AN10921

BLF7G20LS-200 Doherty 1.805 to 1.88 GHz RF power amplifier

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Document information

Info	Content
Keywords	BLF7G20LS-200, Doherty, RF, LDMOS
Abstract	This application note describes the design and performance of a power amplifier for base station applications using two BLF7G20LS-200 power LDMOS transistors in a Doherty configuration. The performance of the BLF7G20LS-200 Doherty design when used in tandem with Optichron's OP6180 DPD development system is also described.

Revision history

Rev	Date	Description
01	20100716	Initial version

Contact information

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1. Introduction

The test circuit described in this document was built to evaluate the performance of a state-of-the-art power amplifier for base station applications. The amplifier design uses two BLF7G20LS-200 devices arranged in a Doherty configuration. The BLF7G20LS-200 is one of NXP Semiconductors' latest 7th Generation LDMOS devices and utilizes NXP's advanced LDMOS process. The BLF7G20LS-200 is an internally matched (both the input and output) device, allowing for an amplifier to be designed with high gain and good gain flatness and phase linearity over a frequency band from 1805 MHz to 1880 MHz.

The data presented in this application note provides an indication of the typical performance of a symmetric Doherty configuration using two BLF7G20LS-200 power transistors. The performance of the BLF7G20LS-200 Doherty design when used in tandem with Optichron's OP6180 DPD development system is also described.

2. Circuit description

The test circuit was built on a 25 mil PCB made from Rogers 3006 material and is illustrated in Figure 1. A schematic diagram is shown in Figure 2. The (drain-source) supply voltage is 30 V. The gate biasing circuits are connected through the 30 V power supplies. There are two 8 V regulators on board. I_{Dqmain} and V_{GSpeak} can be set using the potentiometers.

The OP6180 development board provides all the functionality needed to evaluate a PA together with the OP6180 DPD solution. For more information about the OP6180 DPD solution and development system go to http://www.optichron.com/products/tools.php or contact sales@optichron.com.

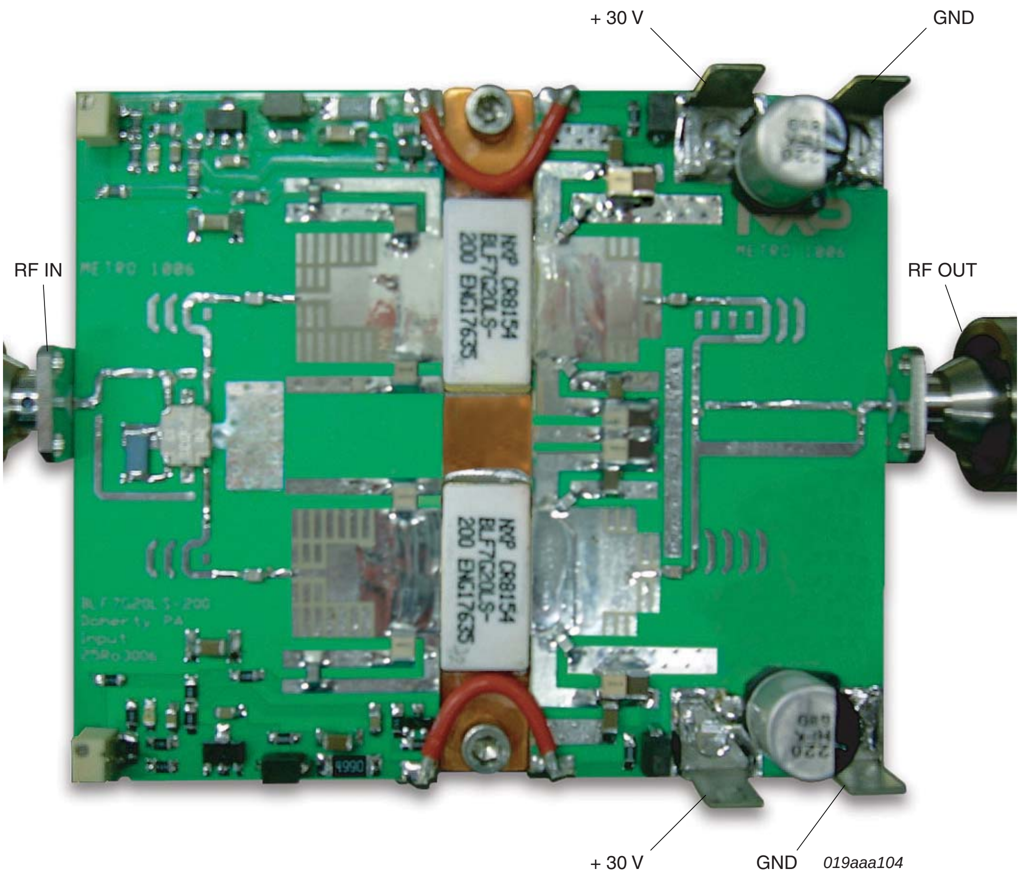

Fig 1. 2 × BLF7G20LS-200 Doherty PA test circuit

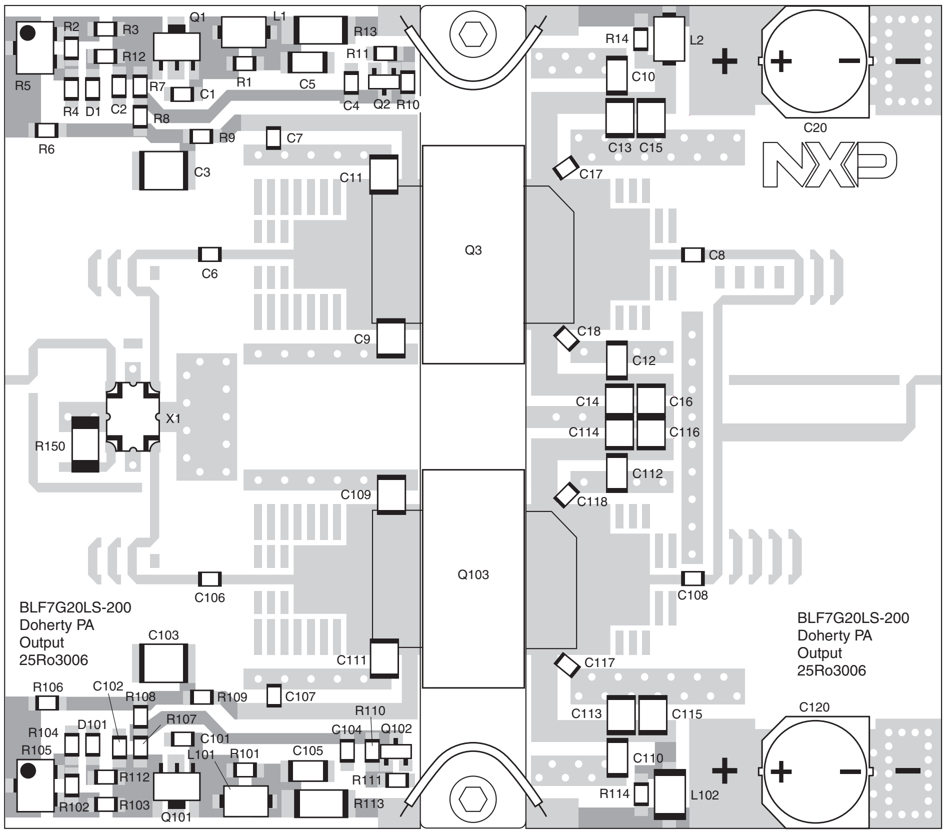

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Fig 2. Power amplifier for base station applications

3. Optichron OP6180 Digital Pre-Distortion (DPD)

Optichron delivers state-of-the-art DPD technology with the OP6180. This integrated transmit path solution provides CFR and DPD functionality, delivering up to 60 MHz of signal bandwidth and PAE approaching 60 % with LDMOS transistors for all 2G, 3G and 4G protocols.

3.1 System description

Optichron supplies a complete development platform, the OP6180-DEV, for evaluating the performance of the Optichron OP6180 with any power amplifier.

The OP6180-DEV includes all necessary transmit path functionality, with the exception of the power amplifier and driver, making it possible to connect a power amplifier lineup directly to the OP6180 and to evaluate its performance with state-of-the-art CFR and DPD. The Optichron development platform shown in Figure 3, operates from 700 MHz to 3.7 GHz and is managed via a GUI for ease of use.

