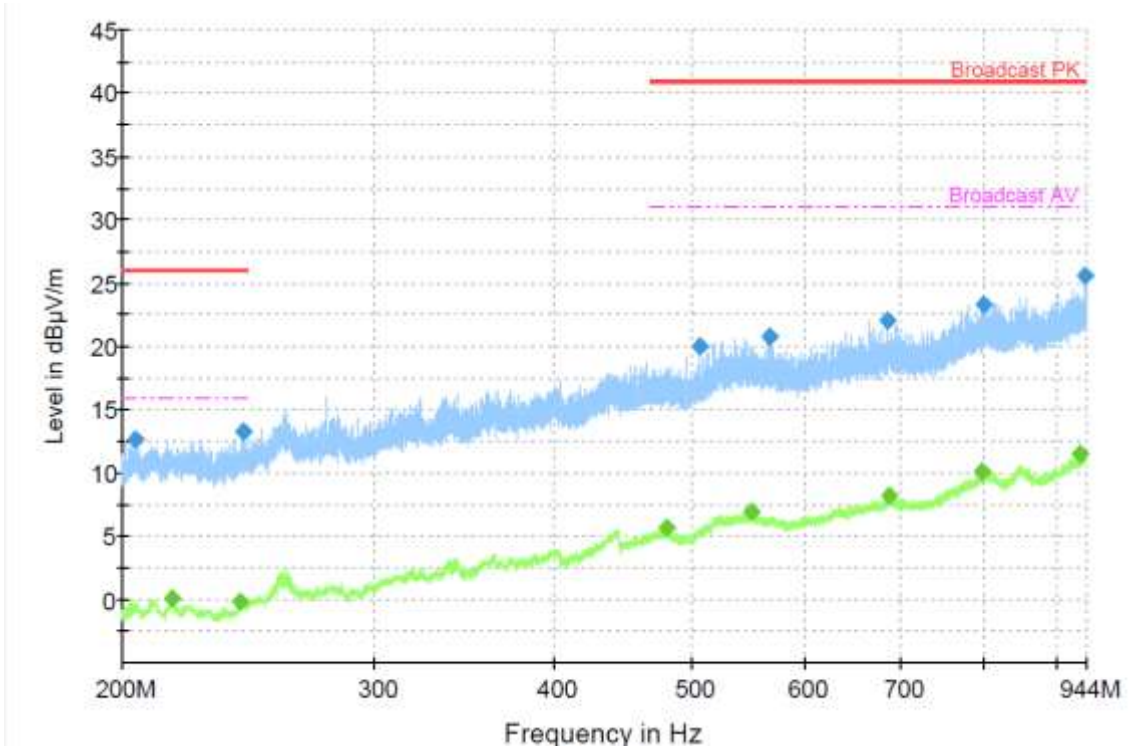


Mobile

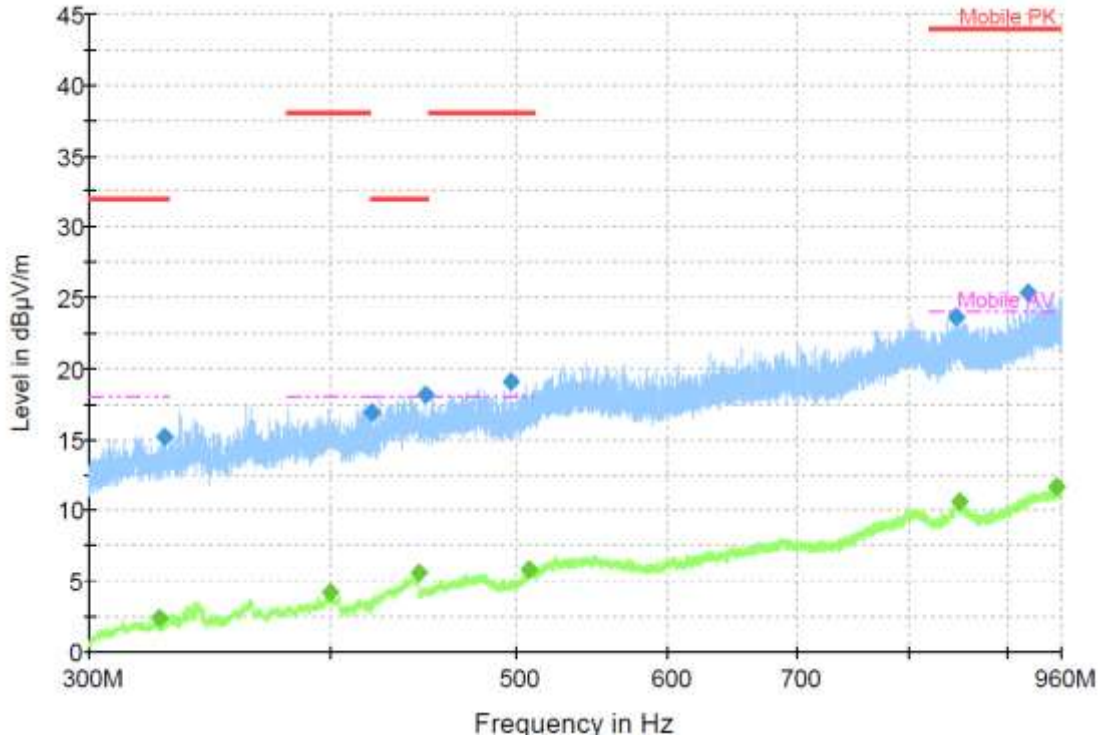


Pavlin: RE 200 MHz – 1 GHz

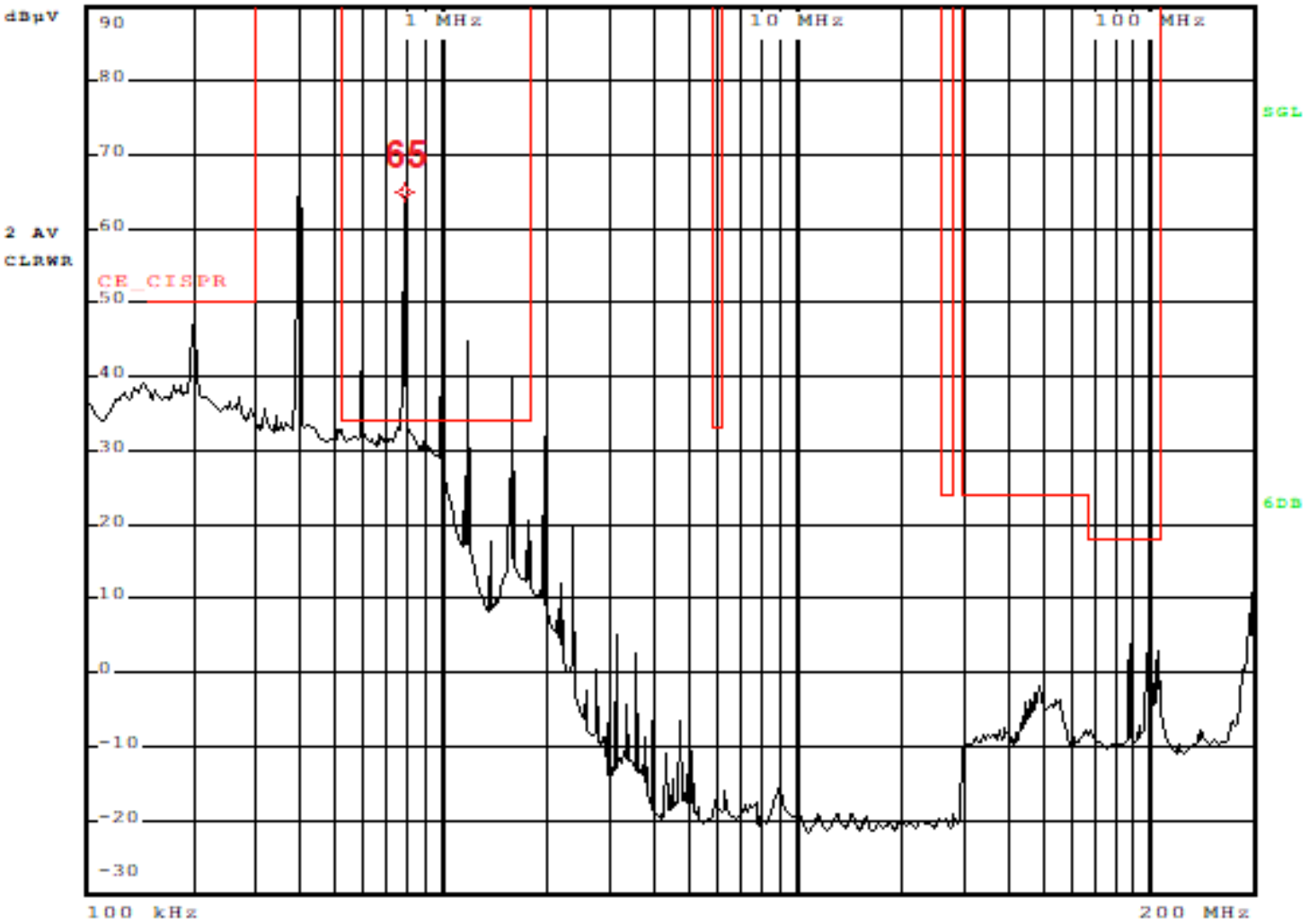
Broadcast

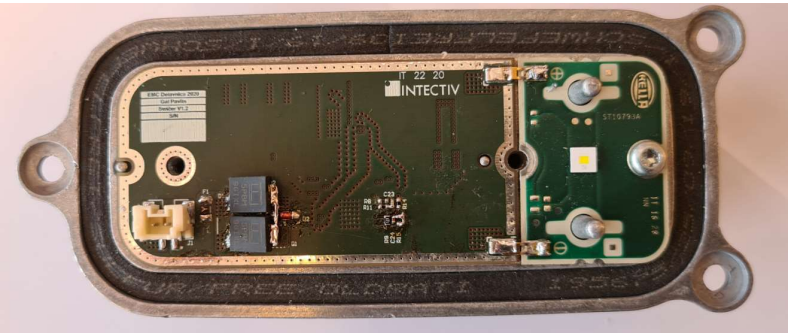


Mobile



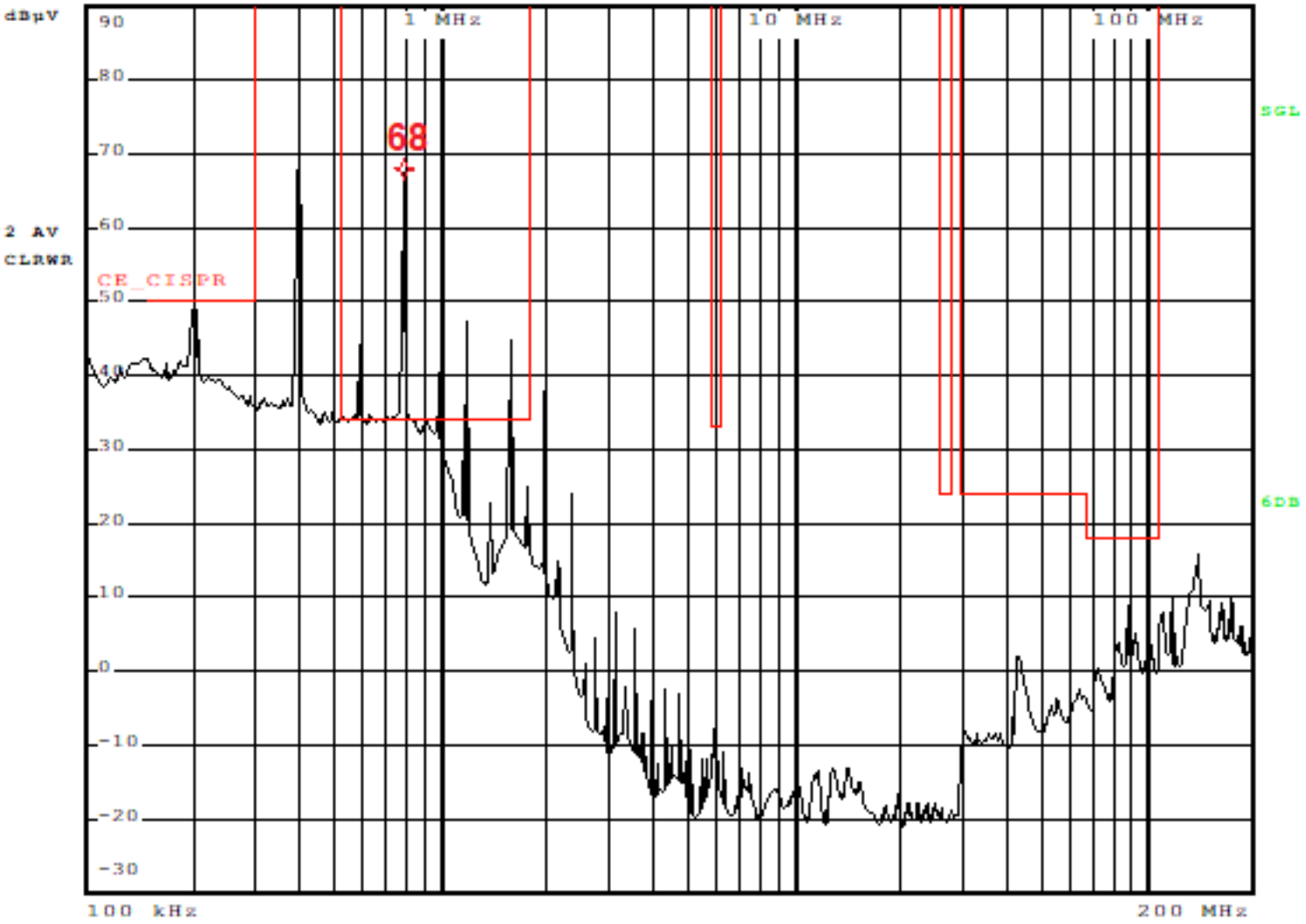
Pavlin: CE brez TB

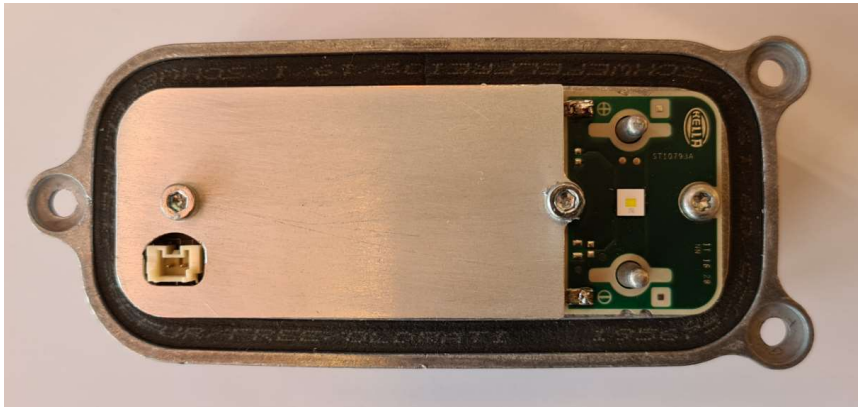




Za 1 dB pod razred 1

Pavlin: CE z TB



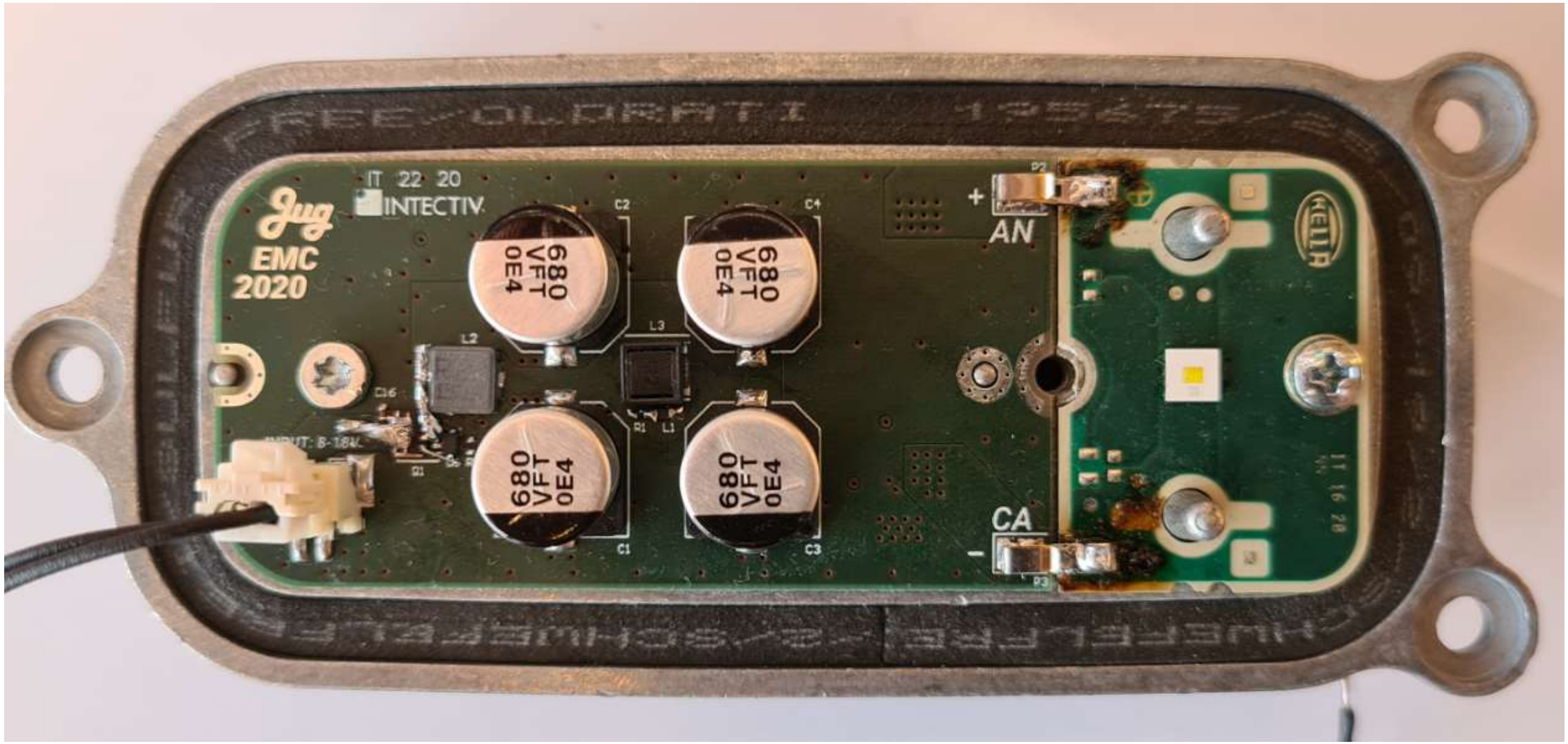


Za 2 dB čez razred 1

Pavlin: BOM

Designator	P/N	Quantity
C1	865080542005	1
C5, C6	875105544003	2
C13, C14, C15, C16	885012208094	4
C17, C18, C19, C20, C21	885012207053	5
D1	5.0SMDJ18AS	1
D2	BZT52-B12X	1
D3	PMEG4010BEA115	1
