AR191191

BLF989E, 470 to 700 Mhz

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AMPLEON

Application Report

Document information	
Status	Company public
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Abstract	Measurement results of an A-symmetric Ultra Wideband Doherty design with BLF989E for 470 to 700 Mhz

1. Revision History

Table 1: Report revisions

Revision	Date	Description	Author
0.0	20191218	Final version	Walter Sneijers

2. Contents

1. Revision History **2**
2. Contents **2**
3. List of figures **2**
4. List of tables **3**
5. General description **3**
6. Biasing and practical aspects **4**
7. Performance Summary **5**
8. Performance Details **6**
8.1 DVB-T measurement (no correction), Pavg=180W 6
8.2 DVB-T measurements with pre-correction, Pavg=180W 7
8.3 Pulsed CW measurements 9
8.4 Pulsed CW power sweeps 10
8.5 Network analyzer (AM-AM and AM-PM) 11
8.6 Module spread 13
9. Hardware **14**
9.1 Board Image 14
9.2 Copper Layout 15
9.3 Component Mapping 15
9.4 Bill of materials 16
9.5 Board material 17
9.6 Device markings 17
10. Legal information **18**
10.1 Definitions 18
10.2 Disclaimers 18
10.3 Trademarks 18
10.4 Contact information 18

3. List of figures

Figure 1 AR191191, 470-700Mhz demo top view 3
Figure 2 DVB-T, (Drain) efficiency (not corrected) Vgs_p=0.25 – 0.7V 6
Figure 3 DVB-T, Gain (not corrected)......... Vgs_p=0.25 – 0.7V 6
Figure 4 DVB-T, (Drain) efficiency + Gain .. Pre-corrected values 7
Figure 5 DVB-T, MER + Shoulder (4.3Mhz distance) Pre-corrected values 7
Figure 6 DVB-T, Ppeak + PAR ....Pre-corrected values 8
Figure 7 Pulsed CW, P6dB [W] ....Vgs_p = 0.4 ÷ 0.7V 9
Figure 8 Pulsed CW, PxdB .... Vgs_p=0.5V 9
Figure 9 Pulsed CW, Gain [dB] as function of Pout [W] Vgs_p=0.6V 10
Figure 10 Pulsed CW, Efficiency [%] as function of Pout [W] Vgs_p=0.6V 10
Figure 11 NA power sweep, Gain [dB] .... Vgs_p=0.6V 11
Figure 12 NA power sweep, normalised phase [°] Vgs_p=0.6V 11
Figure 13 DVB-T Drain eff, module spread . Vgs_p=0.5V 13
Figure 14 Pulsed CW 10%/100µs.............P6dB [W] 13
Figure 15 Picture of AR191191, 470-700Mhz board 14
Figure 16 Layout drawing 15

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Figure 17 Component drawing....................15

4. List of tables

Table 1: ....Report revisions 2
Table 2: ....Performance summary, in band 470-700Mhz 5
Table 3: ....AR191191, Pre-corrrected data 474Mhz (ch21) - 690Mhz (ch48).....8
Table 4: ....NA power sweep data Vgs_p=0.6V..12
Table 5: ....Bill of Materials...16
Table 6: ....Board specifications 17
Table 7: ....Device specifics..17

5. General description

This report presents the measurement results of the A-symmetric Ultra Wideband Doherty demo AR191191. The device BLF989E used is 180Wavg DVB-T, 9th generation LDMOS in a SOT539 package. BLF989E lower section is the Main amplifier, the upper section is the Peak amplifier. The power ratio is 1:1.5 for optimum efficiency with DVB-T (and ATSC-3) signals. The presented demo was designed for the frequency band 470 to 700 Mhz (a relative bandwidth of 39%).
AR191191 is the reference 470-700Mhz demonstrator.

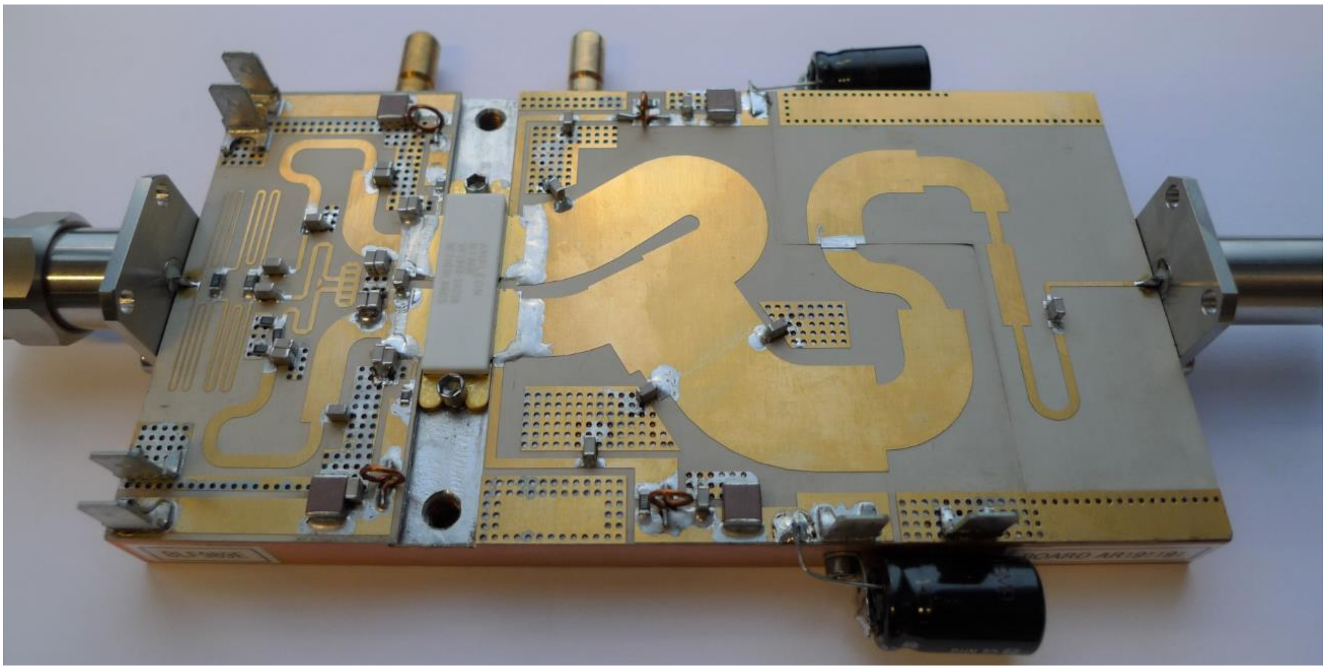

Figure 1 AR191191, 470-700Mhz demo top view

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6. Biasing and practical aspects

The efficiencies presented are based on the currents of the drain feeds only.
I.e. the biasing currents for the gate circuitry have not been included.
The biasing is as follows:

V_{DD_MAIN} = 50V
V_{DD_PEAK} = 50V
V_{GS_MAIN} = approx. 2.2V, leading to an I_{DQ_MAIN}=600mA
V_{GS_PEAK} = 0.5V (range 0.25 – 0.7 V, can vary dependent on frequency and device)

The application is built on a copper heatsink and is water cooled.
The application is designed on 2 different (output) pcb materials to realise practical line widths near the transistor drains and 50Ω output.
Both transistor and pcb's are soldered on a baseplate to achieve optimum performance.
Special care is needed when the pcb's are not soldered on the baseplate to prevent bad grounding contact near the transistor and/or the transformer interface (connection of the 2 output pcb's).