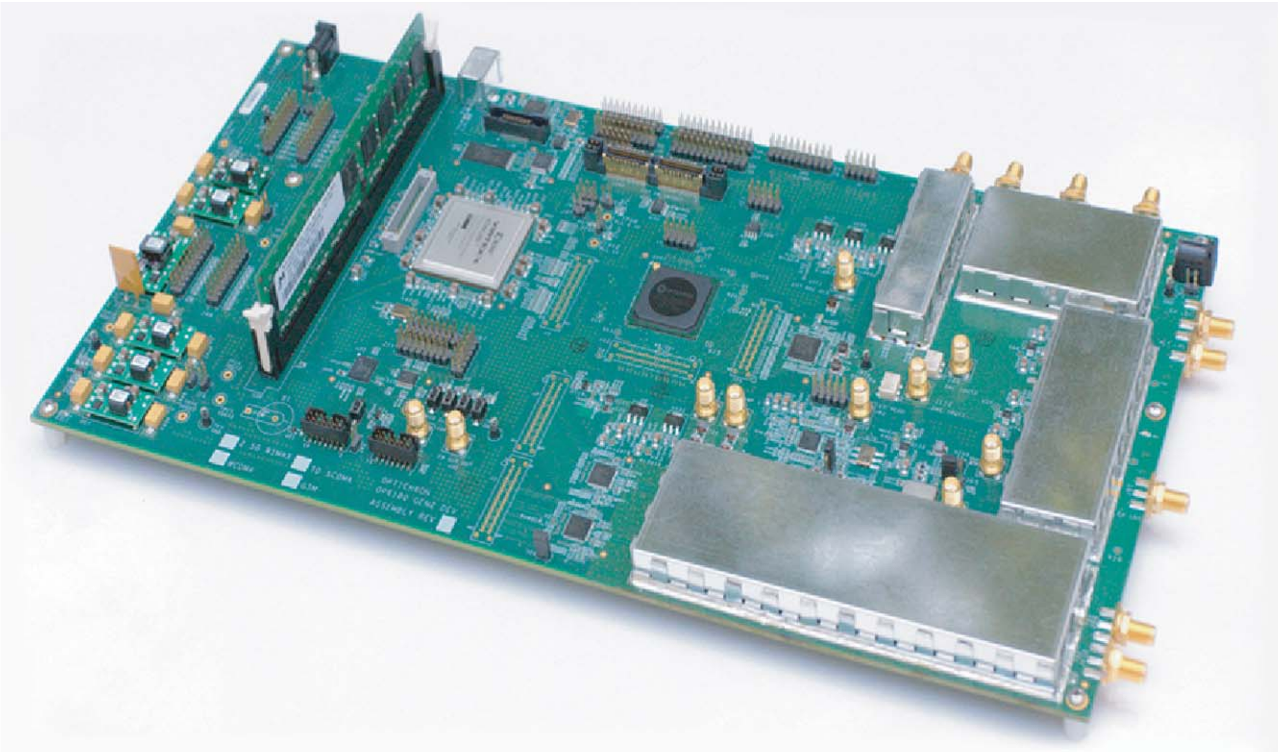

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Fig 3. OP6180-DEV development platform

The data presented in Section 5.5 was obtained with the Optichron OP6180-DEV connected to the NXP BLF7G20LS-200 power amplifier. The simplified block diagram shown in Figure 4 illustrates the system configuration. All functionality, with the exception of the band pass filter, power amplifier and power attenuator is located on the development platform. For ease of use, the development platform includes a pattern generator managed via the GUI.

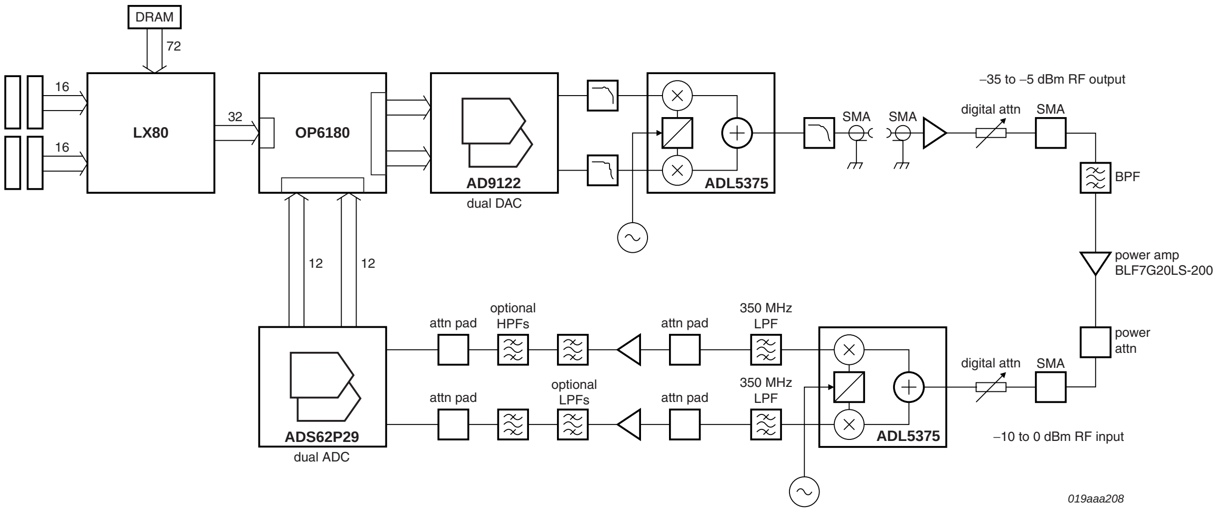


Fig 4. Simplified block diagram of the OP6180-DEVS

Both the OP6180 development platform and the BLF7G20LS-200 Doherty PA are available (from Optichron and NXP respectively) to allow the performance of the test circuit to be independently verified. Schematics and design files are also available from Optichron for the OP6180-DEV to provide designers with a head start in developing an optimized solution that meets their requirements. The tables and plots shown in Section 5.5 present the performance obtained with the combination of the Optichron OP6180-DEV and the NXP BLF7G20LS-200 Doherty PA illustrated in Figure 4.

4. Characterization summary

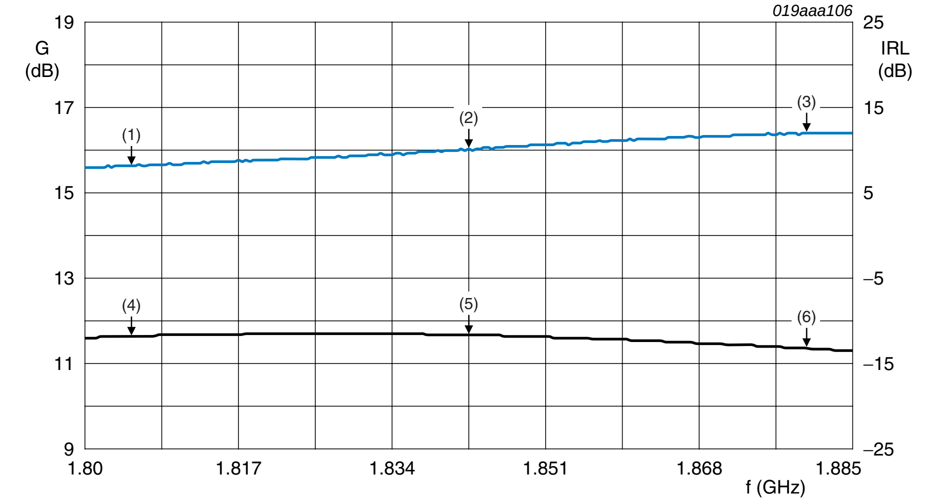
The amplifier has been characterized as follows:

- Gain, delay, and input return loss at P_O = 46 dBm, V_{DS} = 30 V, I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V were measured using a network analyzer.
- Standard IS95 ACPR, gain and efficiency measurements were taken over a range of power levels with I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 for V_{DS} = 30 V (the IS95 signal was comprised of pilot, paging, sync, and traffic channels 8 to13 having a peak/average ratio at 0.01 % probability of 9.7 dB.)
- 6-carrier GSM IMD, gain and efficiency measurements were taken over a range of power levels with I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V for V_{DS} = 30 V (the 6-carrier GSM signal had a peak/average ratio at 0.01 % probability of 7.1 dB and a spacing of 4 MHz).
- Power and efficiency measurements were taken over a range of power levels on a pulsed CW signal with a 12 μs pulse width and 10 % duty cycle with I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V for V_{DS} = 30 V.
- ACPR (or IMDs) and efficiency were measured at several power levels using a variety of GSM, W-CDMA and LTE signals, both with and without digital predistortion, using Optichron's OP6180 DPD development platform.