D4	ES1A-M3/61T	1
F1	C1T5	1
FB1	742792693	1
L1	74437324010	1
L2	744373965047	1
Q1	TPN1R603PL	1
Q2	BSZ0506NSATMA1	1
Q3	FDMC8010ET30	1
R14	WSL1206R0100FEA	1
https://octopart.com/bom-tool/ulz03DFT		**6.99 € each**

Matjaž Jug


Jug
EMC
2020
IT 22 20
INTECTIV
680
VFT
0E4
680
VFT
0E4
680
VFT
0E4
680
VFT
0E4
AN
CA
+
–
HELLA

Jug: Delovanje

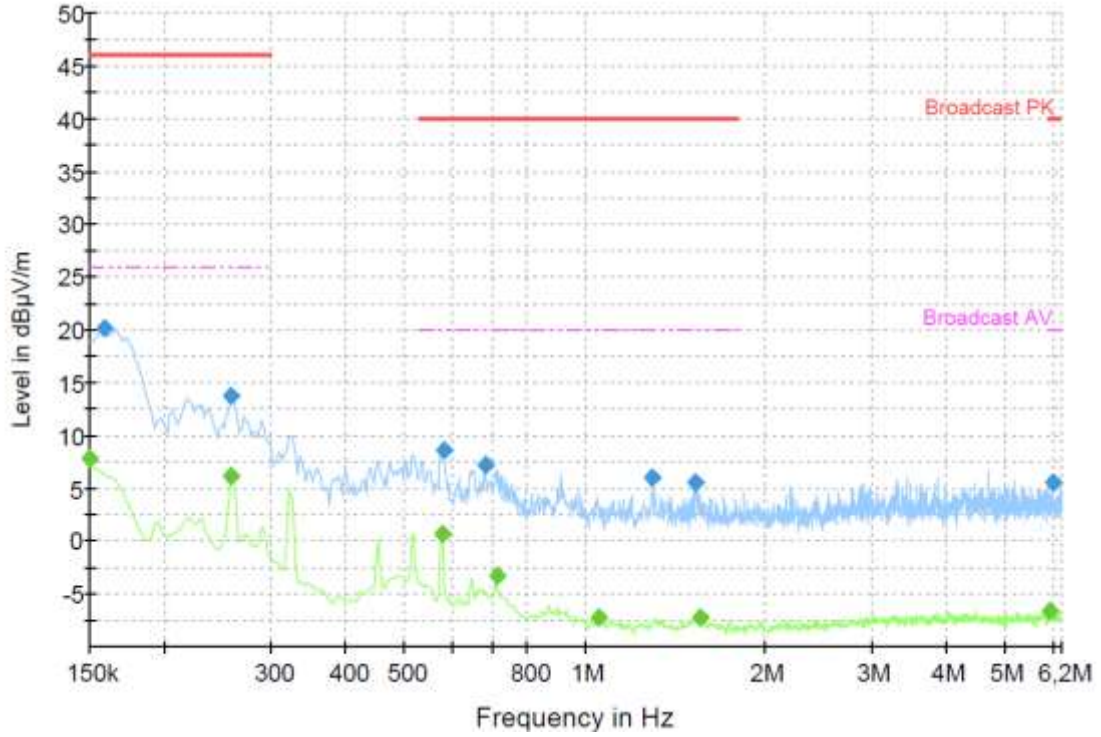
Iout [A]	Uout [V]	Pout [W]	n [%]
5.85	3.48	20.358	**82.9**

Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]
7	18	1.82	13.5	24.57

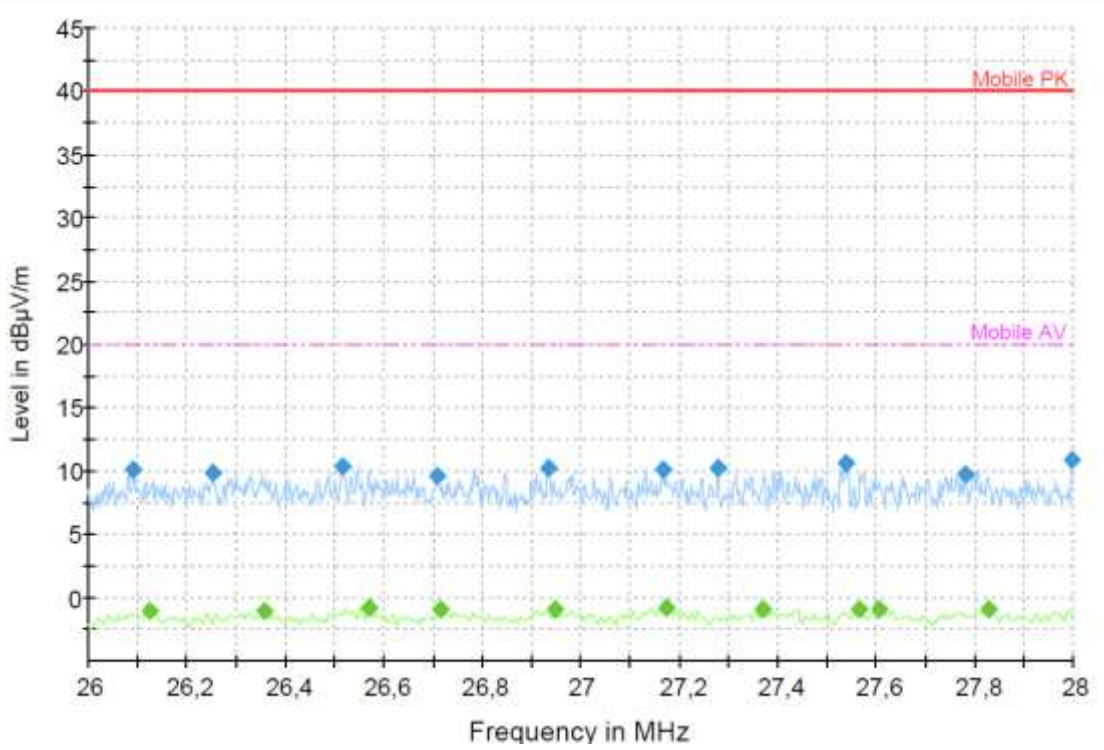
Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]
1480	**5.04**	6.52	**240**