Demo board designs:
AR191170 = 1st prototype 470-700Mhz board
AR191191 = reference demo 470-700Mhz board
AR191201 = 1st reproduction 470-700Mhz board (see fig. 13 + 14)

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7. Performance Summary

Table 2: Performance summary, in band 470-700Mhz

Parameter	Condition-1	Condition-2	Unit	Pulsed CW	DVB-T
Power		Idq_m=0.6A Vgs_p=0.5V	W		180
Gain		Idq_m=0.6A Vgs_p=0.5V	dB		14.5 - 17
Drain Efficiency		Idq_m=0.6A Vgs_p=0.5V	%		46 - 54
P_{6dB}	100µs/10%	Idq_m=0.6A Vgs_p=0.5V	W	1000	-
PAR output signal	CCDF0.01%	Idq_m=0.6A Vgs_p=0.5V	dB		7 – 7.5
PAR output signal -c	Pre-corrected[1,2] CCDF0.01%	Idq_m=0.6A Vgs_p=0.5V	dB		> 7.5
Shoulder distance[1,2,3]		Idq_m=0.6A Vgs_p=0.5V	dBc		< -37.5
MER		Idq_m=0.6A Vgs_p=0.5V	dBc		> 34.5

Note 1: Input PAR DVB-T signal 9.5dB @ CCDF0.01%

Note 2: Pre-distorter: ProTelevision PT3000

Note 3: Shoulder distance ±4.3Mhz

The amplifier can deliver 180W average DVB-T power or pulsed CW 1000W (P6dB) over the whole bandwidth 470-700Mhz.
All RF measurements were performed with a 750Mhz LPF coupled towards the power meter. This avoids any harmonic content in the measured output power.
The wideband Klopfenstein transformer has 9 sections.
Note that the amplifier will not isolate mismatch impedances in the harmonic band.

Pre-correction:
The pre-corrected measurements were performed with a ProTelevision PT3000 exciter.
Idq/Vgs settings can be optimised for each channel. Note that some UHF channels need more correction on AM-AM (and AM-PM) distortion, which can be influenced by Vgs_p.

Vgs_p(eak) has a significant impact on efficiency. Best trade-off between (peak) power and efficiency was achieved at a Vgs_p of 0.5V. Different transistor batches can result in different Vgs settings dependent on transistor Vgs_threshold level.

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8. Performance Details

The amplifier was measured with a DVB-T 8K signal (8Mhz signal bandwidth) and with a pulsed CW signal. Vgs_p is (normally) fixed at 0.4V but can be varied at each channel, likewise Idq_main or Vdd. The measured freq range is 450 – 714Mhz.

8.1 DVB-T measurement (no correction), Pavg=180W

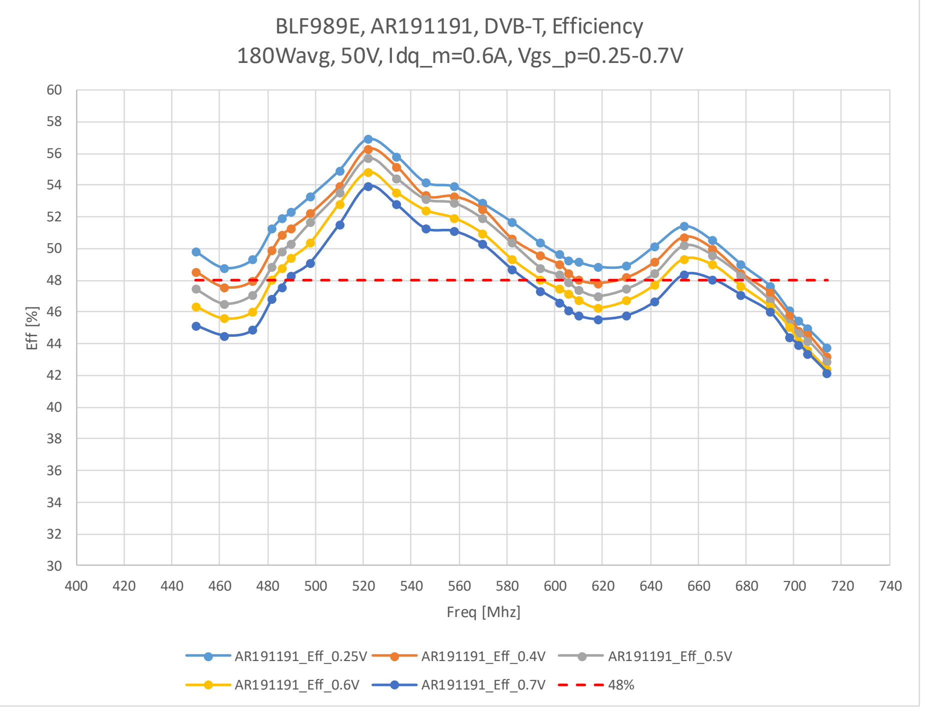

Figure 2 DVB-T, (Drain) efficiency (not corrected) Vgs_p=0.25 – 0.7V

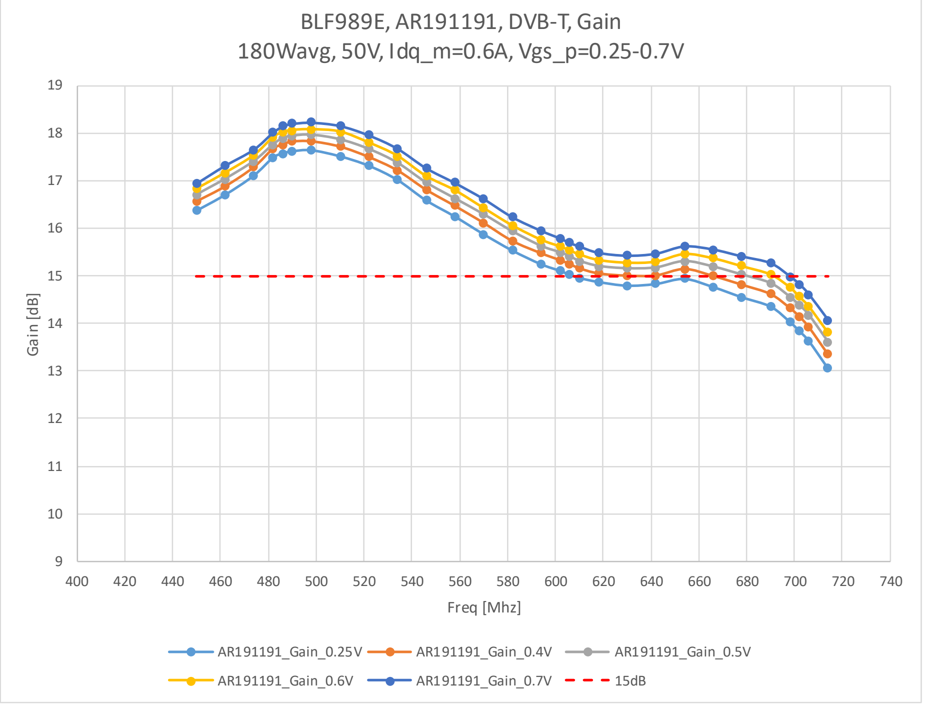

Figure 3 DVB-T, Gain (not corrected) Vgs_p=0.25 – 0.7V

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8.2 DVB-T measurements with pre-correction, Pavg=180W

Pre-corrected data (ProTelevision PT3000).
The measured freq range is 474 – 690Mhz.