5. RF performance

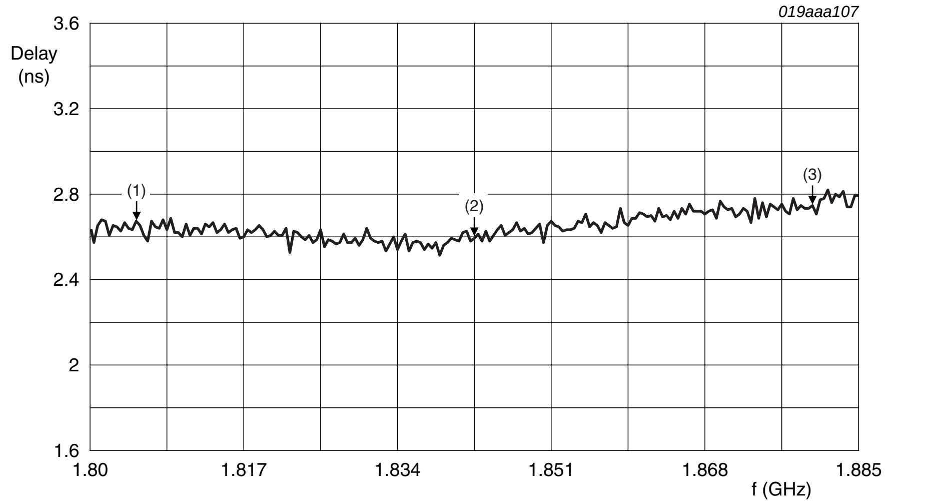
5.1 Network analyzer measurements

Network analyzer measurements were taken under the following conditions: P_O = 46 dBm, V_{DS} = 30 V, I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V



(1) S21: 1.805100 GHz; 15.6260 dB
(2) S21: 1.842500 GHz; 16.0215 dB
(3) S21: 1.879900 GHz; 16.4014 dB
(4) S11: 1.805100 GHz; 11.8145 dB
(5) S11: 1.842500 GHz; 11.6621 dB
(6) S11: 1.879900 GHz; 13.2417 dB

Fig 5. Gain and input return loss as a function of frequency at P_O = 46 dBm



(1) S21: 1.805100 GHz; 2.6711 ns
(2) S21: 1.842500 GHz; 2.5904 ns
(3) S21: 1.879900 GHz; 2.7470 ns

Fig 6. Delay as a function of frequency at P_O = 46 dBm

5.2 IS95 measurements

IS95 measurements were taken under the following conditions:
V_{DS} = 30 V, I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V

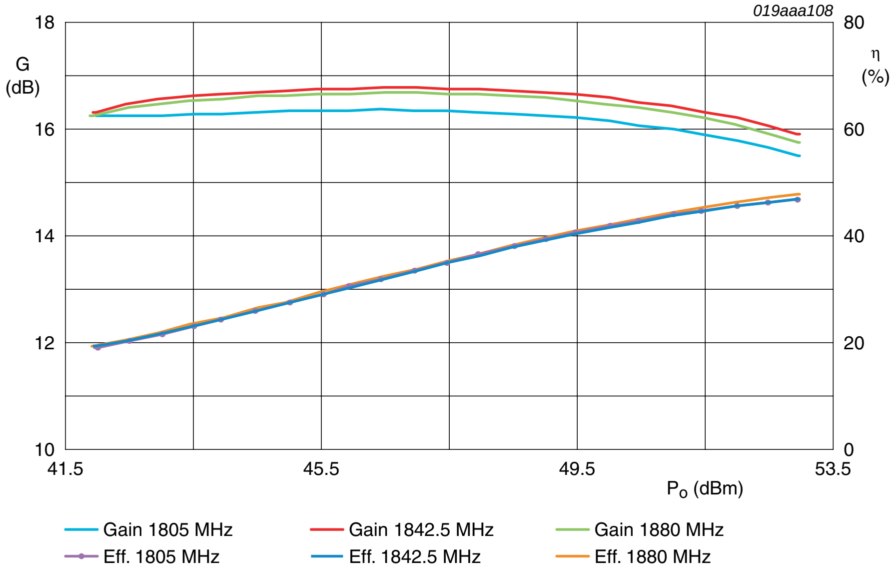
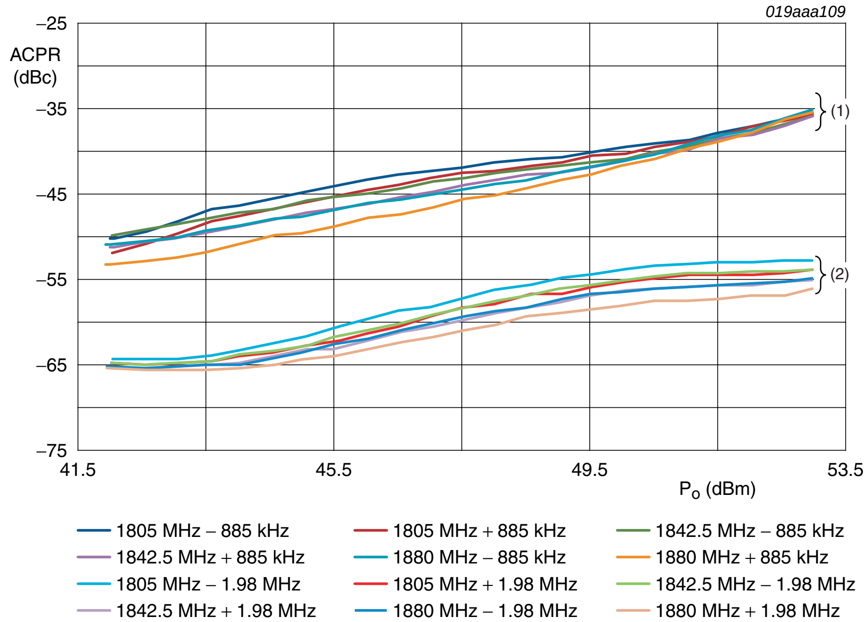


Fig 7. Gain and drain efficiency as a function of output power; $T_{heatsink}$ = 25 °C



(1) Adjacent channel

(2) Alternate channel

Channel BW: 1.23 MHz; Interference BW: 30 kHz

Fig 8. ACPR as a function of output power; $T_{heatsink}$ = 25 °C

5.3 6-carrier multi-carrier GSM measurements

6-carrier multi-carrier GSM measurements were taken under the following conditions: V_{DS} = 30 V, I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V

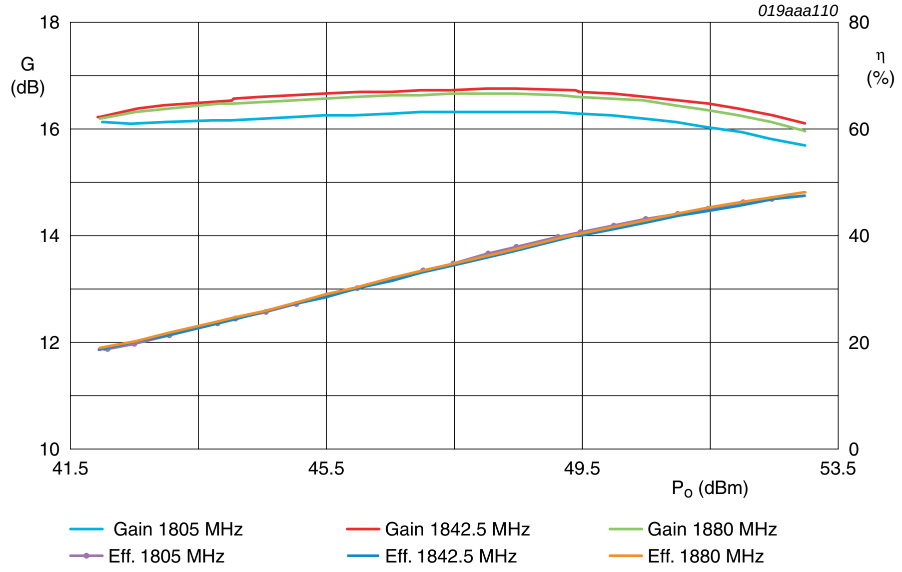
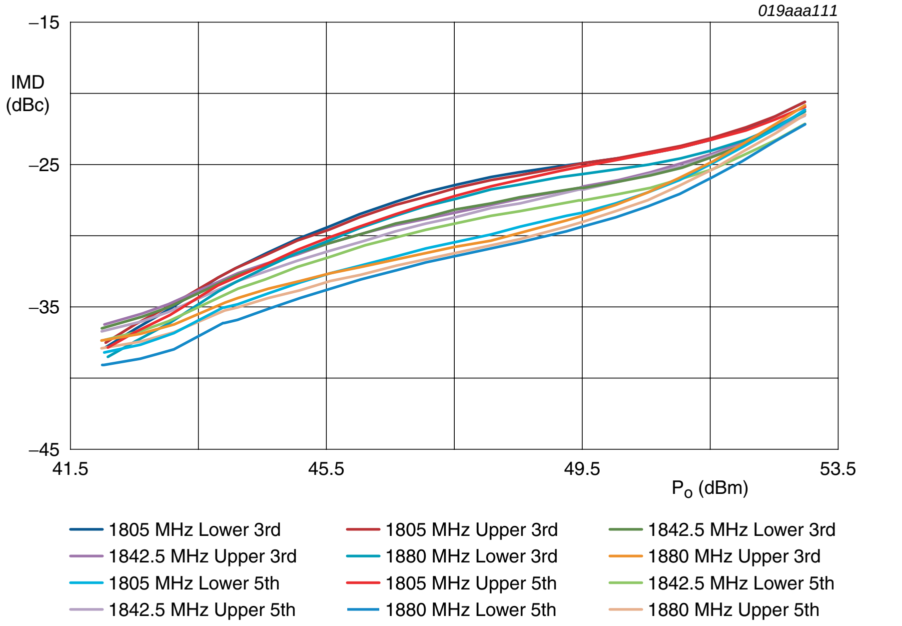