Jug: RE 150 kHz-30 MHz

Broadcast

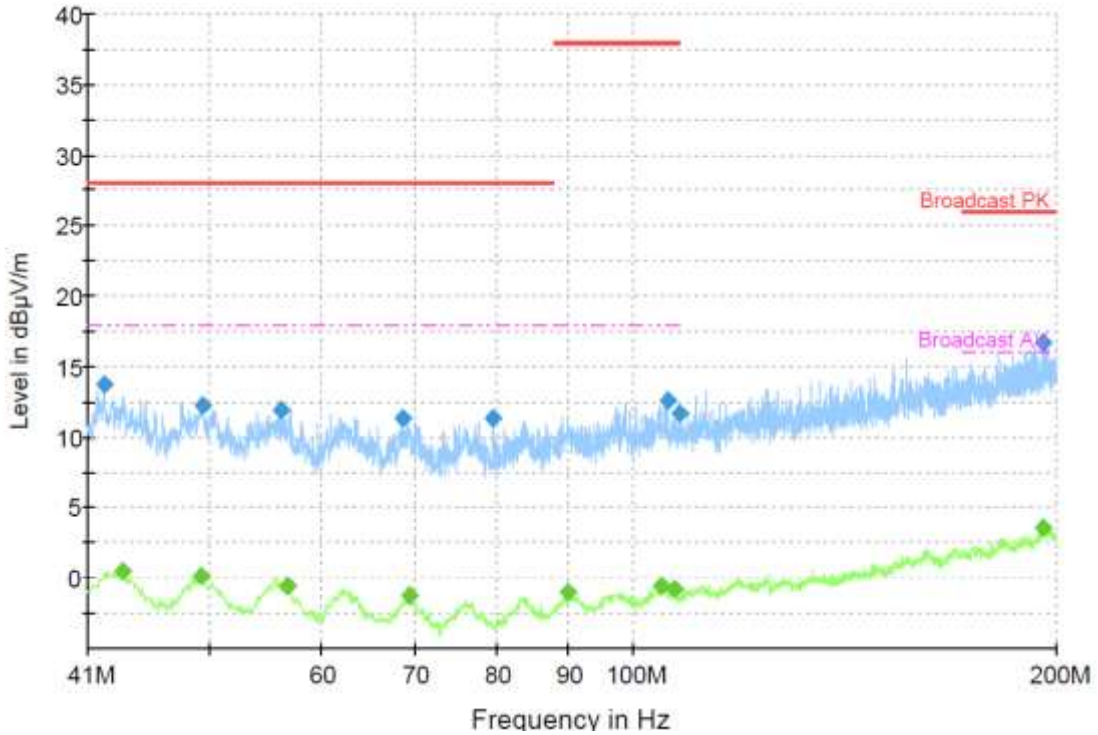


Mobile

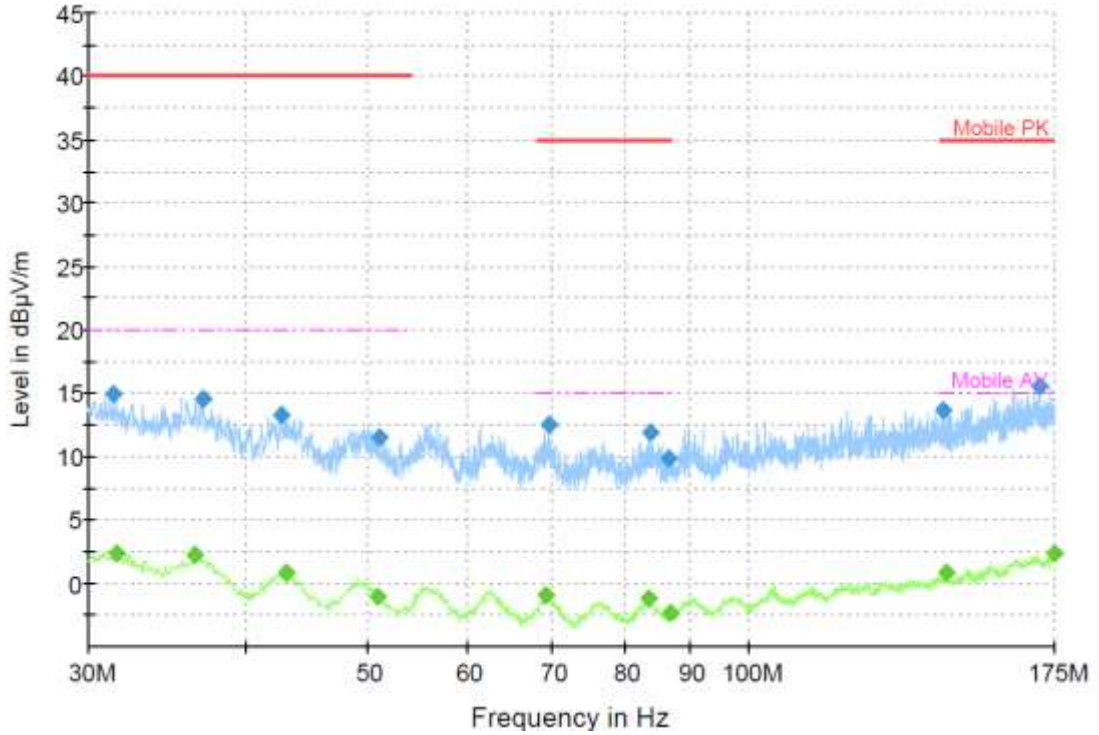


Jug: RE 30 MHz – 200 MHz

Broadcast

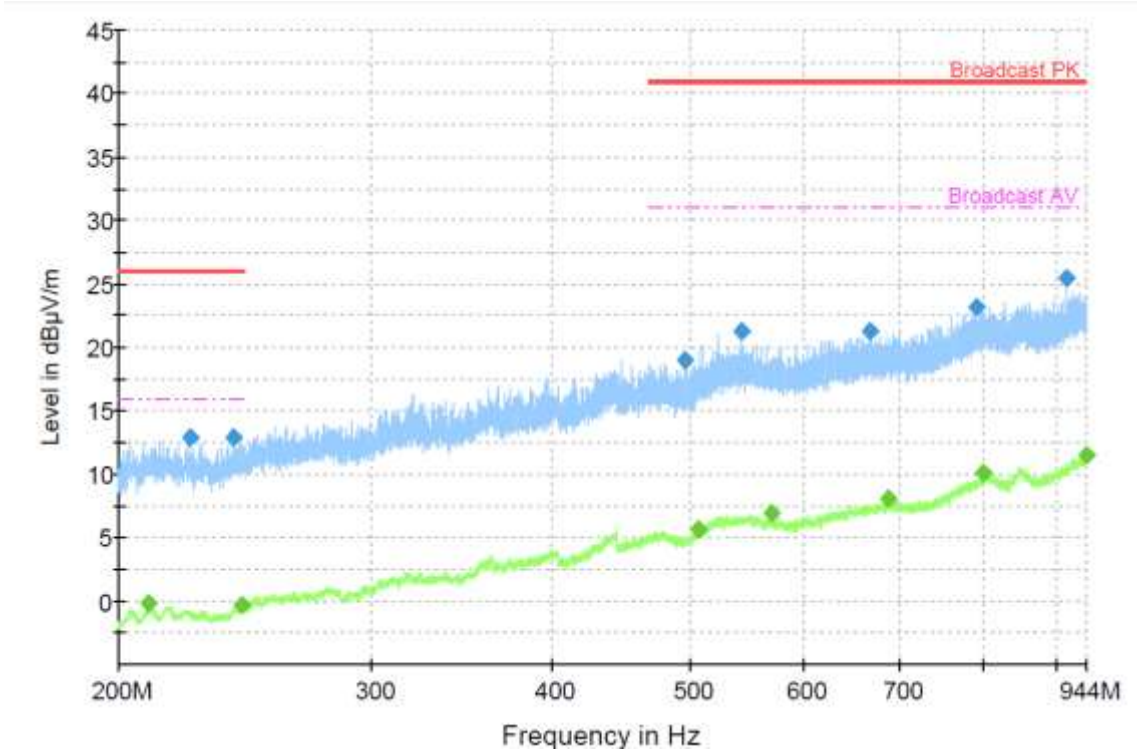


Mobile

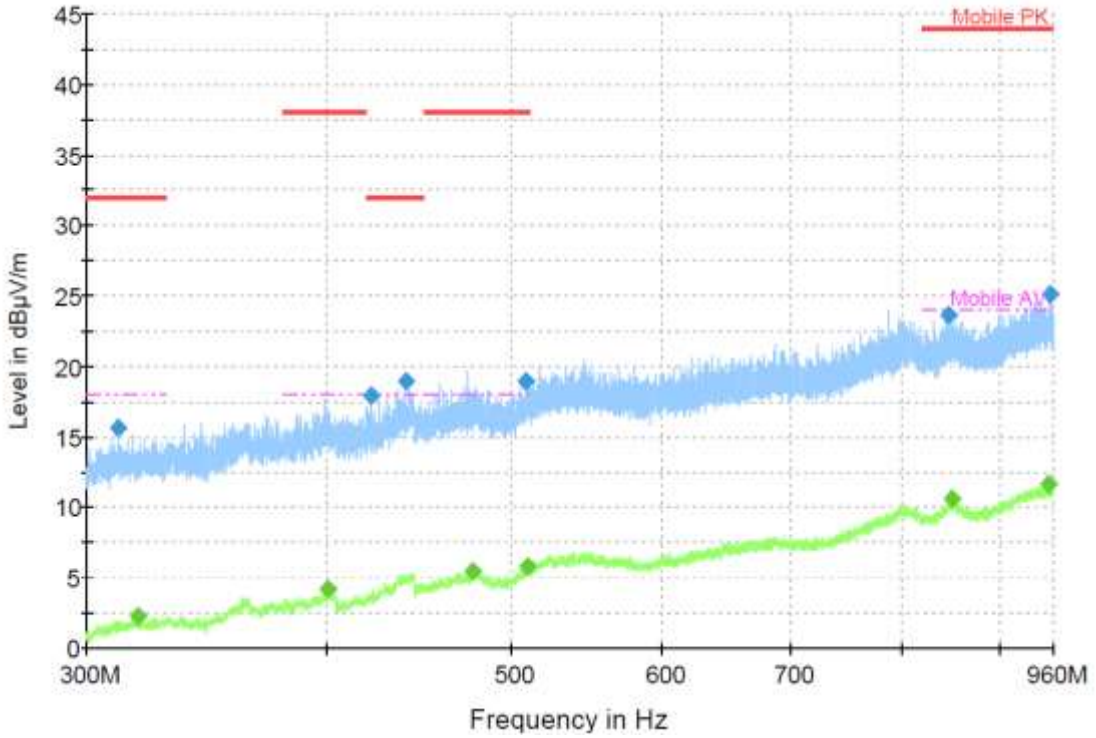


Jug: RE 200 MHz – 1 GHz

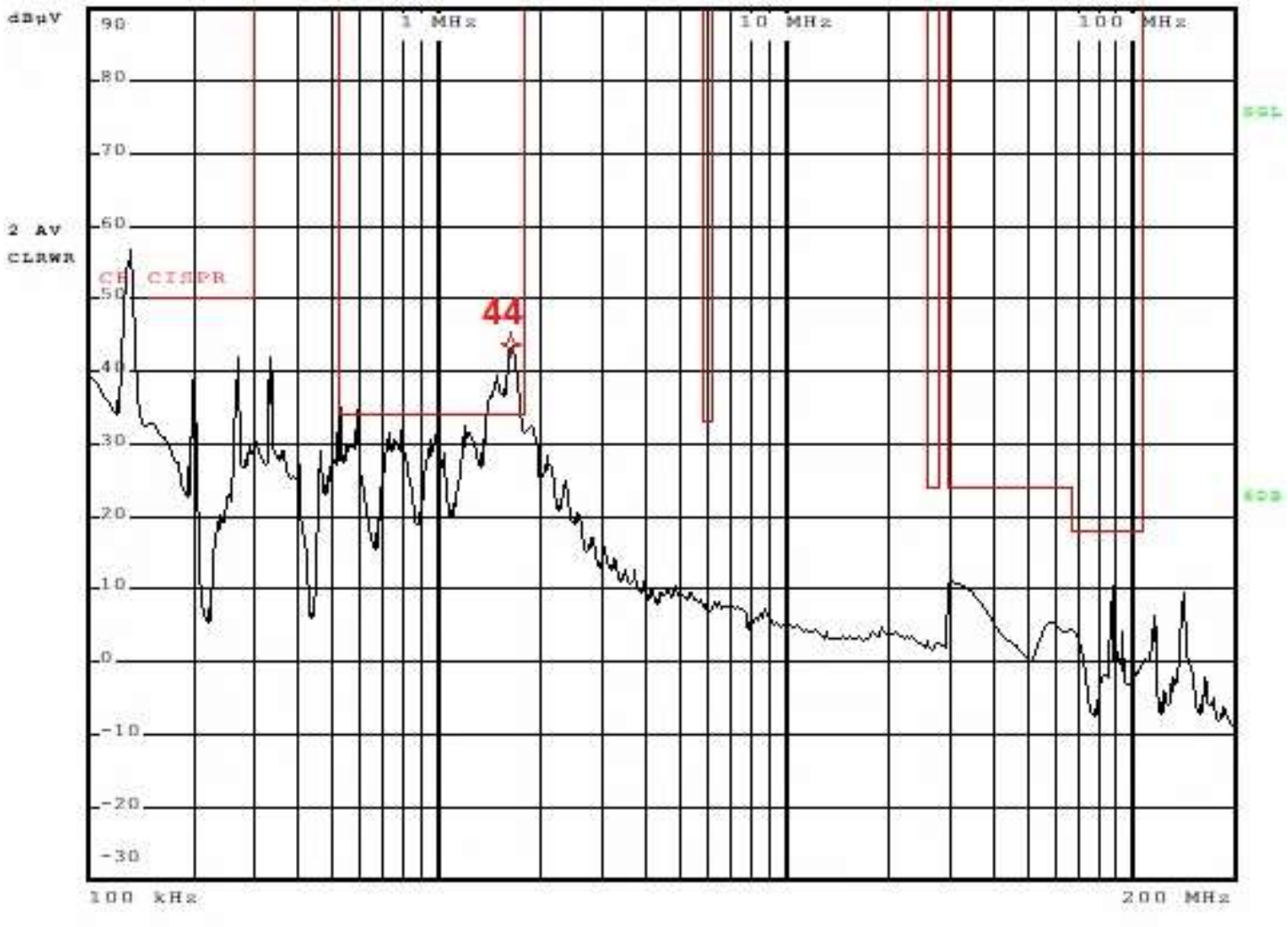
Broadcast



Mobile



Jug: CE



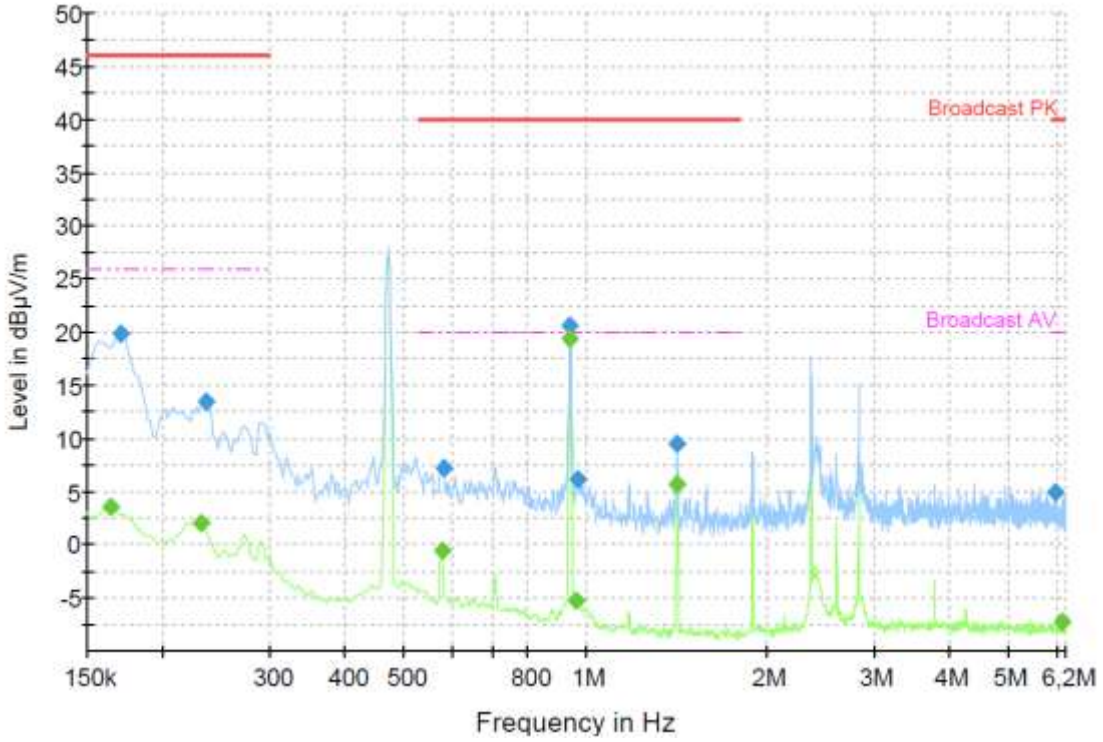
Razred 3

Jug: BOM

Področje uporabe	Part number	opis	količir	cena pri 1000 kc	skupa	Colum
Vhodna zaščita	DMP3007SFG	P MOSFET	1	0.316	0.316	
Vhodni filter	SRP5015TA-R20Y	tuljava	1	0.53	0.53	
Vhodni filter	EEEFK1E681SP	kondenzator	4	0.264	1.056	
Vhodni filter	SRR4828A-1R2Y	tuljava	1	0.335	0.335	
Switcher	SiZ998DT	dual MOSFET	1	0.525	0.525	
Switcher	PA4344.473NLT	tuljava	1	1.751	1.751	
Switcher	TMK325ABJ476MM-T	kondenzator	3	0.368	1.104	
Izhodni filter	SRP5030TA-1R2M	tuljava	1	0.415	0.415	
Switcher	RL2010FK-070R01L	upor 10mR	1	0.134	0.134	
				skupaj USD:	6.166	**5.10 €**