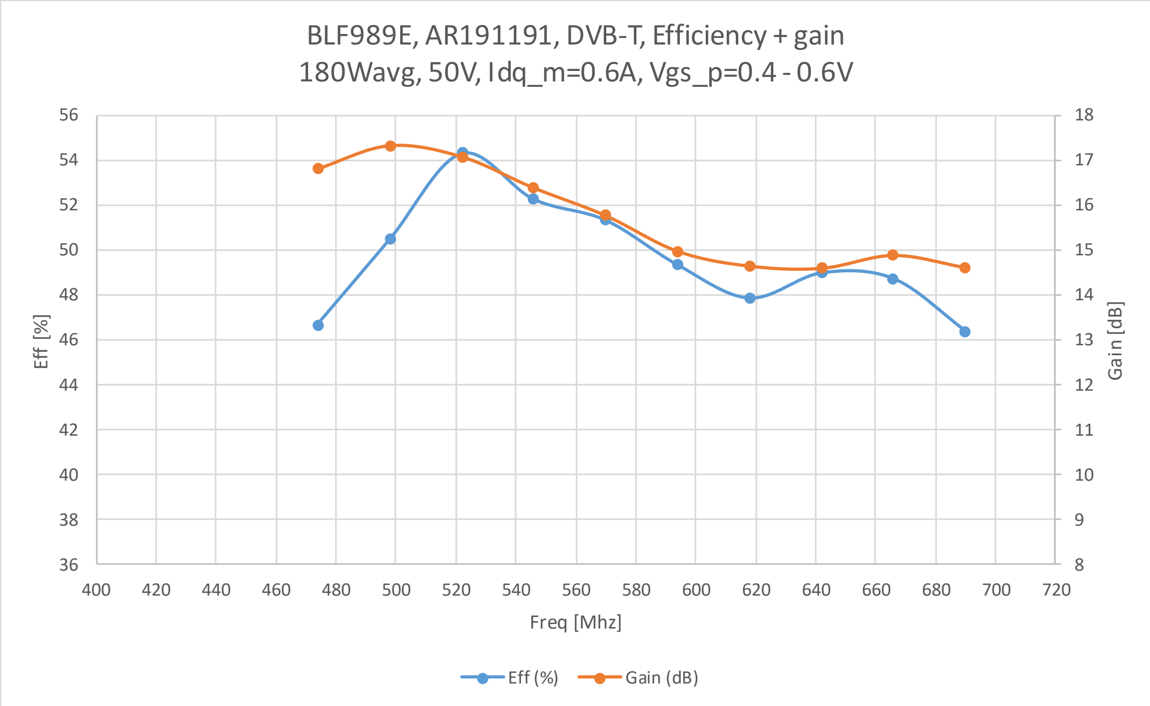

Figure 4 DVB-T, (Drain) efficiency + Gain Pre-corrected values

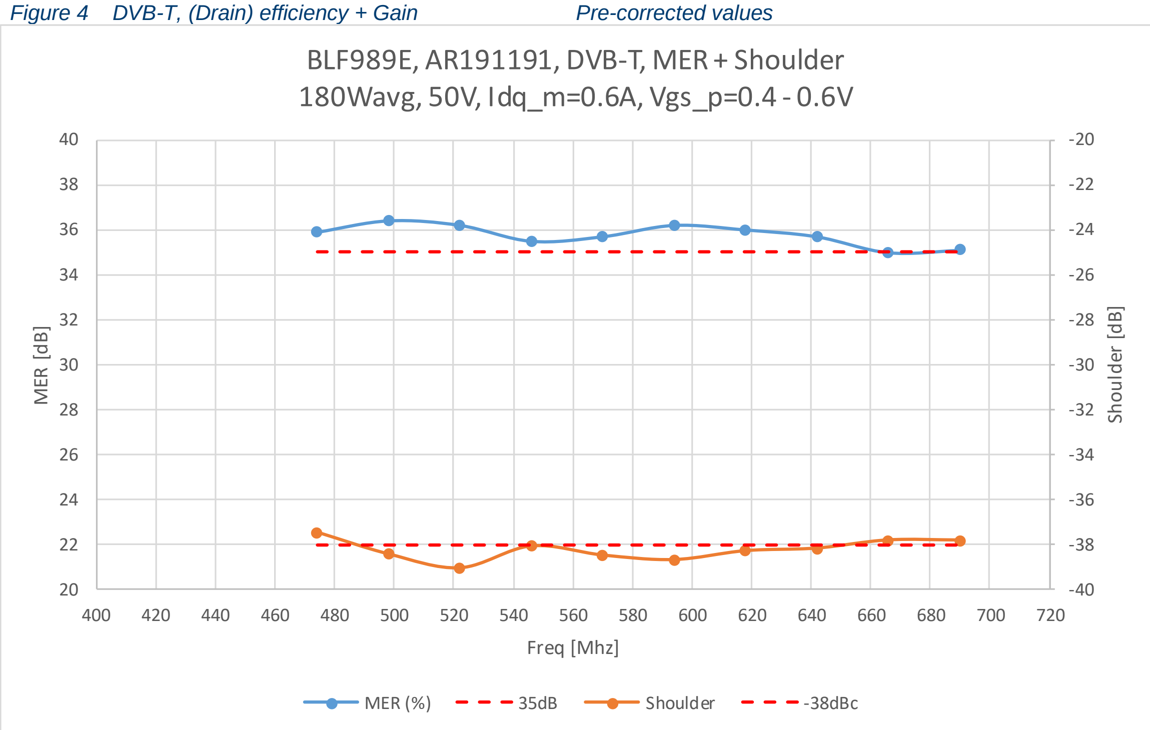

Figure 5 DVB-T, MER + Shoulder (4.3Mhz distance) Pre-corrected values

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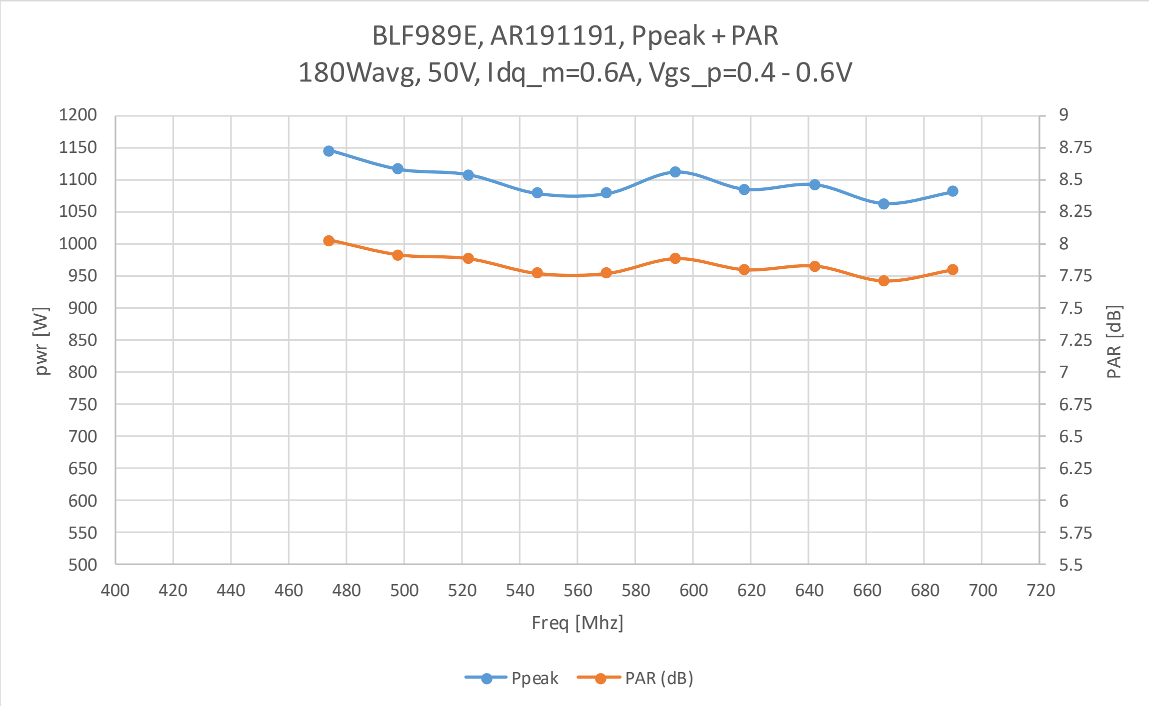