Fig 9. Gain and drain efficiency as a function of output power; $T_{heatsink}$ = 25 °C



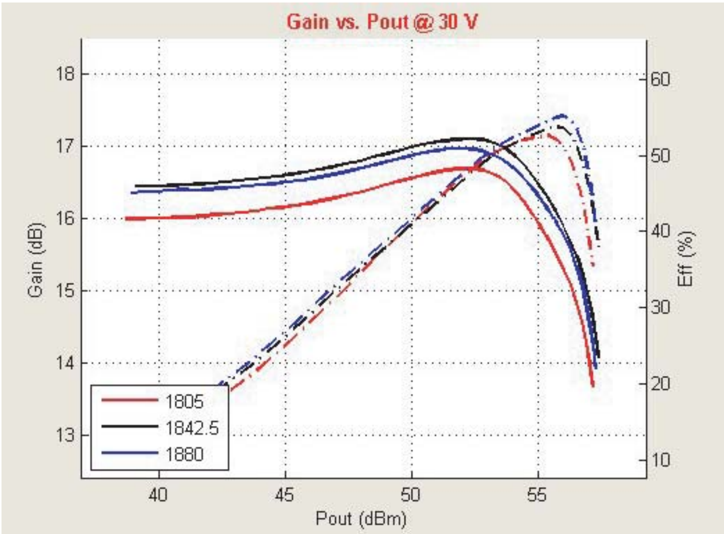
Channel and Interference bandwidth: 30 kHz

Fig 10. 3rd and 5th order intermodulation distortion as a function of output power; $T_{heatsink}$ = 25 °C

5.4 Peak power measurements

Peak power measurements were taken under the following conditions:
V_{DS} = 30 V, I_{Dqmain} = 1300 mA and V_{GSpeak} = 0.375 V

The peak power capabilities of the amplifier were characterized using a pulsed signal (12 μs pulse width and 10 % duty cycle) and measuring the 1 dB and 3 dB compression points.



Freq(MHz)	P1dB (dBm)	P1dB (W)	P3dB (dBm)	P3dB (W)
1805	55.45	351.04	57.18	521.93
1842.5	55.70	371.35	57.39	548.83
1880	55.71	372.59	57.28	533.97

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Fig 11. Gain and efficiency as a function of output power; $T_{heatsink}$ = 25 °C

5.5 Summary of test results with Optichron's OP6180 DPD Development System

The measurements presented below were taken using Optichron's OP6180 DPD development system. The BLF7G20LS-200 Doherty design, when used in combination with this state-of-the-art digital pre-distortion system, yields the results shown for combinations of GSM, W-CDMA and LTE signals. The multi-carrier GSM data is referenced to both Class 1 and Class 2 IMD specifications. The measurement results are summarized in Table 1 to Table 5. The plots in Figure 12 to Figure 20 show samples of the more important signals.

Table 1. MC-GSM performance summary for Optichron OP6180 DPD and NXP 2 x BLF7G20LS-200 Doherty PA

			Efficiency (%)		P_O (dBm)		P_O (W)		Efficiency difference (%)	P_O (dBm) difference	P_O (dBm) difference
Signal BW (MHz)	Number of carriers	PAR (dB)	Class 1 IMD ≤ –70 dBc	Class 2 IMD ≤ –60 dBc	Class 1 IMD ≤ –70 dBc	Class 2 IMD ≤ –60 dBc	Class 1 IMD ≤ –70 dBc	Class 2 IMD ≤ –60 dBc	Class 2 % – Class 1 % (% points)	Class 2 – Class 1	P_O (W)
50	8	6.5	24.9 %	43.6 %	44.17	50.41	26.1	109.2	18.7	6.2	83.8
50	6	6.2	28.8 %	42.3 %	45.6	49.96	36.3	99.1	13.5	4.4	62.8
40	8	6.5	33.0 %	47.6 %	46.8	51.55	47.5	142.9	14.6	4.8	95.4
40	6	6.2	35.9 %	47.6 %	47.7	51.68	59.2	147.2	11.8	4.0	88.1
30	8	6.5	32.8 %	46.3 %	46.7	50.92	47.2	123.6	13.5	4.2	76.4
30	6	6.2	40.9 %	49.8 %	49.2	52.16	82.2	164.4	8.9	3.0	82.2
20	8	6.5	39.3 %	48.2 %	48.8	51.9	76.6	166.3	9.0	3.1	89.8
20	6	6.2	40.1 %	49.5 %	48.9	52.2	78.2	141.9	9.4	3.3	63.7

Table 2. W-CDMA performance summary for Optichron OP6180 DPD and NXP 2 x BLF7G20LS-200 Doherty PA

	PAR (dB)	Efficiency (%)	P_O (dBm)	P_O (W)	Worst IMD (dBc)
60 MHz W-CDMA 1100000011[1]	7.7	42.5	49.33	85.7	–50.7
35 MHz W-CDMA 1100011[2]	7.8	41.0	49.47	88.5	–59.1
20 MHz W-CDMA 1111[3]	6.0	43.5	50.29	106.9	–60.5
20 MHz W-CDMA 1001[3]	7.05	42.2	50.16	103.8	–62.9

[1] V_{DD} = 28 V; I_{DD} = 7.2 A.

[2] V_{DD} = 30 V; I_{DD} = 7.2 A.

[3] V_{DD} = 30 V; I_{DD} = 8.2 A.

Table 3. LTE performance summary for Optichron OP6180 DPD and NXP 2 x BLF7G20LS-200 Doherty PA

	PAR (dB)	Efficiency (%)	P_O (dBm)	P_O (W)	Worst IMD (dBc)
60 MHz LTE 20/0/20	7.9	35.8	47.00	50.1	–50.5
50 MHz LTE 10/20/20	7.8	45.5	51.13	129.7	–50.8
20 MHz LTE 20	6.0	43.5	50.29	106.9	–60.5

Table 4. W-CDMA + 4C-GSM performance summary for Optichron OP6180 DPD and NXP 2 x BLF7G20LS-200 Doherty PA

9.6 MHz 4c GSM + 1c W-CDMA PAR 9.1 dB; 18 MHz total occupied BW; efficiency = 41.6 % GSM IMD 3rd order ≤ –60 dBc; P_O = 49.54 dBm; P_O = 89.9 W; V_{DD} = 30 V; I_{DD} = 7.2 A