Hella: RE 150 kHz-30 MHz

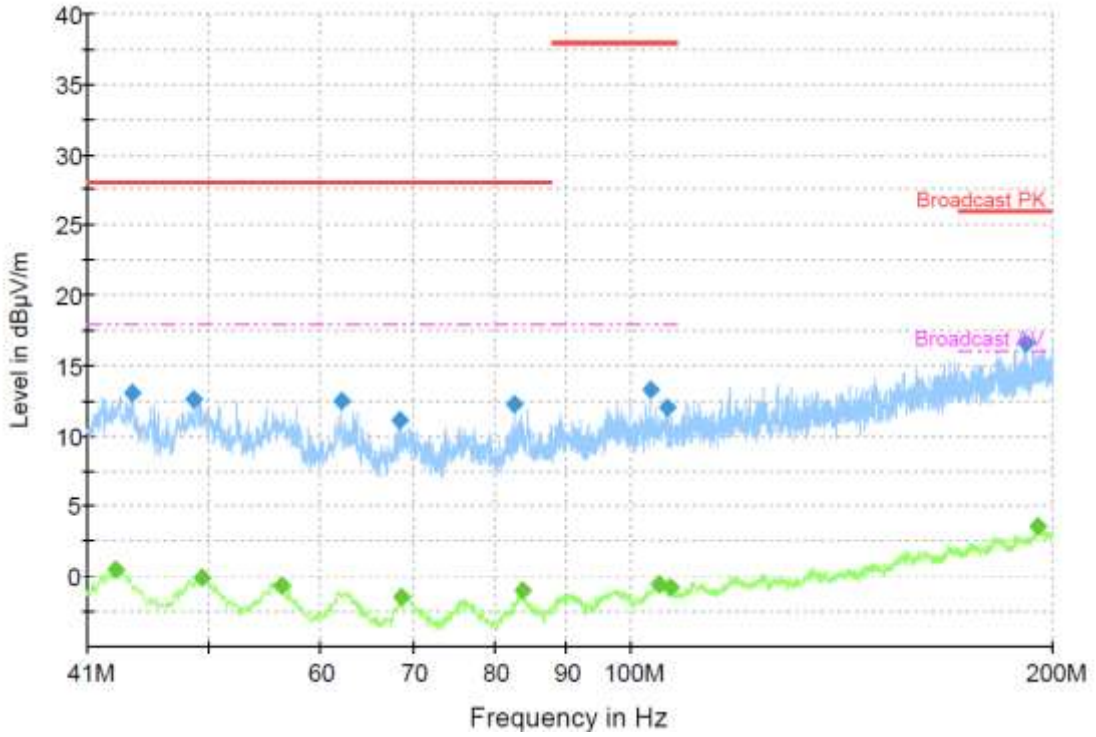
Broadcast



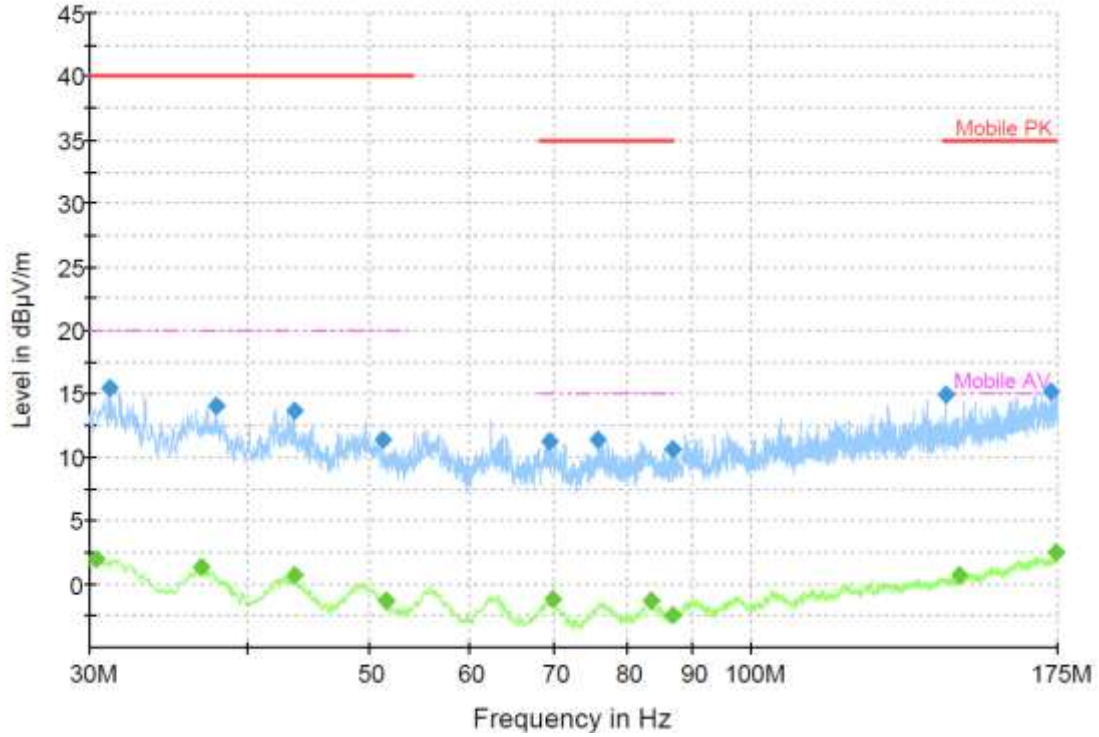
Mobile

Hella: RE 30 MHz – 200 MHz

Broadcast

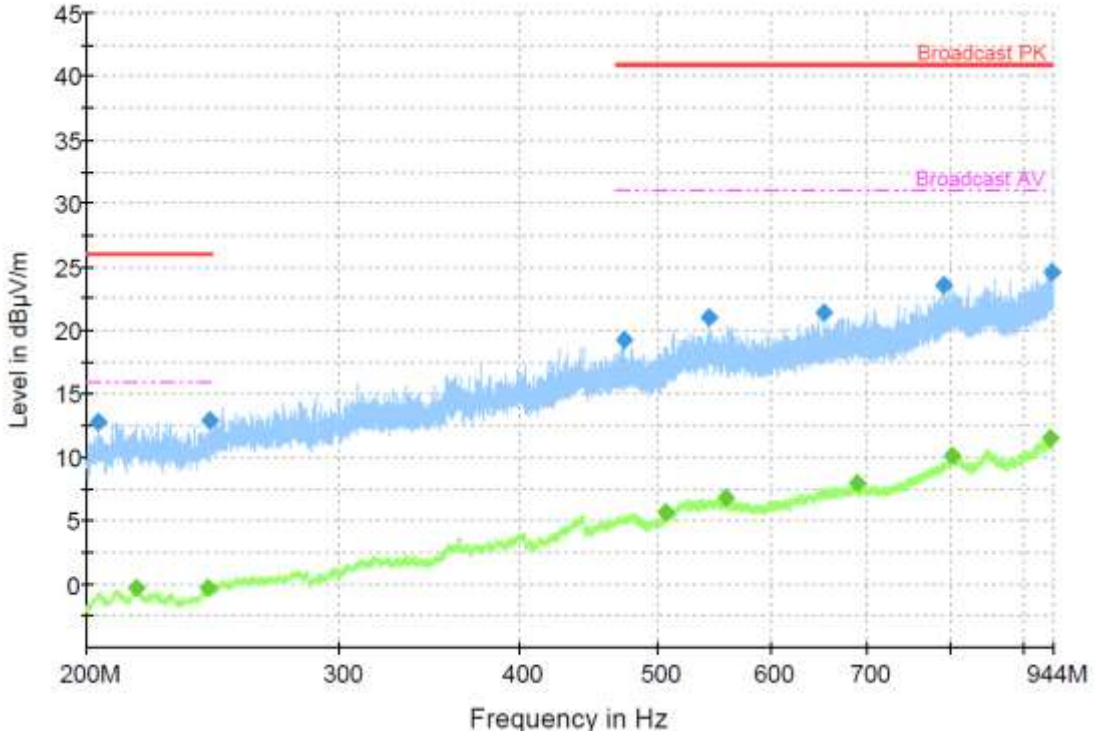


Mobile

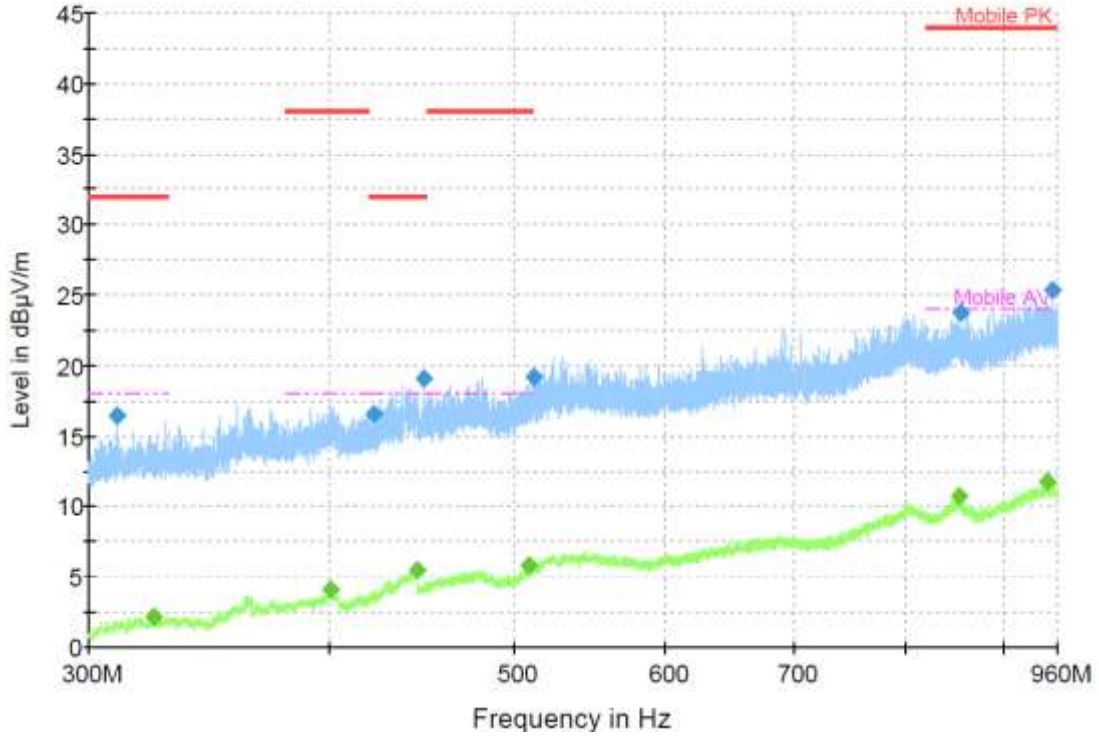


Hella: RE 200 MHz – 1 GHz

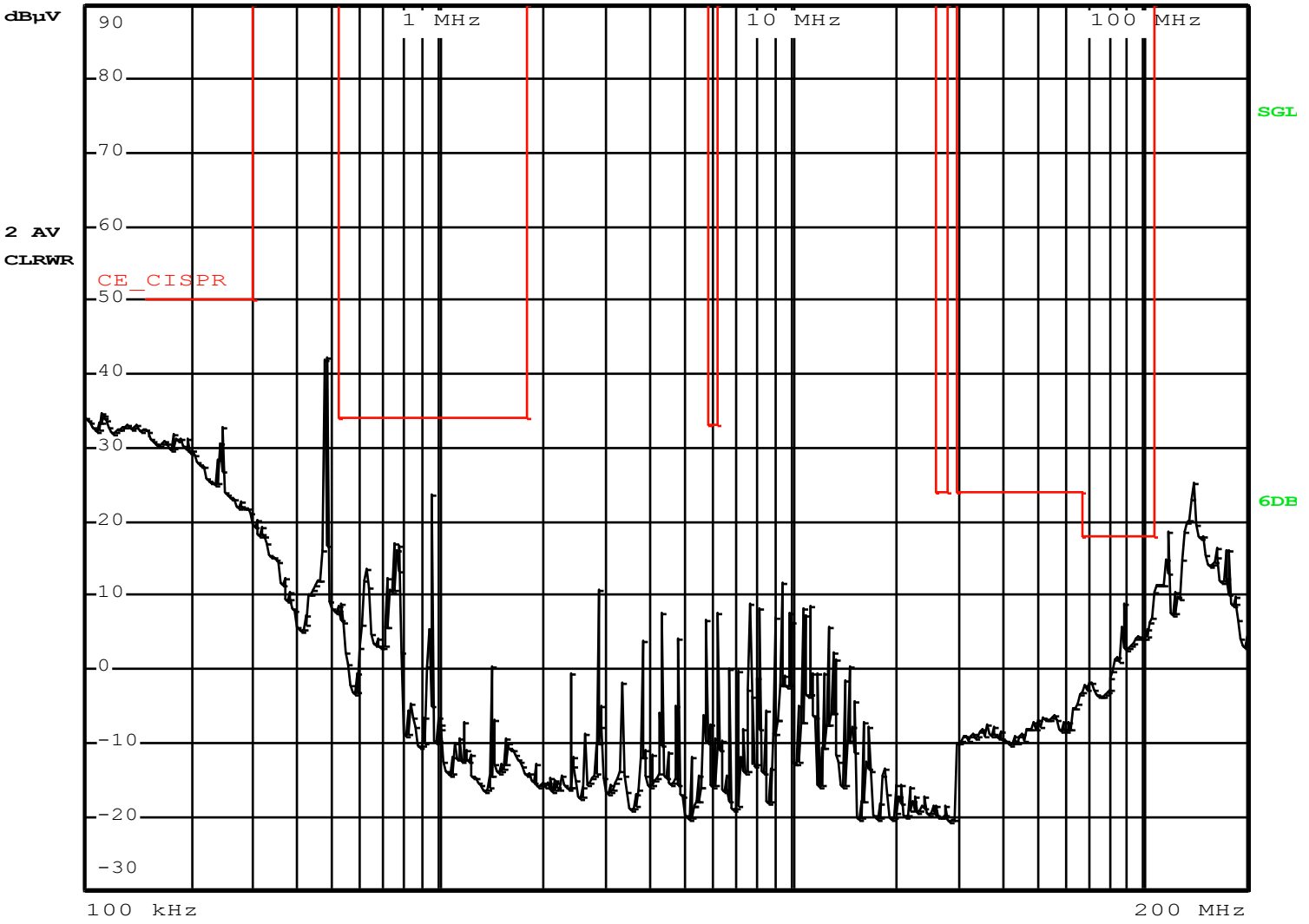
Broadcast



Mobile

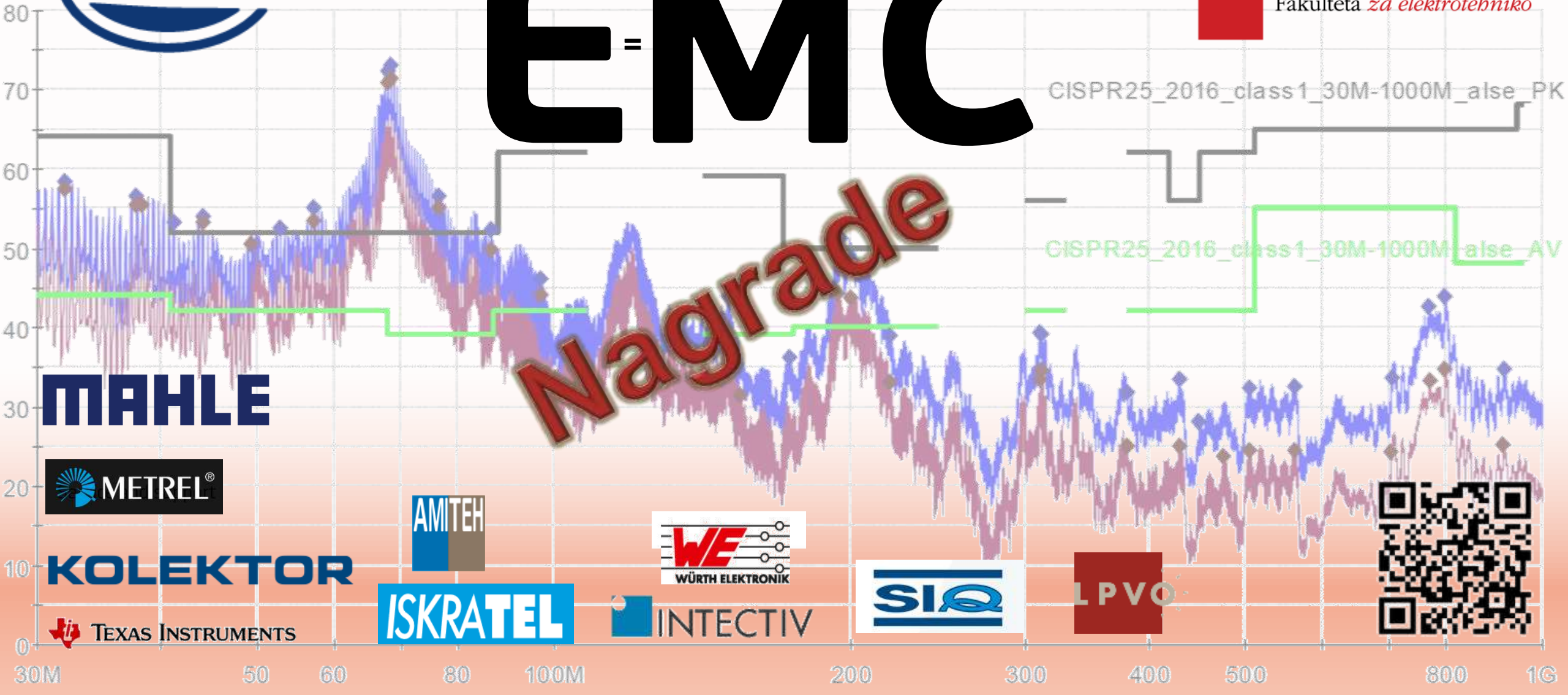


Hella: CE


dBµV
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
1 MHz
10 MHz
100 MHz
SGL
6DB
2 AV
CLRWR
CE_CISPR
100 kHz
200 MHz