Figure 6 DVB-T, Ppeak + PAR Pre-corrected values

AR191191											
Freq	Idq_main	Vgs_peak	**Gain (dB)**	**Eff (%)**	**_PAE (%)**	**PAR (dB)**	**Pavg**	**Ppeak**	**MER (%)**	**ACPR4M3L (dBc)**	**CPR4M3H (dE**
474	0.6	0.5	16.80	46.67	45.70	8.03	180.37	1145.69	35.9	-37.48	-38.74
498	0.6	0.5	17.32	50.47	49.54	7.91	180.50	1116.28	36.4	-38.44	-39.24
522	0.6	0.5	17.08	54.32	53.26	7.88	180.35	1107.97	36.2	-39.06	-39.20
546	0.6	0.5	16.38	52.28	51.08	7.77	180.33	1078.63	35.5	-38.09	-38.79
570	0.6	0.5	15.77	51.34	49.98	7.77	180.31	1078.52	35.7	-38.49	-38.52
594	0.6	0.4	14.97	49.34	47.77	7.88	181.01	1112.02	36.2	-38.69	-39.38
618	0.6	0.4	14.64	47.85	46.21	7.80	180.21	1085.16	36	-38.30	-38.80
642	0.6	0.4	14.59	48.98	47.28	7.83	180.22	1092.49	35.7	-38.18	-39.14
666	0.6	0.6	14.88	48.72	47.13	7.71	180.14	1063.25	35	-37.82	-37.82
690	0.6	0.6	14.61	46.37	44.77	7.80	179.57	1081.27	35.1	-37.83	-37.85

Table 3: AR191191, Pre-corrrected data 474Mhz (ch21) - 690Mhz (ch48)

The top table shows the pre-corrected measurements at 180Wavg. A minimum MER of 35dB with a shoulder distance of 38dBc was achieved over the band 474-690Mhz.
The trade-off between higher power and lower efficiency/higher gain was made via Vgs_p.

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8.3 Pulsed CW measurements

Pulse condition: 100µs/10%. P6dB gives the best indication of the peak power capability.