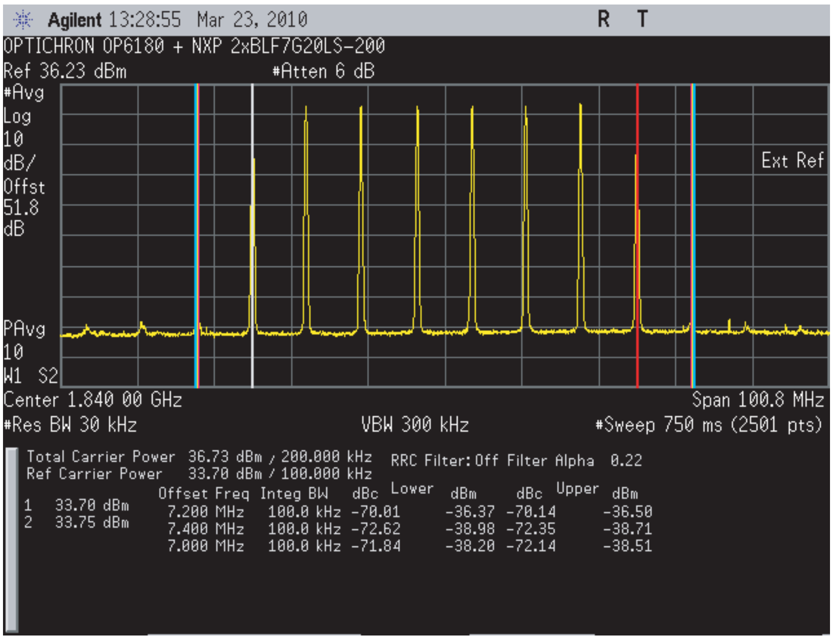
Frequency offset (MHz)	Spectrum IMD (dBc)	Spectrum BW (kHz)	Measured IMD (dBc)
ACLR			
5	–44.2	3.84	–52.85
10	–49.2	3.84	–53.36
Spectrum emission test			
2.515	–12.5	30	–28.59
2.715	–12.5	30	–28.22
3.515	–24.5	30	–28.46
4	–24.5	30	–28.31
≥ 4.0	–115.5	1000	–13.22

Table 5. LTE + 4C-GSM performance summary for Optichron OP6180 DPD and NXP 2 x BLF7G20LS-200 Doherty PA

9.6 MHz 4c GSM + 10 MHz 1c LTE PAR 7.86 dB; 19.6 MHz total occupied BW; efficiency = 43.8 % GSM IMD 3rd order ≤ –60 dBc; P_O = 50.32 dBm; P_O = 107.6 W; V_{DD} = 30 V; I_{DD} = 8.2 A

Frequency offset (MHz)	Spectrum IMD (dBc)	Spectrum BW (kHz)	Measured IMD (dBc)
ACLR			
10	–44.2	10	–52.15
20	–44.2	10	–51.38
Spectrum emission test			
0.05	–5.5	100	–23.86
5.05	–12.5	100	–24.65
10.05	–12.5	100	–24.35
10.5	–13	1000	–14.55

5.5.1 Performance pre-distorted using Optichron's OP6180 DPD development system



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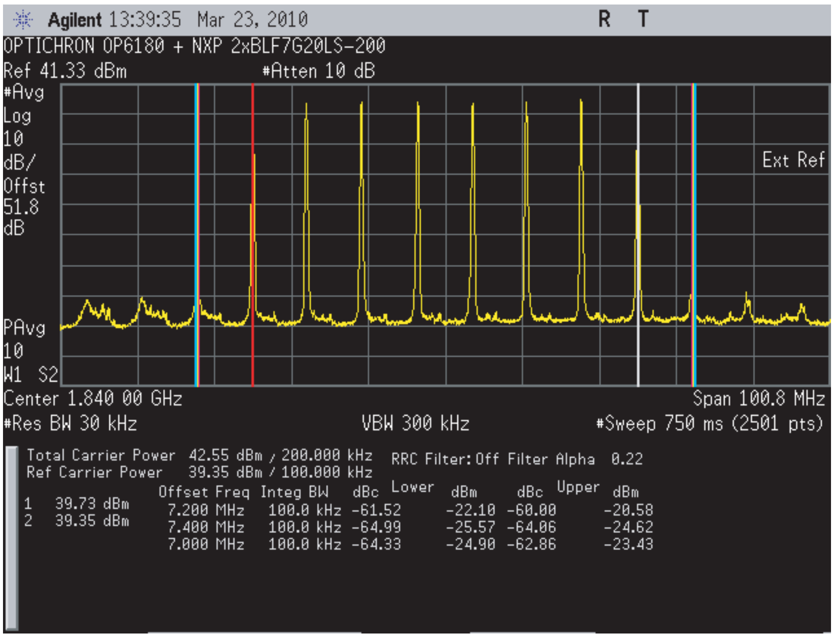
a. Class 1: P_O = 44.17 dBm, 26.1 W; efficiency = 24.9 %; V_{DD} = 30 V; I_{DD} = 3.5 A



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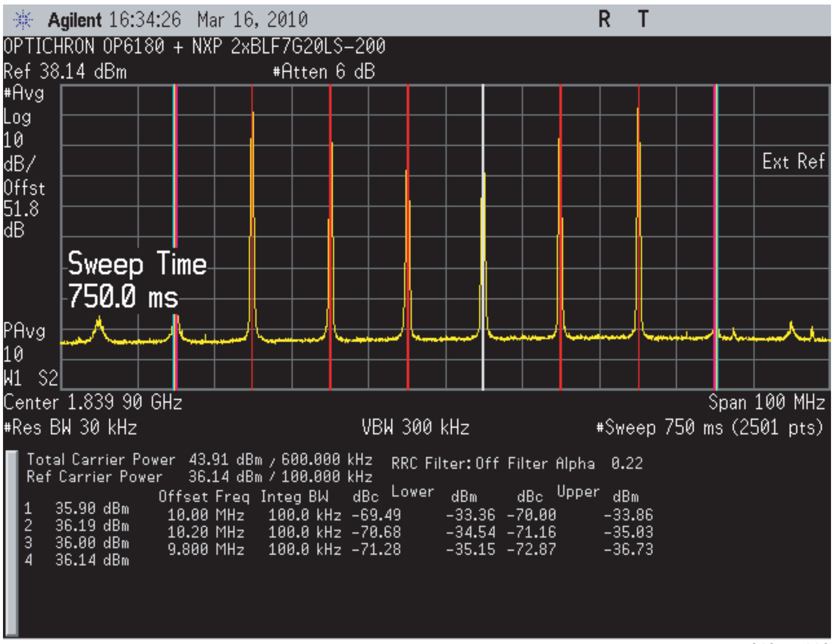
b. Class 2: P_O = 50.41 dBm, 109.9 W; efficiency = 43.6 %; V_{DD} = 30 V; I_{DD} = 8.4 A

Fig 12. 8-carrier GMSK, 50 MHz



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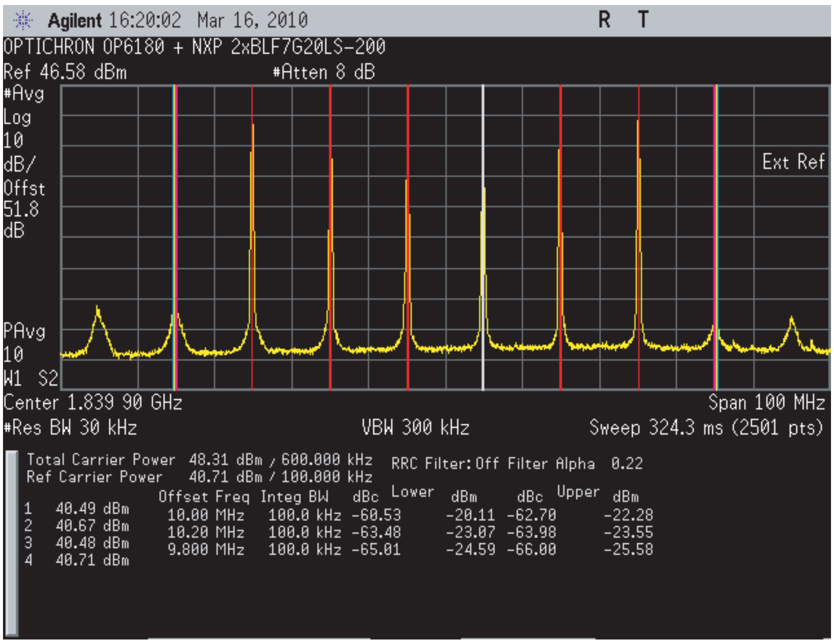
a. Class 1: P_O = 45.6 dBm, 36.3 W; efficiency = 28.8 %; V_{DD} = 30 V; I_{DD} = 4.2 A