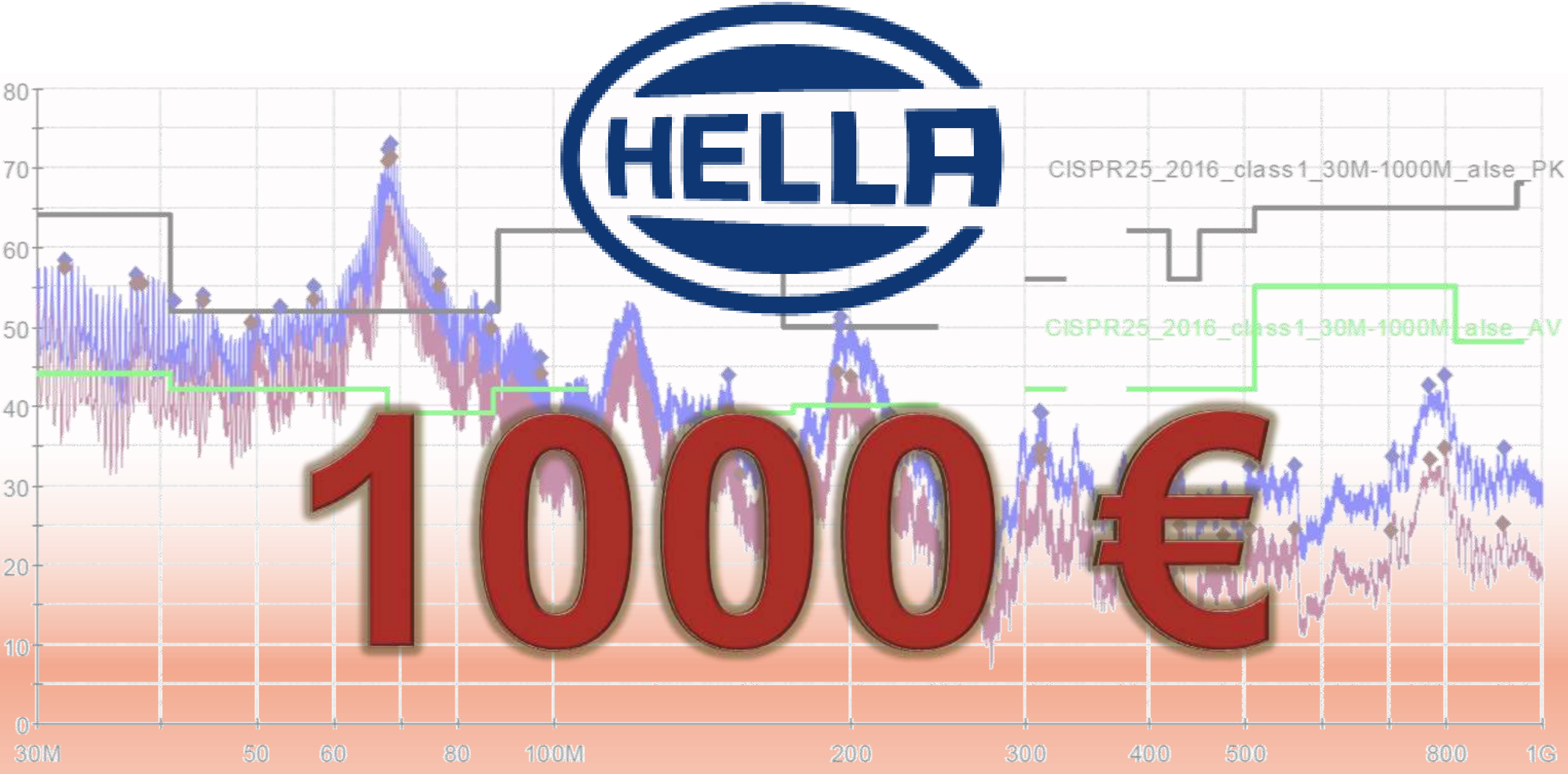
Načrtovanje elektronike za $E=MC^2$

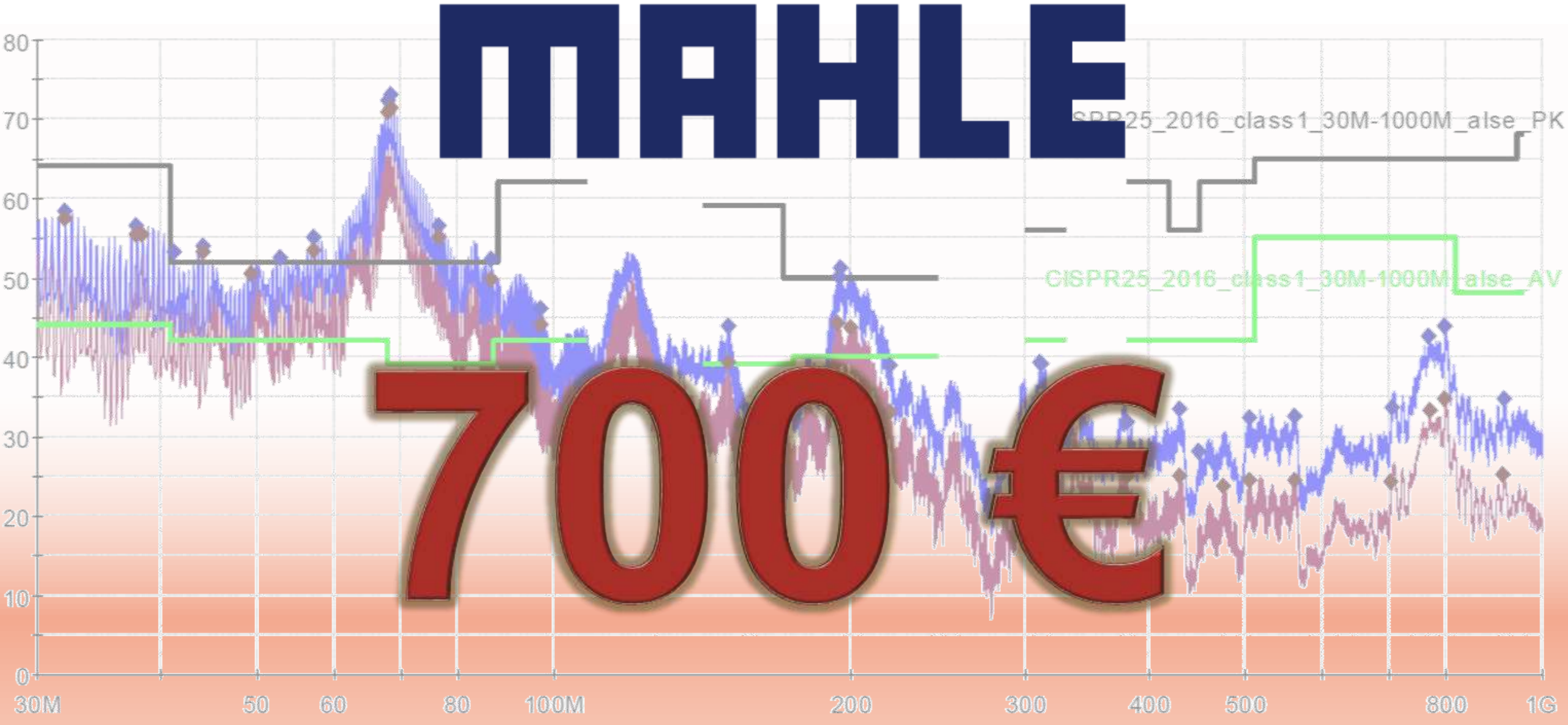
Univerza v Ljubljani
Fakulteta za elektrotehniko