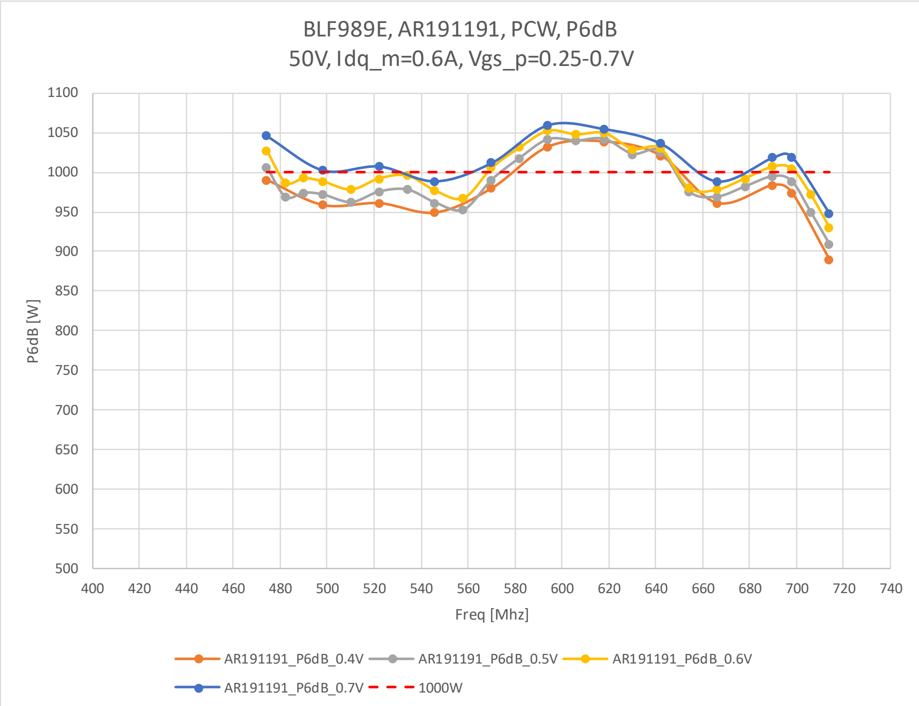

Figure 7 Pulsed CW, P6dB [W] Vgs_p = 0.4 ÷ 0.7V

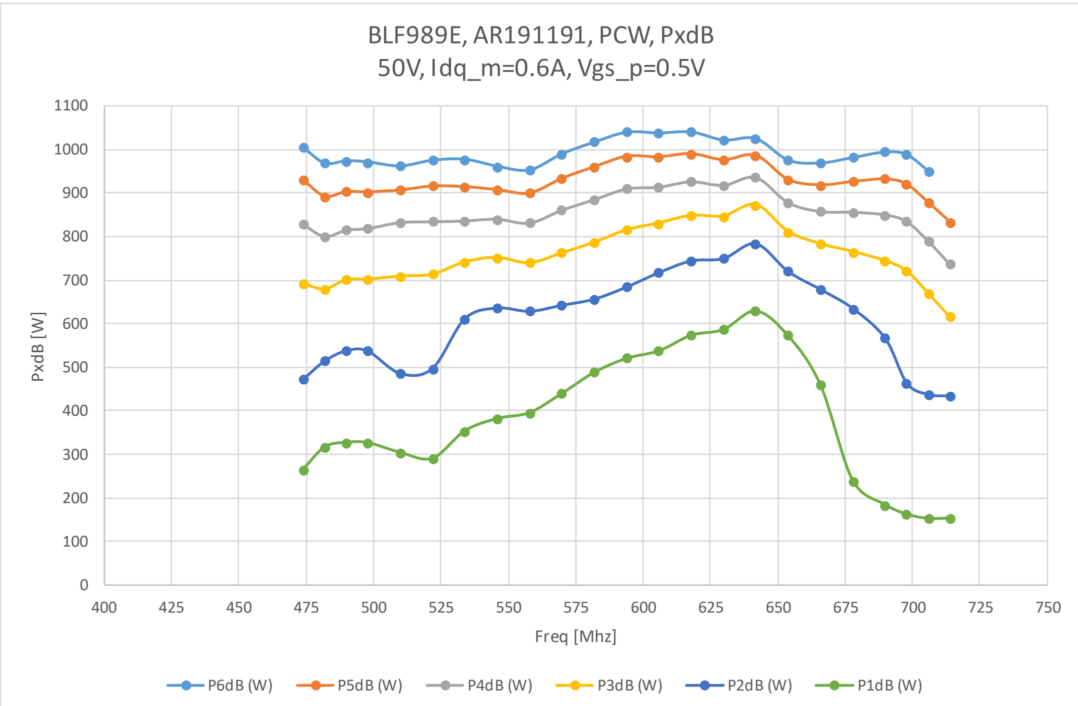

Figure 8 Pulsed CW, PxdB Vgs_p=0.5V

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8.4 Pulsed CW power sweeps

Pulse condition: 100µs/10%. Vgs_p=0.6V

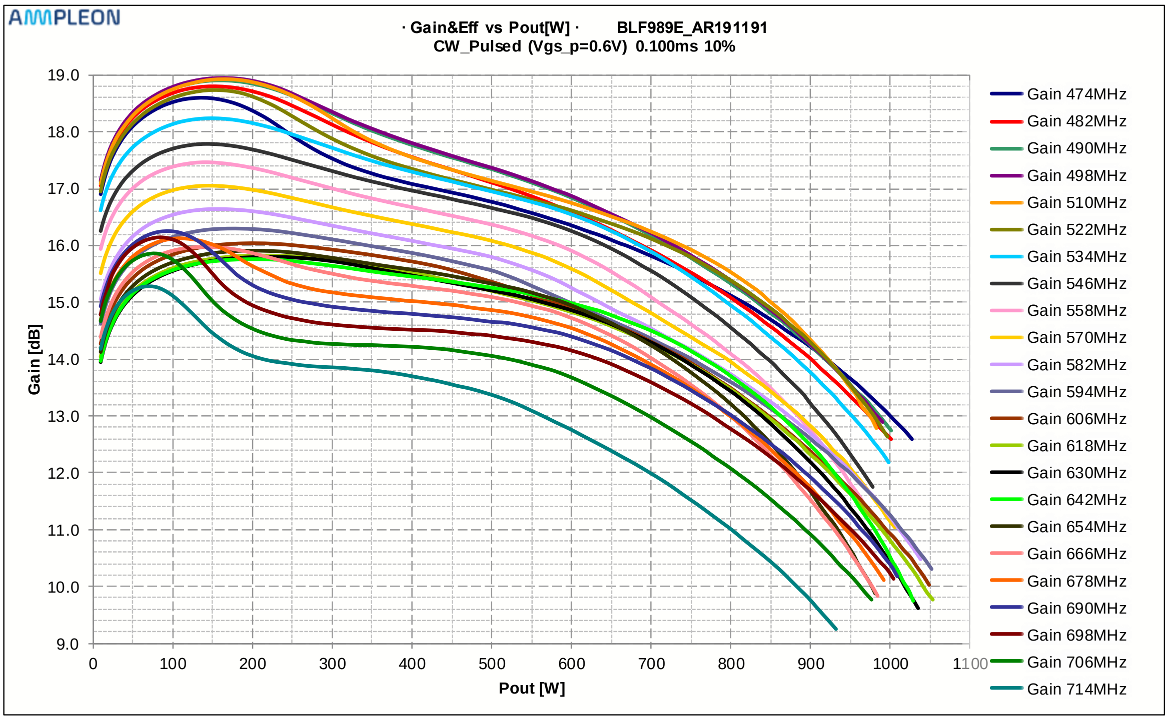

Figure 9 Pulsed CW, Gain [dB] as function of Pout [W] Vgs_p=0.6V

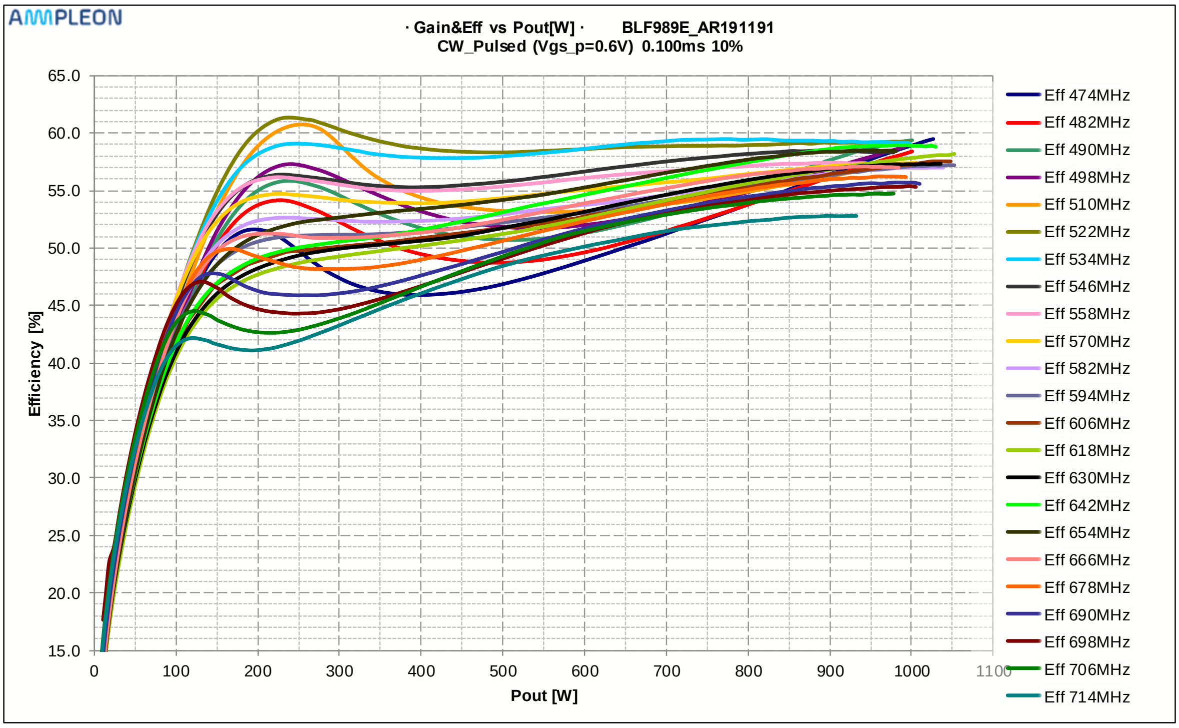

Figure 10 Pulsed CW, Efficiency [%] as function of Pout [W] Vgs_p=0.6V

Good pre-correction at 180Wavg (DVB-T) can be achieved when the pulsed CW power at P6dB is approx. 1kW. This was achieved in the band 470-700Mhz. The Pre-corrected DVB-T data on page 7/8 confirm this.

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8.5 Network analyzer (AM-AM and AM-PM)