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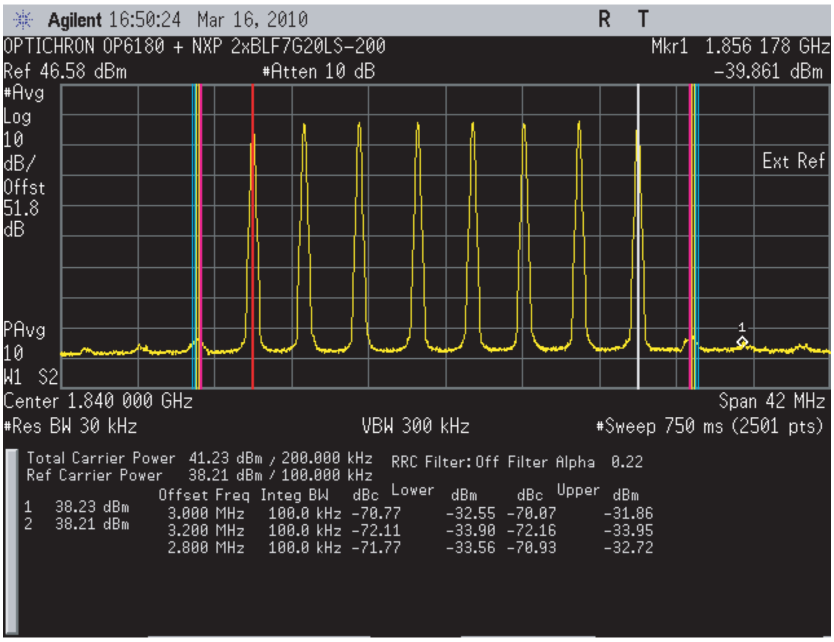
b. Class 2: P_O = 49.96 dBm, 99.1 W; efficiency = 42.3 %; V_{DD} = 30 V; I_{DD} = 7.8 A

Fig 13. 6-carrier GMSK, 50 MHz



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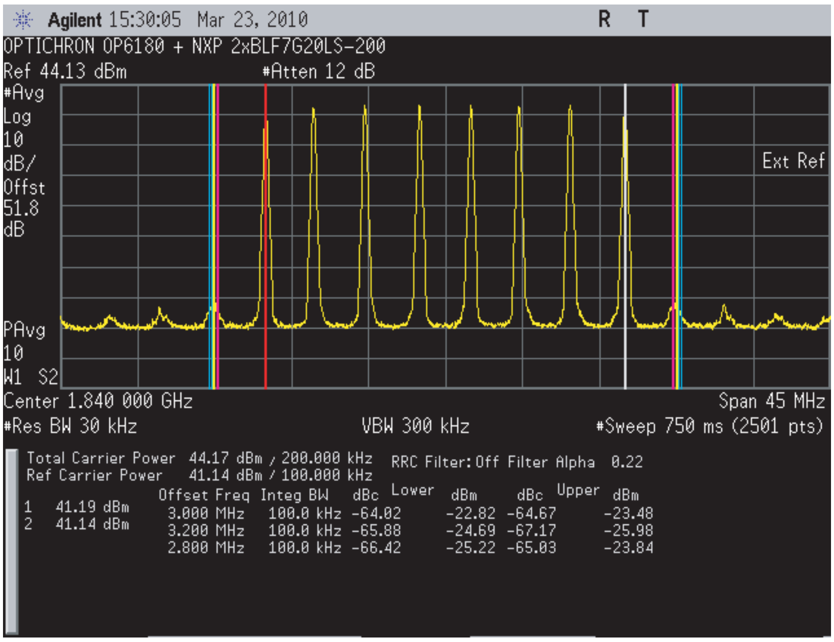
a. Class 1: P_O = 48.84 dBm, 76.6 W; efficiency = 39.3 %; V_{DD} = 30 V; I_{DD} = 6.5 A



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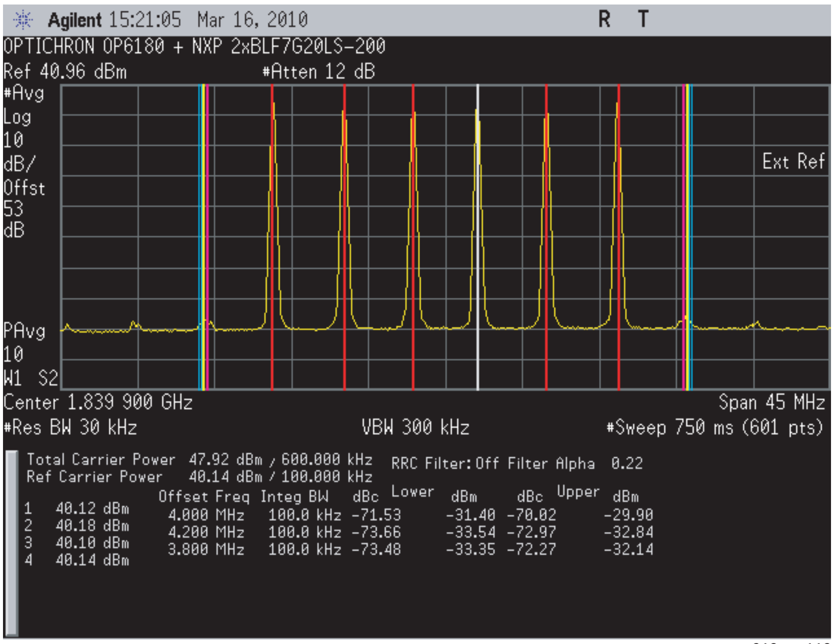
b. Class 2: P_O = 51.90 dBm, 154.3 W; efficiency = 48.2 %; V_{DD} = 30 V; I_{DD} = 10.7 A

Fig 14. 8-carrier GMSK, 20 MHz



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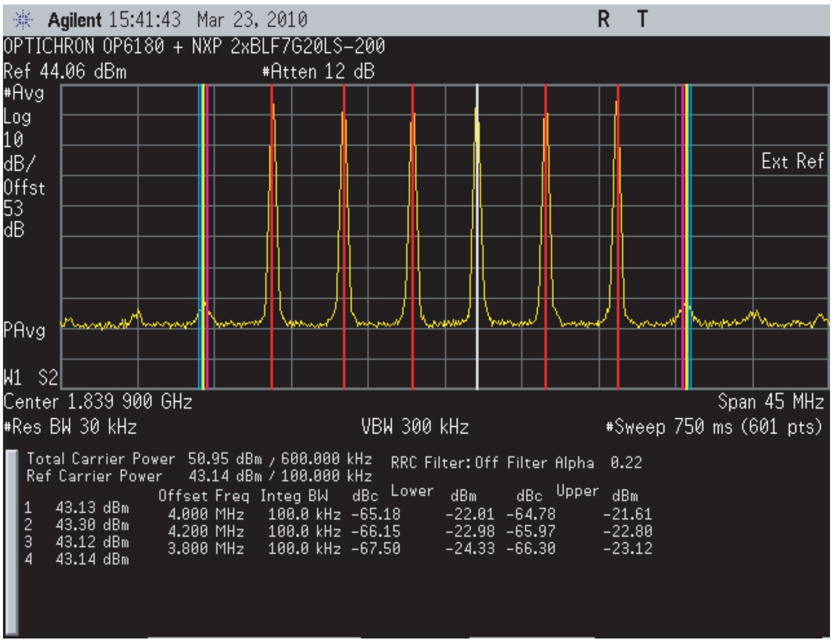
a. Class 1: P_O = 48.93 dBm, 78.2 W; efficiency = 40.1 %; V_{DD} = 30 V; I_{DD} = 6.5 A



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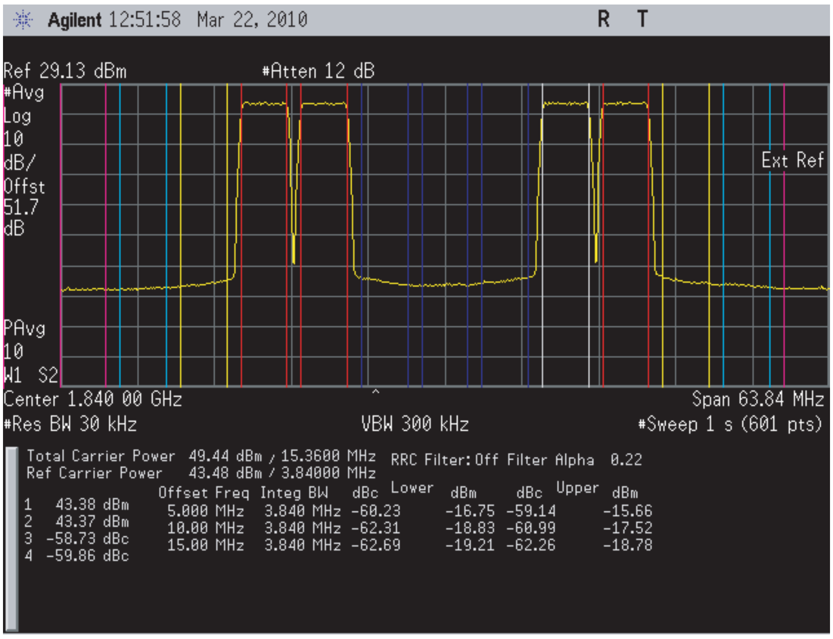
b. Class 2: P_O = 52.21 dBm, 166.3 W; efficiency = 49.5 %; V_{DD} = 30 V; I_{DD} = 11.2 A