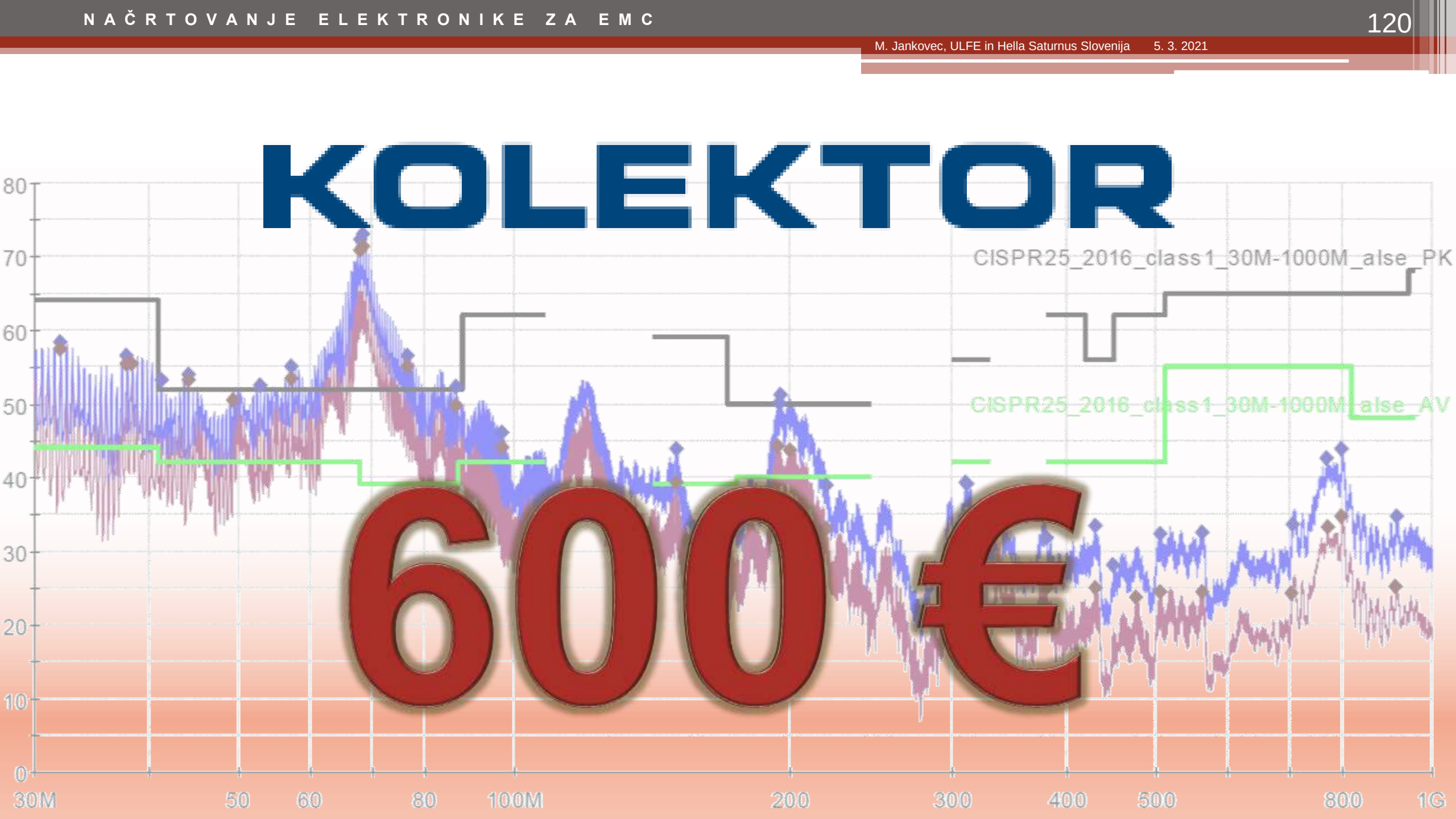


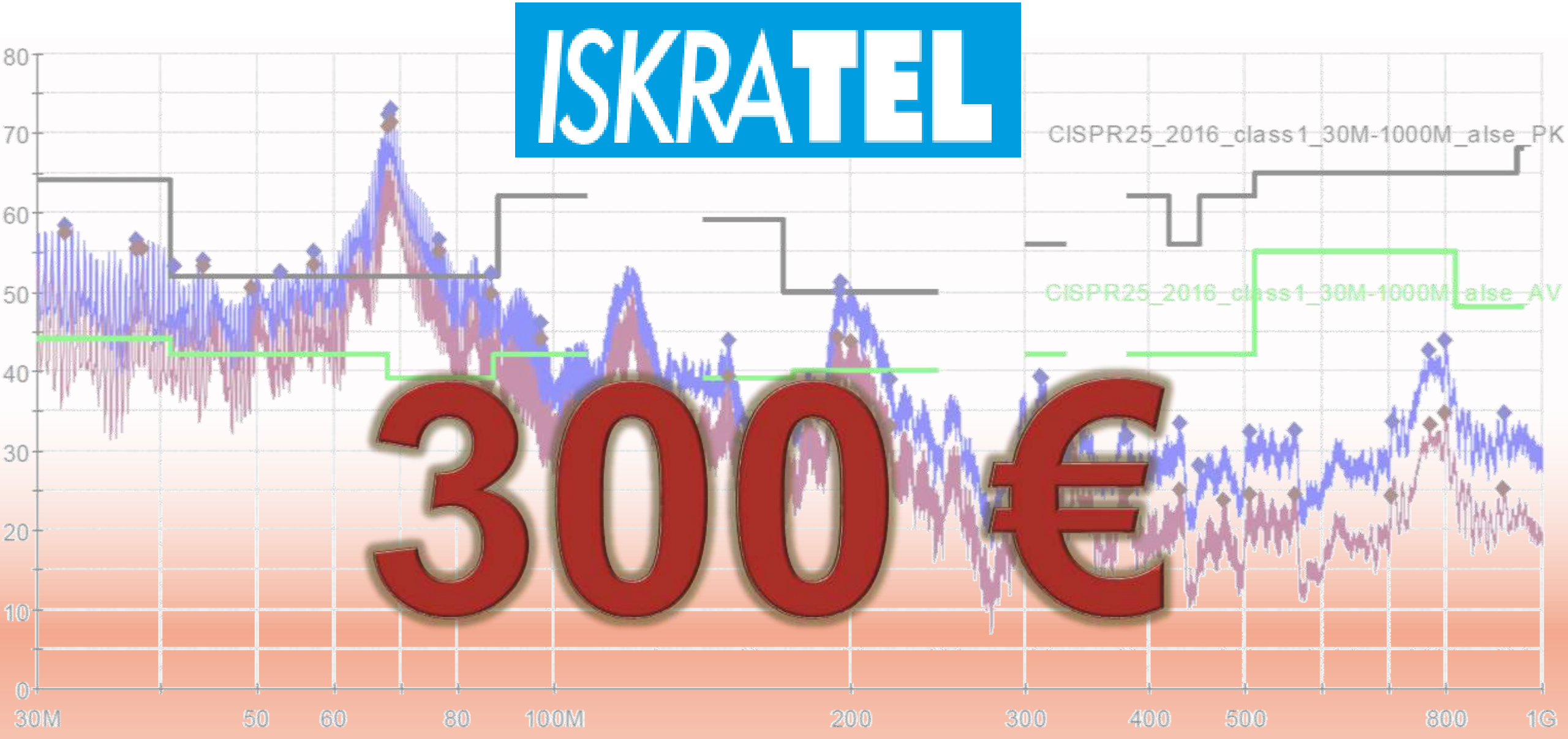
Nagrade

HELLA
MAHLE
METREL
KOLEKTOR
AMITEH
ISKRATEL
TEXAS INSTRUMENTS
WÜRTH ELEKTRONIK
INTECTIV
SIQ
LPVO

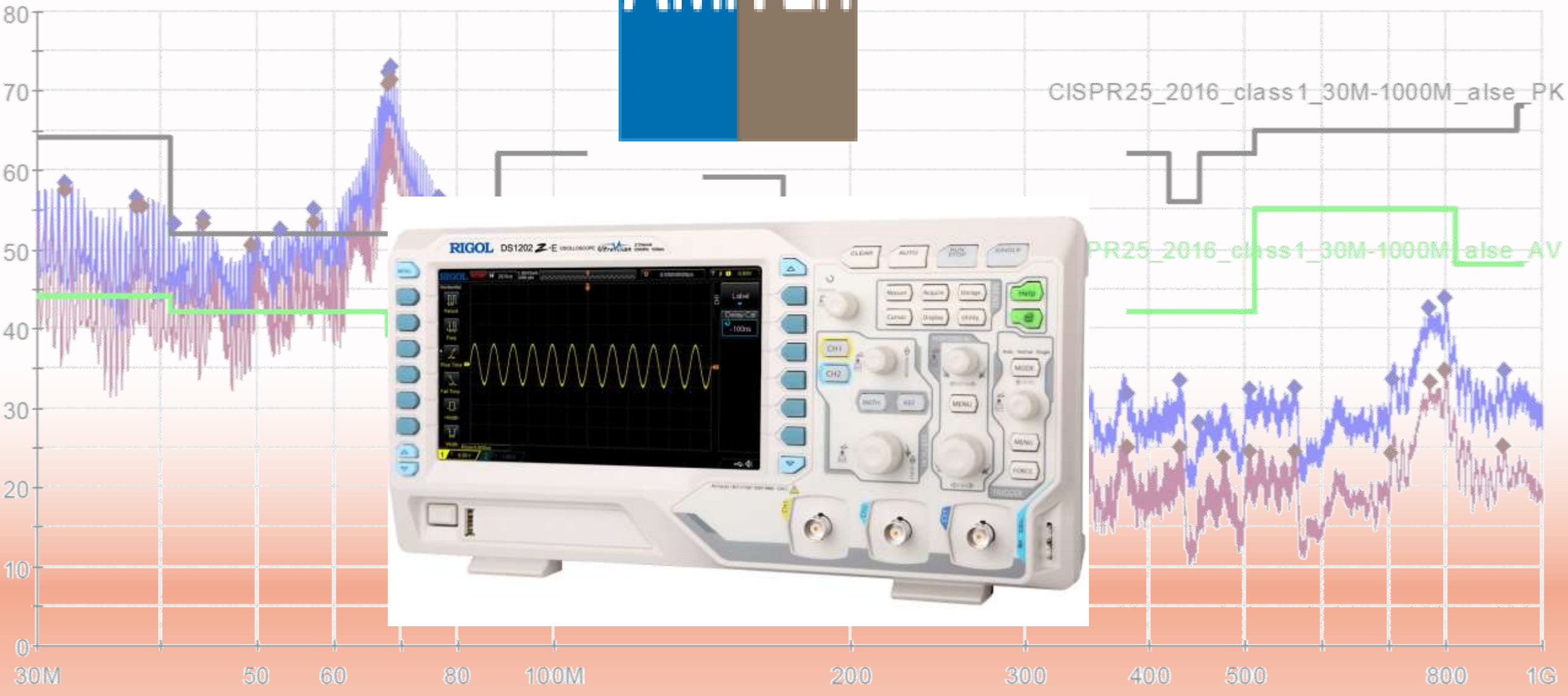

HELLA
CISPR25_2016_class1_30M-1000M_alse_PK
CISPR25_2016_class1_30M-1000M_alse_AV
1000€
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G

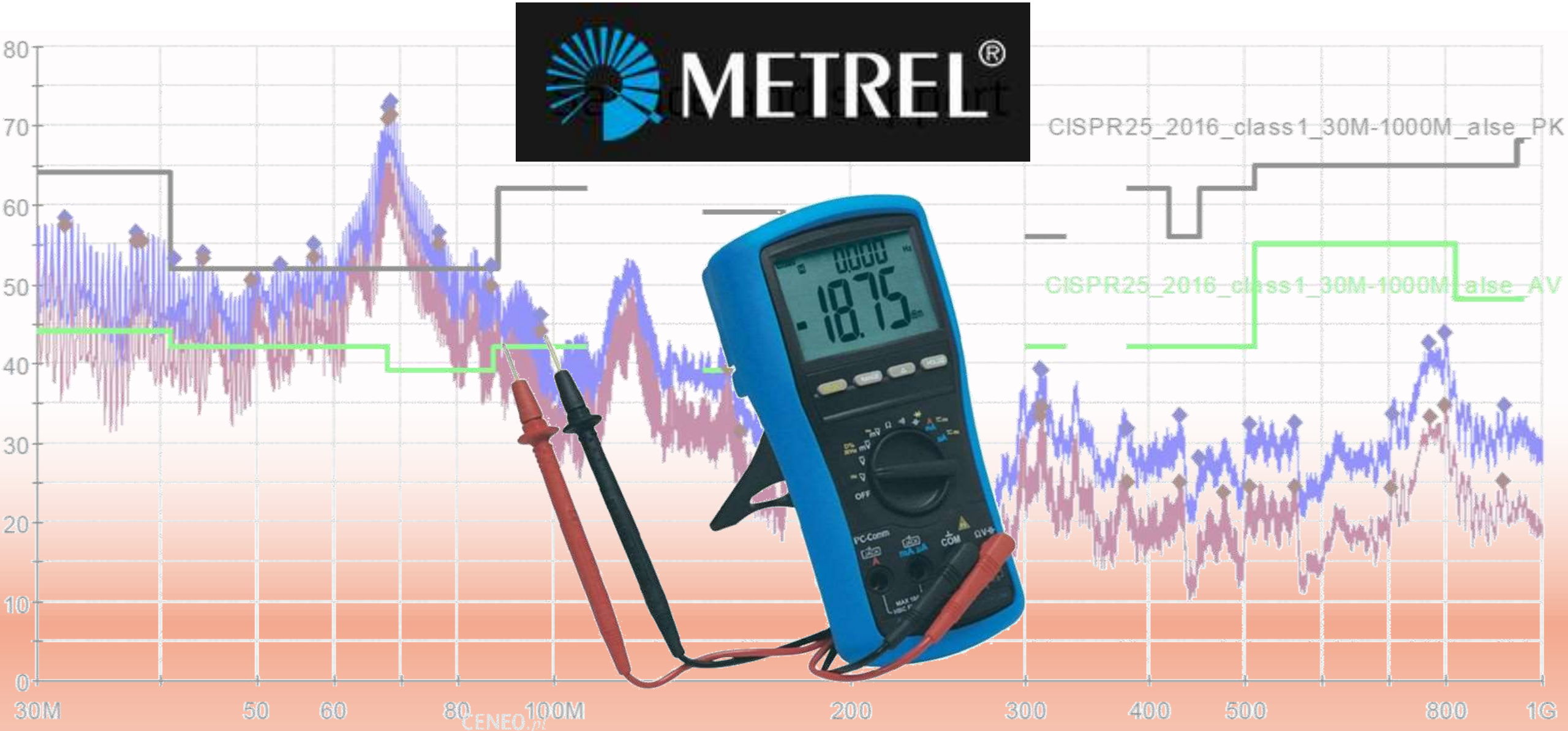

MAHLE
CISPR25_2016_class1_30M-1000M_alse_PK
CISPR25_2016_class1_30M-1000M_alse_AV
700€
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G


KOLEKTOR
CISPR25_2016_class1_30M-1000M_alse_PK
CISPR25_2016_class1_30M-1000M_alse_AV
600 €
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G