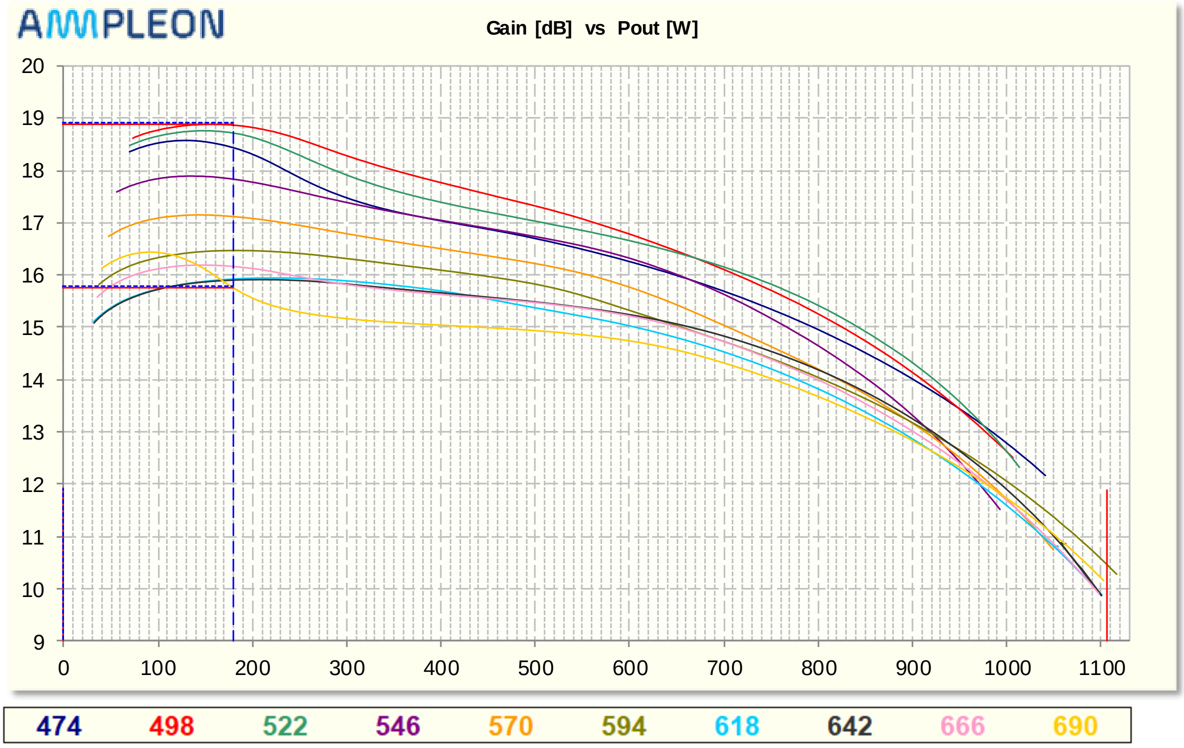

Figure 11 NA power sweep, Gain [dB] Vgs_p=0.6V

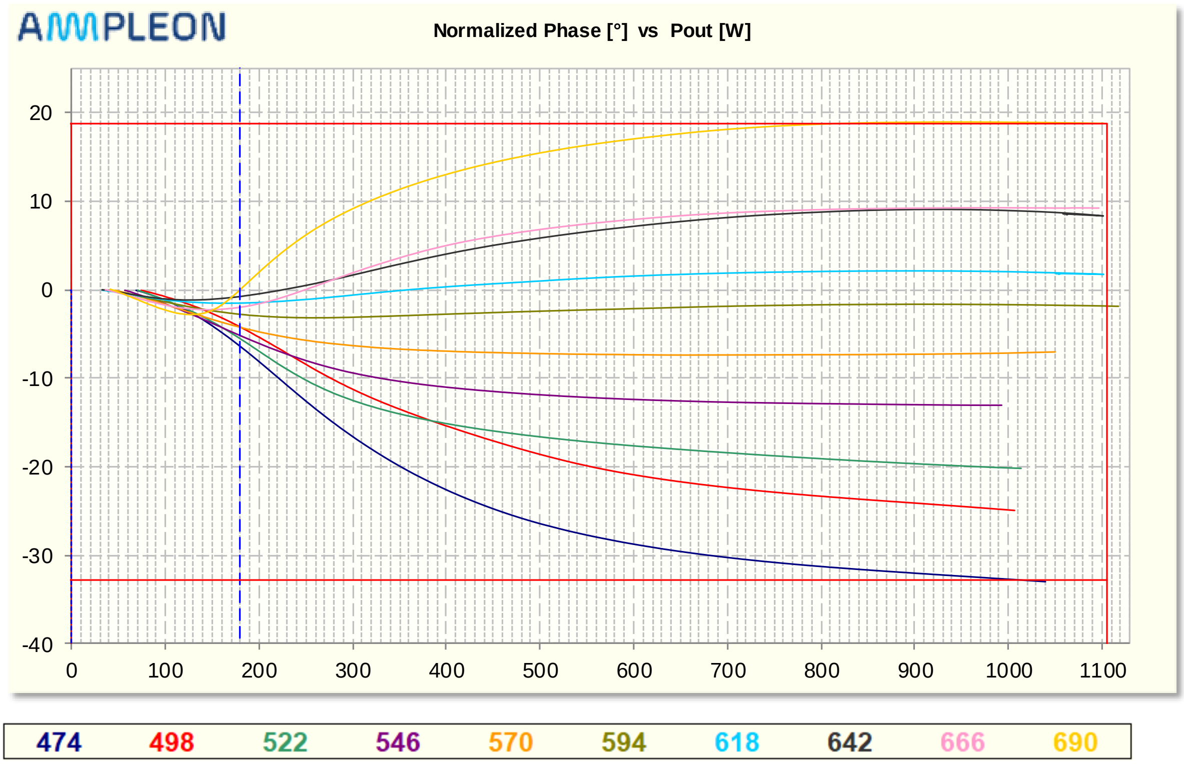

Figure 12 NA power sweep, normalised phase [°] Vgs_p=0.6V

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Frequency [MHz]	474	498	522	546	570	594	618	642	666	690
MaxGain [dB]	18.58	18.89	18.76	17.88	17.17	16.46	15.96	15.92	16.19	16.43
MaxEff [%]	58.44	58.46	62.26	58.92	57.98	59.29	59.71	61.43	62.19	59.77
MaxPout [dBm]	60.17	60.03	60.06	59.97	60.21	60.48	60.42	60.42	60.40	60.42
MaxPout [W]	1040.31	1005.95	1014.28	992.37	1050.05	1117.13	1101.04	1100.90	1097.05	1102.08
P6dB [dBm]	60.06	59.93	59.98	59.89	60.13	60.44	0.00	0.00	60.35	60.36
P6dB [W]	1012.87	983.22	994.44	975.99	1030.02	1106.16	0.00	0.00	1083.48	1087.15
Eff@6dB [%]	57.71	56.98	58.18	57.73	57.92	59.21	0.00	0.00	61.99	59.72
nPhase@6dB [°]	-32.78	-24.78	-20.20	-13.12	-7.12	-1.81	0.00	0.00	9.22	18.78
P1dB [dBm]	54.55	55.73	55.12	56.54	57.16	57.60	57.92	58.35	57.83	53.39
P1dB [W]	284.87	374.32	324.88	450.74	519.58	575.36	619.31	684.45	607.31	218.21
Eff@P1dB [%]	49.30	54.63	60.47	56.32	55.22	53.62	53.97	57.13	58.33	50.99
P6dB-P1dB [dB]	5.51	4.19	4.86	3.36	2.97	2.84	-57.92	-58.35	2.51	6.97
@Pwr [dBm] (=179.89W)	52.55	52.55	52.55	52.55	52.55	52.55	52.55	52.55	52.55	52.55
Gain@Pwr [dB]	18.44	18.87	18.72	17.82	17.13	16.46	15.94	15.91	16.16	15.75
Eff@Pwr [%]	53.01	56.16	60.04	57.77	56.41	53.07	51.04	52.69	56.29	51.87
Compression [dB]	6.43	6.39	6.43	6.36	6.42	6.20	5.15	5.05	6.29	6.27

Table 4: NA power sweep data Vgs_p=0.6V

The network analyzer (R&S ZVA) data shows slightly higher power levels compared to pulsed CW. Note that this data is generated via CW power sweeps which is different from pulse mode. Another reason could be small calibration differences between both methods.

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8.6 Module spread

The graphs below show efficiency (not pre-corrected) and power (PCW) measurements on 2 prototype boards (AR191170, AR191181) and 5 boards with the final layout (AR191191, AR191201, AR191204, AR201001, AR201003). The reproductions show very similar performance.