Fig 15. 6-carrier GMSK, 20 MHz



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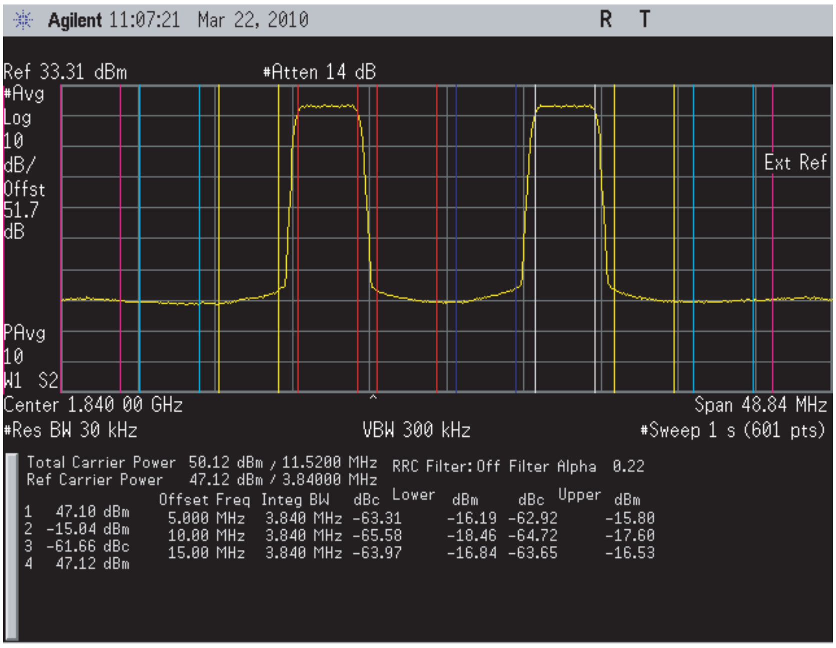
a. 4-carrier W-CDMA, 1100011: P_O = 49.47 dBm, 88.5 W; efficiency = 41.0 %; V_{DD} = 30 V; I_{DD} = 7.2 A



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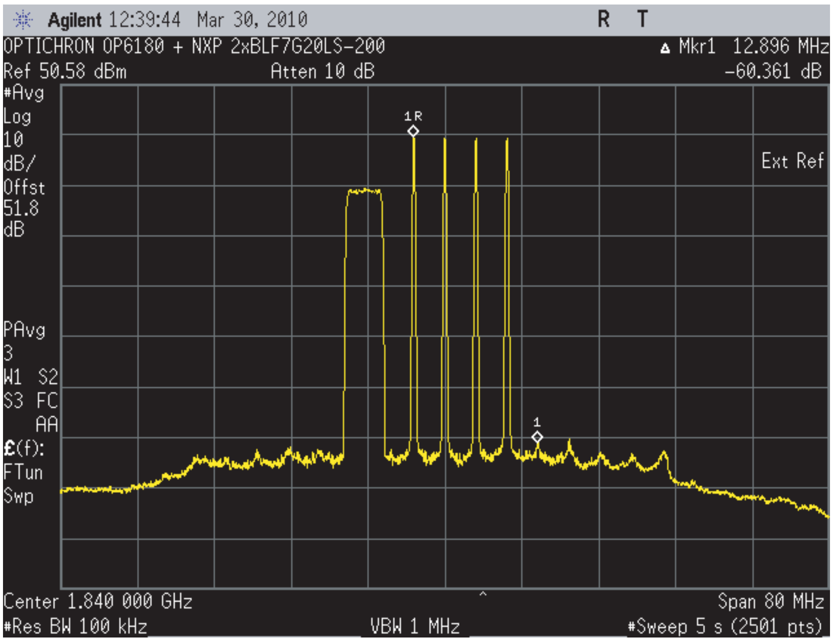
b. 2-carrier W-CDMA, 1001: P_O = 50.16 dBm, 103.8 W; efficiency = 42.2 %; V_{DD} = 30 V; I_{DD} = 8.2 A

Fig 16. W-CDMA



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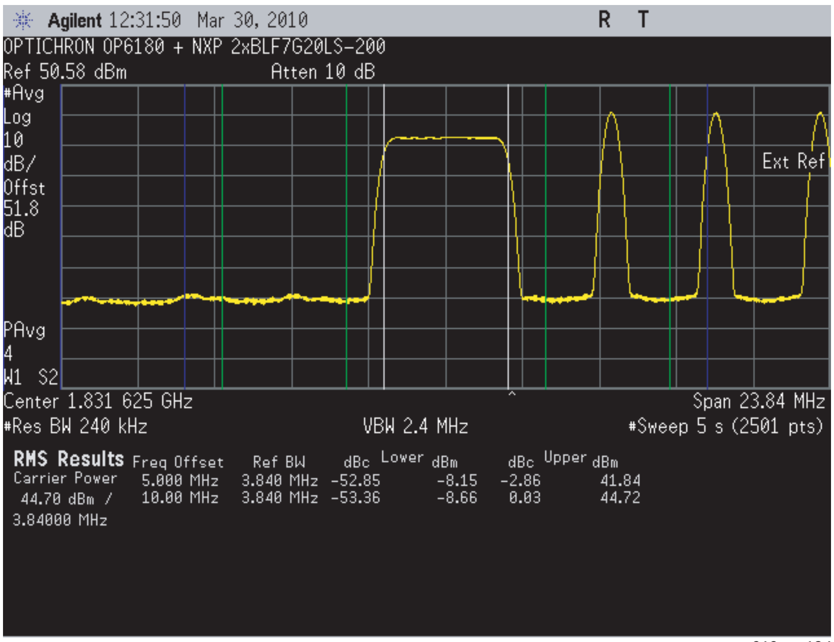
a. Broadband



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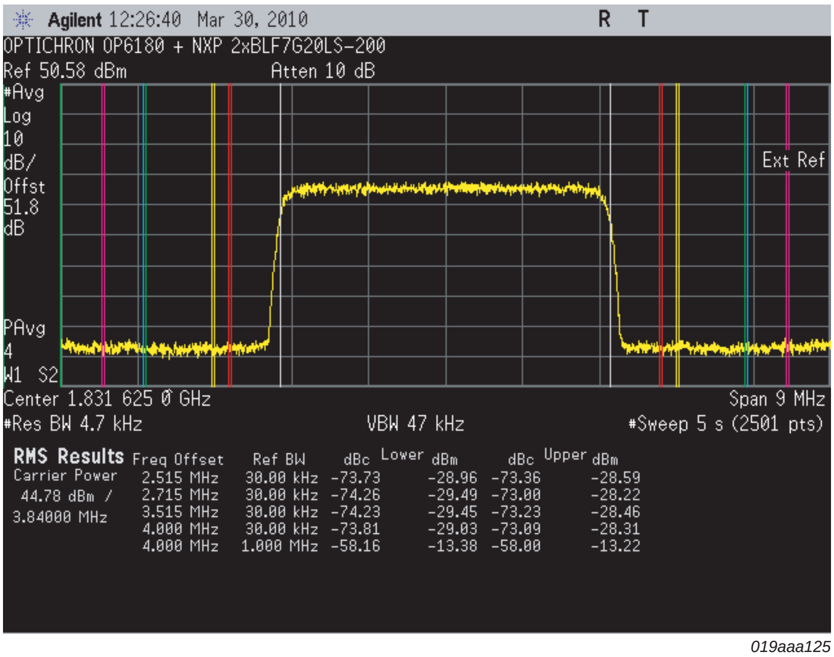
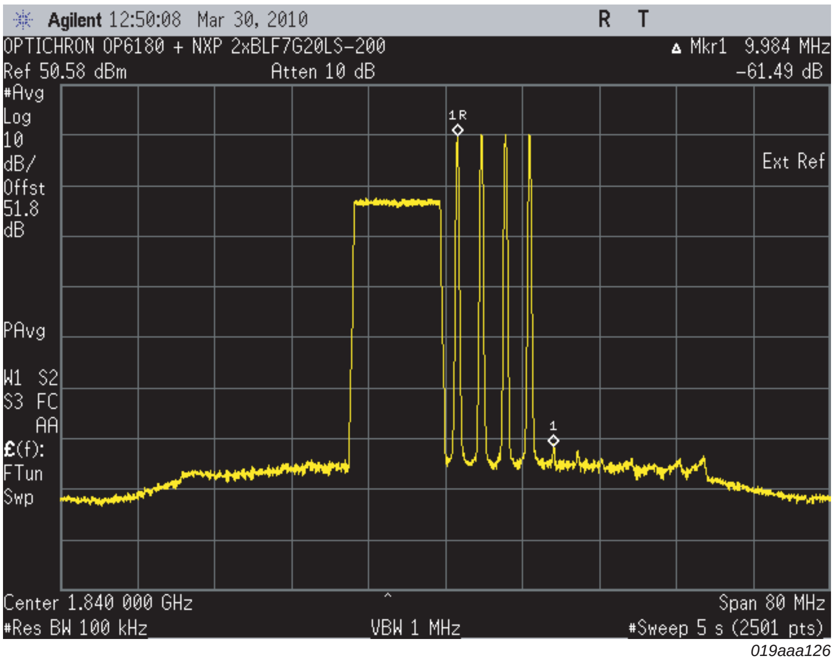
b. ACLR (note that the upper ACLR measurements are not relevant as the GSM carriers fall in that band)