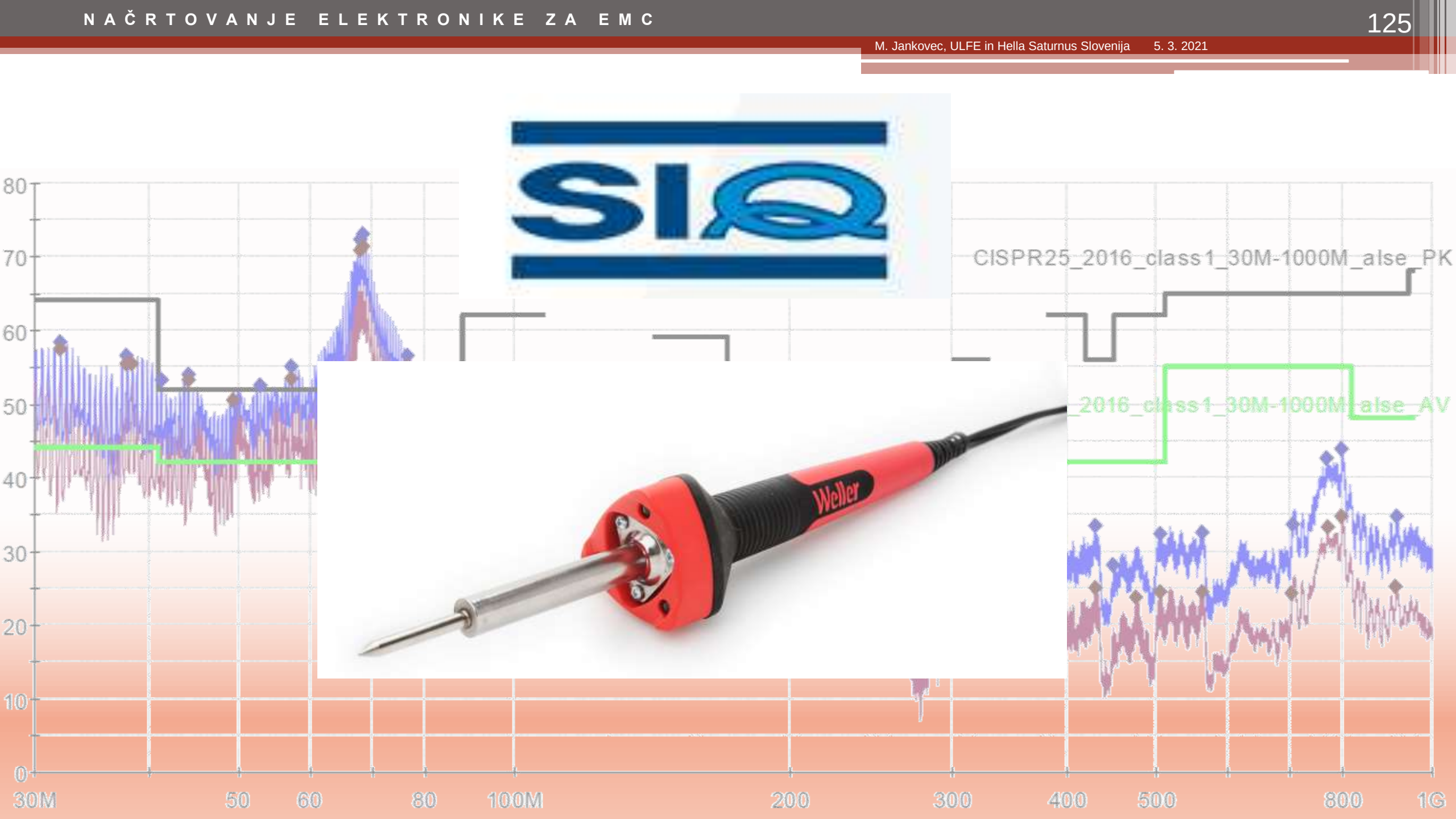

ISKRATEL
CISPR25_2016_class1_30M-1000M_alse_PK
CISPR25_2016_class1_30M-1000M_alse_AV
300 €
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G

AMITEH


80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G
CISPR25_2016_class1_30M-1000M_alse_PK
PR25_2016_class1_30M-1000M_alse_AV
RIGOL
DS1202


METREL®
CISPR25_2016_class1_30M-1000M_alse_PK
CISPR25_2016_class1_30M-1000M_alse_AV
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G


WÜRTH ELEKTRONIK
DESIGN KIT
WE-FC, WE-TFC & WE-TFCH Power Line Common Mode Filter
CISPR25_2016_class1_30M-1000M_alse_PK
2016_class1_30M-1000M_alse_AV
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G


SIQ
CISPR25_2016_class1_30M-1000M_alse_PK
_2016_class1_30M-1000M_alse_AV
Weller
80
70
60
50
40
30
20
10
0
30M
50
60
80
100M
200
300
400
500
800
1G

Končni rezultati: Delovanje

Tekmovalec	Umin [V]	Umax [V]	Iin [A]	Uin [V]	Pin [W]	Iout [A]	Uout [V]	Pout [W]	n [%]	Iout_pp [mA]	Iout_min [A]	Iout_max [A]	Uout_pp [mV]	Delovanje	Izkoristek	Točke
Debevc	6	18	1.78	13.5	24.03	6.44	3.56	22.9264	**95.4**	140	**	**	30	50	52.0	**102.0**
Šivic	8	18	1.74	13.5	23.49	5.98	3.44	20.5712	**87.6**	140	**	**	30	50	12.9	**62.9**
Cvijanovič Hudoklin	7.5	18	1.82	13.5	24.57	5.9	3.62	21.358	**86.9**	200	**	**	100	50	9.6	**59.6**
Pavlin	7	18	1.8	13.5	24.3	5.8	3.64	21.112	**86.9**	140	**	**	40	50	9.4	**59.4**
Šmelcer #1	7	18	1.8	13.5	24.3	5.88	3.56	20.9328	**86.1**	60	**	**	20	50	5.7	**55.7**
Remec	8	18	1.79	13.5	24.165	6	3.46	20.76	**85.9**	100	**	**	20	50	4.5	**54.5**
Šmelcer #2	7	18	1.75	13.5	23.625	5.8	3.46	20.068	**84.9**	60	**	**	20	50	-0.3	**49.7**
Hella	8	18	1.8	13.5	24.3	5.86	3.62	21.2132	**87.3**	**1520**	**5.04**	6.56	**1000**	35	11.5	**46.5**
Šmelcer #3	7	18	1.81	13.5	24.435	5.9	3.46	20.414	**83.5**	60	**	**	20	50	-7.3	**42.7**
Čeferin #1	7	18	1.86	13.5	25.11	5.74	3.67	21.0658	**83.9**	**480**	5.44	5.92	160	45	-5.5	**39.5**
Čeferin #2	8	18	1.82	13.5	24.57	5.9	3.42	20.178	**82.1**	180	**	**	30	50	-14.4	**35.6**
Jug	7	18	1.82	13.5	24.57	5.85	3.48	20.358	**82.9**	**1480**	**5.04**	6.52	**240**	35	-10.7	**24.3**
Pivk/Nagode	7	18	1.1	13.5	14.85	**2.8**	**2.2**	11	**74.1**	**7500**	**0**	**7.5**	**3800**	25	-54.6	**-29.6**

Končni rezultati: RE

Tekmovalec	RE	Class	Limita (class)	Limita (class+1)	Točke (class)	Točke (class+1)	Dodatne točke	Točke skupaj
Jug	*-9.34*	5			35			**35.0**
Šmelcer #2	*-8.98*	5			35			**35.0**
Šmelcer #1	*-8.76*	5			35			**35.0**
Šmelcer #3	*-8.54*	5			35			**35.0**
Šivic	*-7.53*	5			35			**35.0**
Pavlin	*-5.33*	5			35			**35.0**
Debevc	*-4.03*	5			35			**35.0**
Hella	*-0.55*	*5*			*35*			*35.0*
Čeferin #2	**19.98**	4	22	16	20	35	5.1	**25.1**
Pivk/Nagode	**31.95**	4	32	26	20	35	0.1	**20.1**
Cvijanovič Hudoklin	**31.42**	3	36	28	10	20	5.7	**15.7**
Remec	**24.78**	3	27	21	10	20	3.7	**13.7**
Čeferin #1	**46.3**	2	56	46	5	10	4.9	**9.9**

Končni rezultati: CE

Tekmovalec	CE	Class	Limita (class)	Limita (class+1)	Točke (class)	Točke (class+1)	Dodatne točke	Točke skupaj
Hella	*-8*	*5*			*35*			*35.0*
Šmelcer #1	*-4.5*	5			35			**35.0**
Šmelcer #2	*-4*	5			35			**35.0**
Šmelcer #3	*-3.5*	5			35			**35.0**
Debevc	*0*	5			35			**35.0**
Šivic	**37.5**	4	42	34	20	35	8.4	**28.4**
Jug	**44**	3	50	42	10	20	7.5	**17.5**
Čeferin #2	**51**	2	58	50	5	10	4.4	**9.4**
Remec	**32**	2	36	30	5	10	3.3	**8.3**
Pivk/Nagode	**36**	2	36	30	5	10	0.0	**5.0**
Čeferin #1	**80**	2	80	70	5	10	0.0	**5.0**
Cvijanovič Hudoklin	**60**	1	66	58	0	5	3.8	**3.8**
Pavlin	**68**	0	66		0		-2.0	**-2.0**

Končni rezultati: BOM

Tekmovalec	Cena komponent	Točke
Hella	*4.11 €*	*-20.55*
Cvijanovič Hudoklin	4.11 €	-20.55
Šivic	4.97 €	-24.85
Jug	5.10 €	-25.5
Čeferin #2	5.41 €	-27.05
Šmelcer #1	6.06 €	-30.29
Šmelcer #2	6.06 €	-30.29
Šmelcer #3	6.06 €	-30.29
Debevc	6.52 €	-32.6
Pavlin	6.99 €	-34.95
Čeferin #1	7.95 €	-39.755
Remec	8.49 €	-42.43
Pivk/Nagode	10.40 €	-52

Končni rezultati: razvrstitev

Tekmovalec	Doseganje zahtev	Izkoristek	CE	RE	BCI	Cena	Vsota	Mesto
Debevc	50	52.0	35.0	35.0	30	-32.6	**169.4**	**1**
Šivic	50	12.9	28.4	35.0	30	-24.9	**131.5**	**2**
Hella	*35*	*11.5*	*35.0*	*35.0*	*30*	*-20.6*	*125.9*	
Šmelcer #1	50	5.7	35.0	35.0	30	-30.3	**125.4**	**3**
Šmelcer #2	50	-0.3	35.0	35.0	30	-30.3	**119.4**	**3**
Šmelcer #3	50	-7.3	35.0	35.0	30	-30.3	**112.4**	**3**
Cvijanovič Hudoklin	50	9.6	3.8	15.7	30	-20.6	**88.6**	**4**
Pavlin	50	9.4	-2.0	35.0	30	-35.0	**87.5**	**5**
Jug	35	-10.7	17.5	35.0	30	-25.5	**81.3**	**6**
Čeferin #2	50	-14.4	9.4	25.1	30	-27.1	**73.0**	**7**
Remec	50	4.5	8.3	13.7	30	-42.4	**64.2**	**8**
Čeferin #1	45	-5.5	5.0	9.9	30	-39.8	**44.6**	**7**
Pivk/Nagode	25	-54.6	5.0	20.1	30	-52.0	**-26.5**	**9**

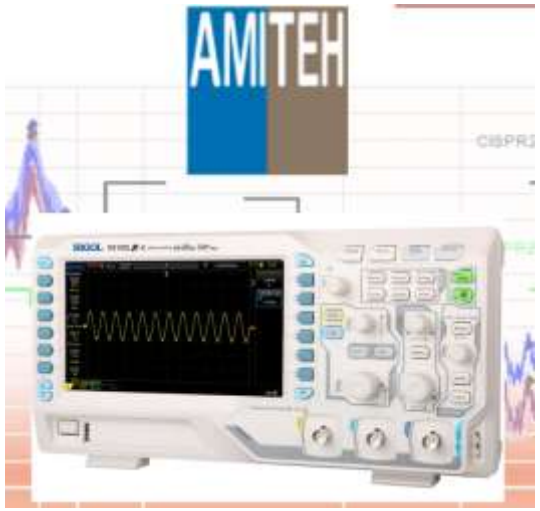
Nagrade

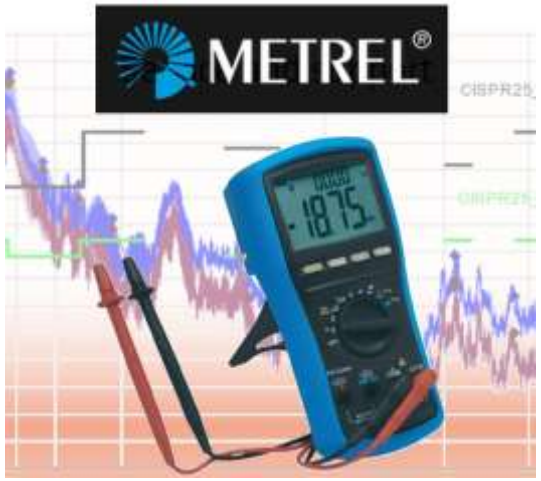
HELLA
1000 €

MAHLE
700 €

KOLEKTOR
600 €

ISKRATEL
300 €





Načrtovanje elektronike za $E=MC^2$

Univerza v Ljubljani
Fakulteta za elektrotehniko

Hvala vsem spozorjem!

HELLA
MAHLE
METREL
KOLEKTOR
AMITEH
ISKRATEL
TEXAS INSTRUMENTS
WÜRTH ELEKTRONIK
INTECTIV
SIQ
LPVO