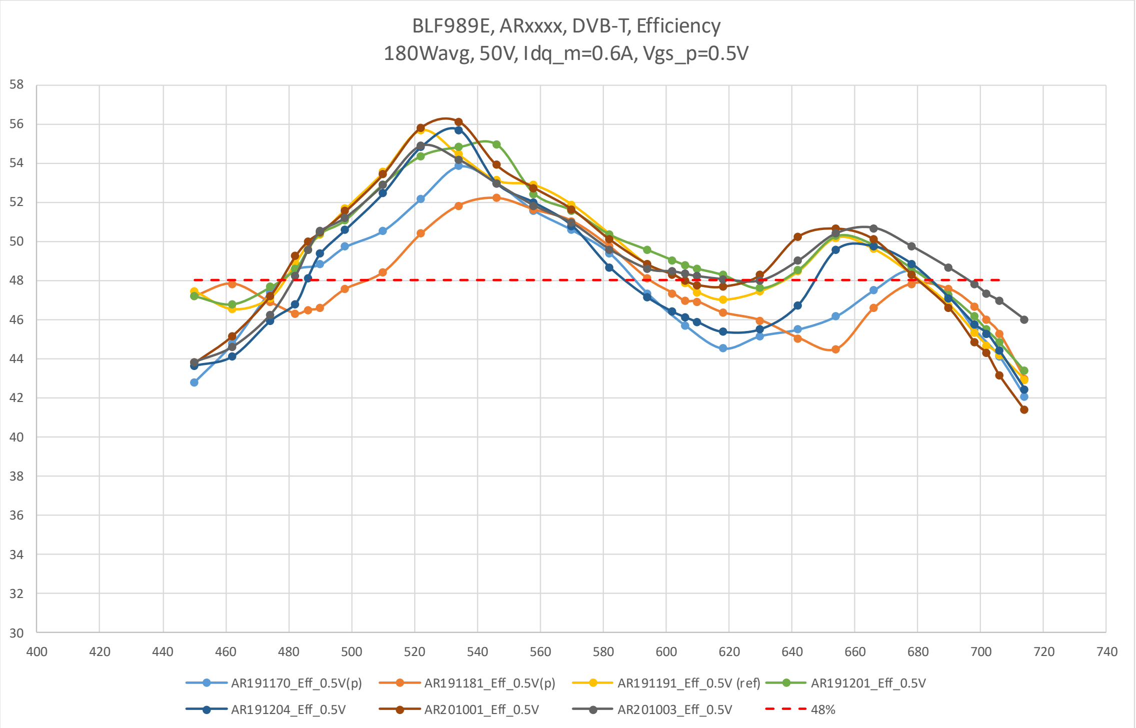

Figure 13 DVB-T Drain eff, module spread Vgs_p=0.5V

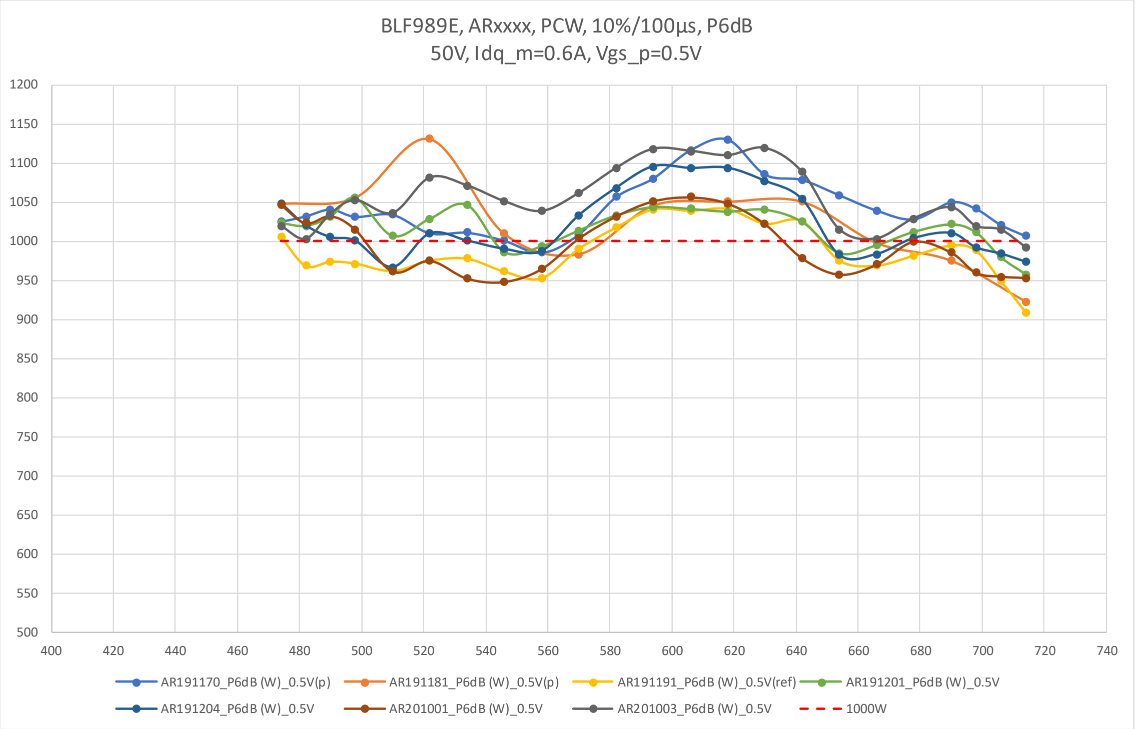

Figure 14 Pulsed CW 10%/100µs P6dB [W]