Fig 17. 1-carrier W-CDMA plus 4-carrier GSM, 18 MHz



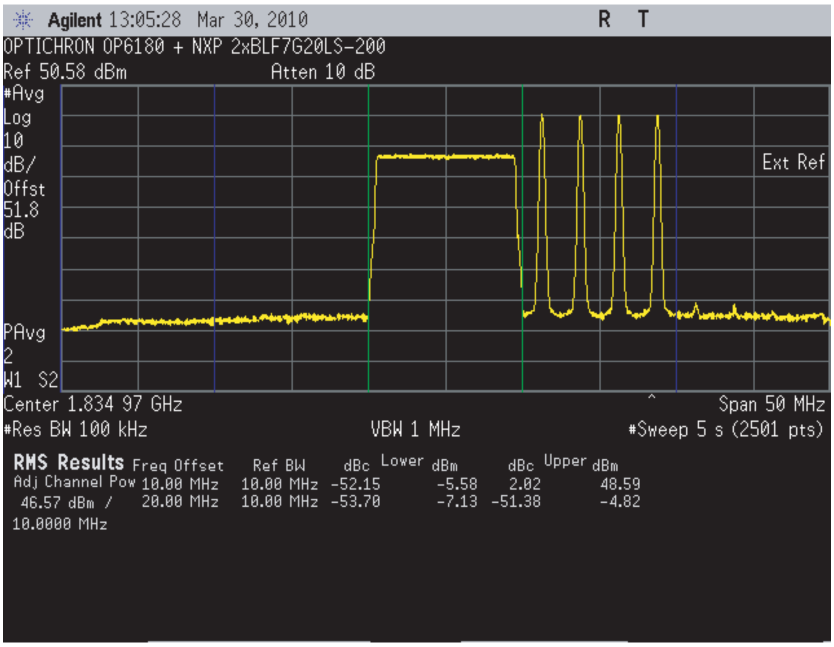
Spectrum emission test

Fig 18. 1-carrier W-CDMA plus 4-carrier GSM, 18 MHz



Broadband

Fig 19. 1-carrier LTE plus 4-carrier GSM, 19.6 MHz



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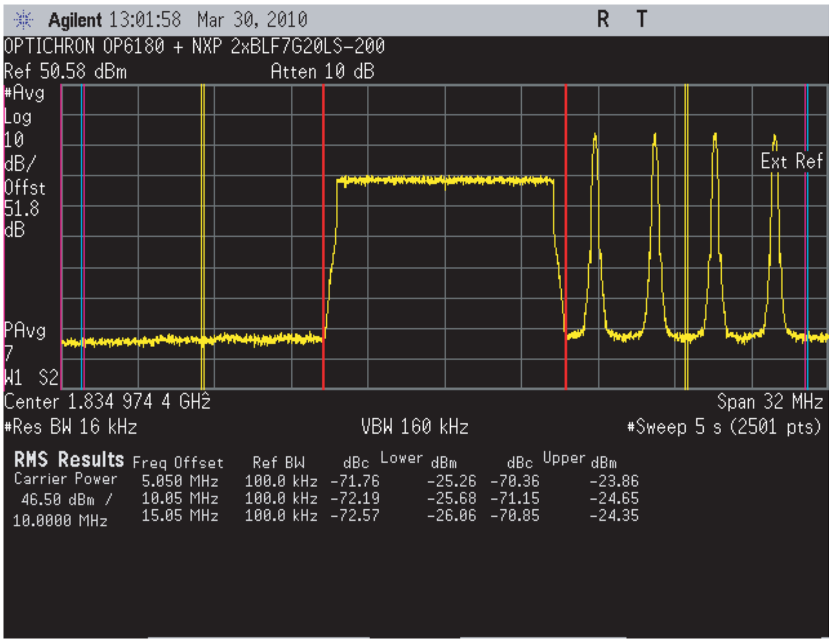
a. ACLR (note that the upper ACLR measurements are not relevant as the GSM carriers fall in that band)



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b. Spectrum emission test

Fig 20. 1-carrier LTE plus 4-carrier GSM, 19.6 MHz

6. Appendix A: Bill of materials

Table 6. Parts list for BLF broadband application circuit; see Figure 2

Component	Value	Manufacturer	Part number
input PCB	25 mil Rogers 3006, ε_r = 6.15, 1 oz copper each side	Ohio Circuits	BLF7G20LS-200 Doherty PA input 25Ro3006
output PCB	25 mil Rogers 3006, ε_r = 6.15, 1 oz copper each side	Ohio Circuits	BLF7G20LS-200 Doherty PA output 25Ro3006
Q1, Q101	78L08 voltage regulator	NJR	NJM#78L08UA-ND
Q2, Q102	2N2222 NPN transistor	Fairchild	MMBT2222
Q3, Q103	BLF7G20LS-200	NXP	BLF7G20LS-200
R1, R14, R101, R114	9.1 Ω	Vishay Dale	CRCW08059R09FKEA
R2, R3, R102, R103, R106	430 Ω	Vishay Dale	CRCW0805432RFKEA
R4	75 Ω	Vishay Dale	CRCW080575R0FKTA
R5, R105	200 Ω potentiometer	Bourns	3214-1-201E
R6	2 kΩ	Vishay Dale	CRCW08052K00FKTA
R7, R107	1.1 kΩ	Vishay Dale	CRCW08051K10FKEA
R8, R108	11 kΩ	Vishay Dale	CRCW080511K0FKEA
R9, R109	5.1 Ω	Vishay Dale	CRCW08055R11FKEA
R10, R110	5.1 kΩ	Vishay Dale	CRCW08055K10FKTA
R11, R111	910 Ω	Vishay Dale	CRCW0805909RFKTA
R12, R112	1.1 kΩ	Vishay Dale	CRCW08051K10FKEA
R13, R113	0.5 W, 499 Ω	Vishay Dale	CRCW2010499RFKEF
R104	0 Ω	Vishay Dale	CRCW080500R0FKTA
R150	EMC SMT 2010 50 W load	EMC	
X1	3 dB hybrid coupler	Anaren	1P503S
L1, L2, L101, L102	Ferroxcube bead	Fair Rite	2743019447
C2, C4, C102, C104	100 nF ceramic 0805	MultiComp	S0805W104K1HRN-P4
C3, C103	4.7 μF	TDK	C4532X7R1H475M
C5, C105	1 μF	TDK	C3216X7R1H105K
C6, C7, C8, C106, C107, C108	15 pF	American Technical Ceramics	600F
C9, C11, C109, C111	2.2 pF	American Technical Ceramics	100B
C13, C14, C113, C114	15 pF	American Technical Ceramics	ATC100B150JT500X
C10, C12, C110, C112	1 μF	Murata	
C15, C16, C115, C116	10 μF	Murata	
C20, C120	220 μF, 50 V electrolytic SMT	Panasonic	PCE3474CT-ND
C117, C118	2.7 pF	American Technical Ceramics	600F
C17, C18	2.4 pF	American Technical Ceramics	600F

7. Abbreviations

Table 7. Abbreviations

Acronym	Description
ACLR	Adjacent Channel Leakage Ratio
ACPR	Adjacent Channel Power Ratio
BW	Bandwidth
CFR	Crest Factor Reduction
CW	Continuous Wave
DPD	Digital Pre-Distortion
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile Communications
GUI	Graphic User Interface
IMD	InterModulation Distortion
IRL	Input Return Loss
LDMOS	Laterally Diffused Metal-Oxide Semiconductor
LTE	Long Term Evolution
MC-GSM	Multi-Carrier GSM
PA	Power Amplifier
PAE	Power-Added Efficiency
W-CDMA	Wideband Code Division Multiple Access

8. References

[1] BLF7G20LS-200 data sheet

9. Legal information

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10. Contents

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