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9. Hardware

9.1 Board Image

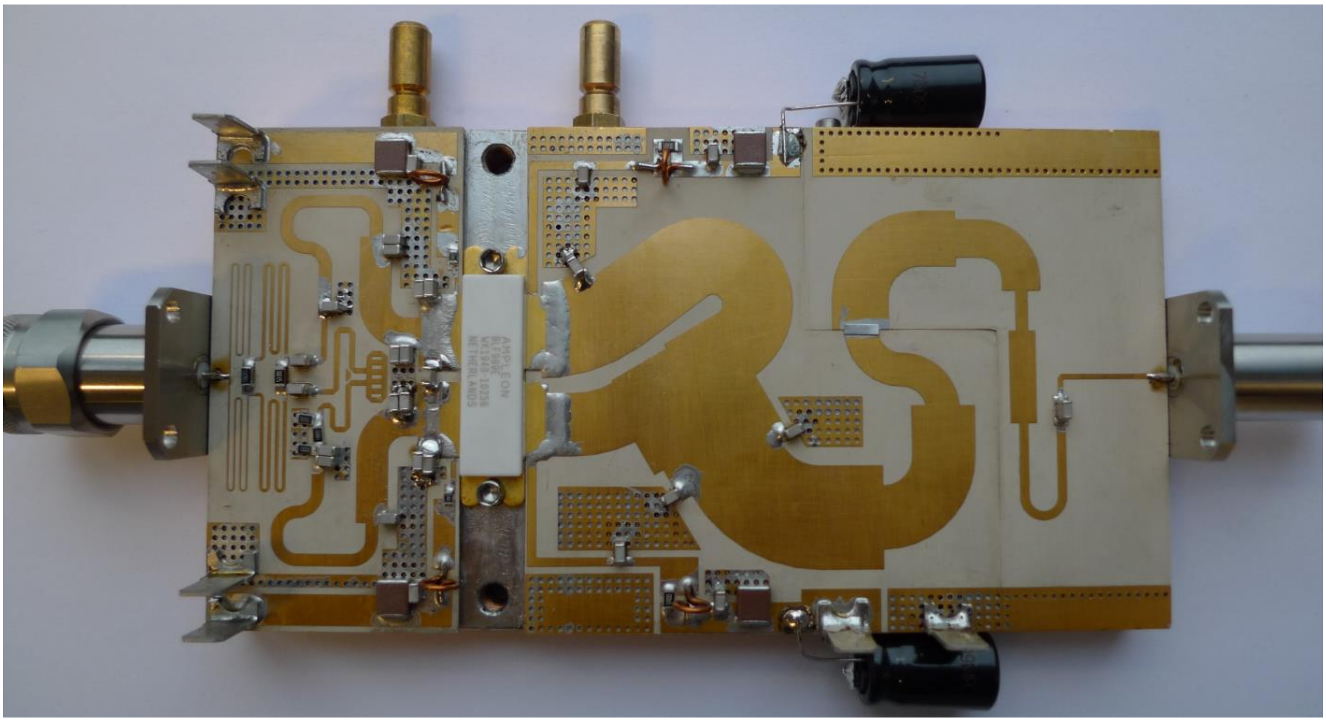

Figure 15 Picture of AR191191, 470-700Mhz board

Board “RF” Dimensions: 135 x 60mm

Total board dimensions: 152 x 80mm

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9.2 Copper Layout

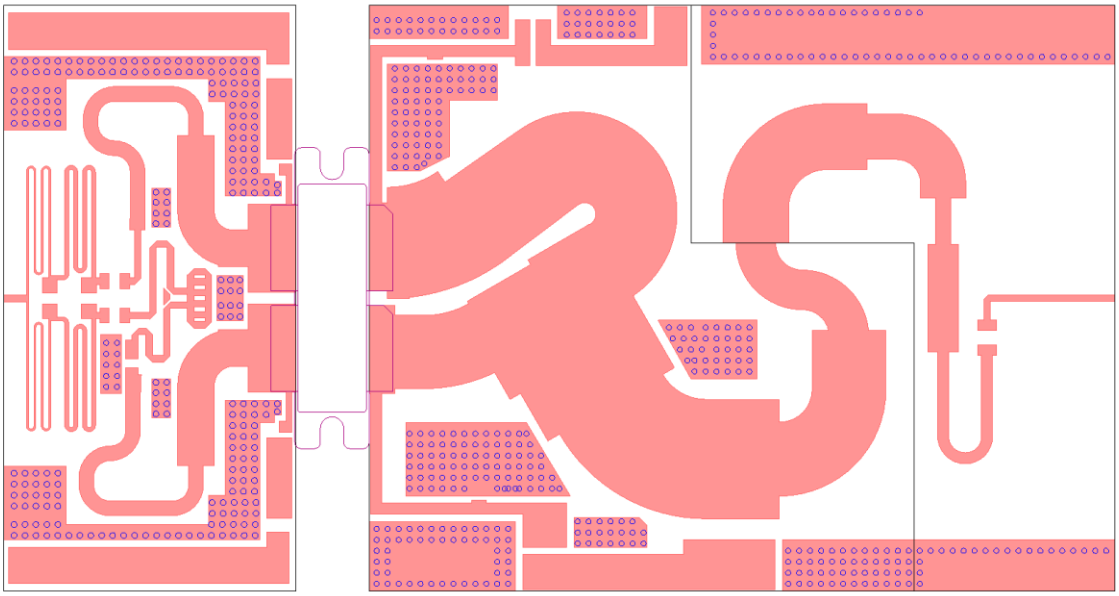

Figure 16 Layout drawing

9.3 Component Mapping

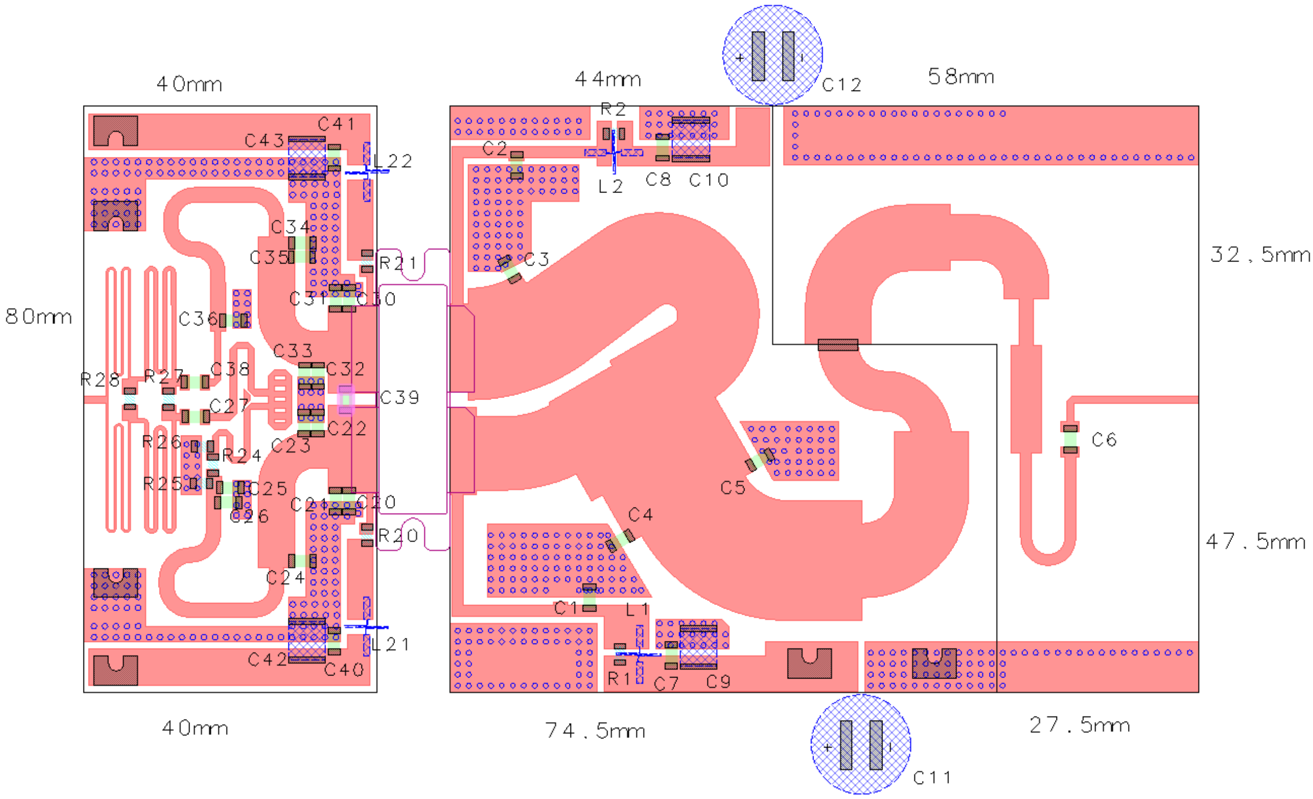

Figure 17 Component drawing

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9.4 Bill of materials

Table 5: Bill of Materials

Description	Value	Case	Supplier	Remark
C1, C2, C7, C8	100pF	ATC800B	ATC	
C3	5.6pF	ATC800B	ATC	
C4, C5	9.1pF	ATC800B	ATC	
C6	51pF	ATC800B	ATC	
C9, C10	4.7µF/63V		TDK	
C11, C12	470µF/63V			
L1, L2	Approx. 10nH			1 turn, 4-5mm diameter
R1, R2	1Ω	1206		
C20, C21, C32, C33	16pF	ATC800B	ATC	
C22, C23, C31, C34	18pF	ATC800B	ATC	
C24, C30	20pF	ATC800B	ATC	
C25, C35, C36	2pF	ATC800B	ATC	
C26	1.5pF	ATC800B	ATC	
C39	5.6pF	ATC800B	ATC	
C27, C38, C40, C41	100pF	ATC800B	ATC	
C42, C43	4.7µF/63V		TDK	
L21, L22	Approx. 10nH			1 turn, 4-5mm diameter
R20, R21	5.6Ω	0805		
R25, R26	300Ω	1206		
R24	18Ω	1206		
R27	2x510Ω	1206		Resistors in parallel
R28	2x180Ω	1206		Resistors in parallel

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9.5 Board material

Table 6: Board specifications

Parameter	Value	thickness	metallisation
Manufacturer	Rogers		
Input pcb	RO3006	25 mil	35µ Cu, ground layer full Cu
Output-1 pcb	RO3010	10 mil	**70µ Cu**, ground layer full Cu
Output-2 pcb	RO3006	25 mil	35µ Cu, ground layer full Cu

Input pcb: 40 x 80 mm

Output pcb 1: 74.5 x 80 mm

Output pcb 2: 58 x 80 mm

9.6 Device markings

Table 7: Device specifics

Parameter	Value
Manufacturer	Ampleon
Device	BLF989E
Marking	wk1948-10256
Comments	

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