AN11152

Reducing the Spurs at RF_out caused by the biasing choke during fast switching on and off in TDD system

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Document information

Info	Content
Keywords	BGA7210, VGA, TDD, Fast Switch, Spurs, OM7921/BGA7210 Customer Evaluation Kit
Abstract	The document provides guidelines to reduce the spurs at RF_out caused by the RF_out stage biasing choke during fast switching OFF the BGA7210.
Summary	The BGA7210 Variable Gain Amplifier with a fast power on/off mode which can be also used in Base station TX-lines using the TDD (time division duplex) operation systems. The BGA7210 RF output stage uses an external biasing choke. During fast switching off the device, the choke induces spurs at the RF-output. This document describes how to reduce the spurs caused by fast switching off the device and the voltage at the inductor.

Revision history

Rev	Date	Description
1.0	20120120	Initial document

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1. Introduction

This document describes how to reduce the spurs at RF_out caused by fast switching off (on) the device when this option is used in TDD operation systems. Measurements shown compare the performance using the original external component list (without the shunt capacitor Csh = 0.68 pF) with a tailored component list, which improves the switching behavior at 2.14 GHz.

The BGA7210 MMIC is an extremely linear Variable Gain Amplifier (VGA), operating from 0.7 GHz to 2.75 GHz. The maximum gain is 30 dB. It has an attenuation range of 31.5 dB. At its minimum attenuation setting it has a maximum power output of 21 dBm, an IP3o of 39 dBm and a noise figure of 6.5 dB.

The BGA7210 has been designed and qualified for the severe mission profile of cellular base stations, but its outstanding RF performance and digital SPI interfacing flexibility make it suitable for a wide variety of applications.

2. Spurs at RF_out and their root cause

Spurs occurs at RF_out during switching off the BGA7210. The root cause is the fast switching of the final stage of the BGA7210 for different reasons, like power saving or to have higher isolation between the RFin and RFout.

The final stage of the BGA7210 is biased by an external inductor which is also in the supply loop. As known, by fast switching off the current through an inductor, the magnetic field will induce a counter electromagnetic force which generates a voltage (spurs).

Vspur = L * di/dt

The induced voltage (Vspur) peak value and duration is dependent on the fall time of the switch off signal, inductor value, voltage, current through the inductor and the load resistance.

3. Options to reduce the spurs at RF-out

The only way to reduce the spurs is to lower the biasing inductor value L2, but that would impact the RF performance, and the matching and the insertion loss would become worse.

Of course the inductor can be damped by series resistor, but this has much more disadvantages than reducing the inductor value.

The induced voltage has two impacts on the circuit:

1. Induced voltage could damage the final amplifier stage, this case is investigated (simulation and measured), and found that the BGA7210 Breakdown voltage is much higher than the measured/simulated spur voltages.
2. Induced voltage generates broadband spurs at the RF-out which can give EMI problems.

To reduce the spurs at RF-out a High pass filter can be used.

There are different HP-filters (Chebyshev, Butterworth, Bessel,…) and types with minimum number of capacitors or inductors.

The Chebyshev filter topology has been selected, because it has high attenuation at the stop band, low slope, and matching can be tuned, and requires a minimum value for the inductors. The choke acts as a first inductor (3.9 nH) in this filter topology and has a low inductance. This will induce less spurs than the original 22 nH biasing inductor (L2).

Solving the EMI problem using HP-filter will also reduce the induced spur voltage!

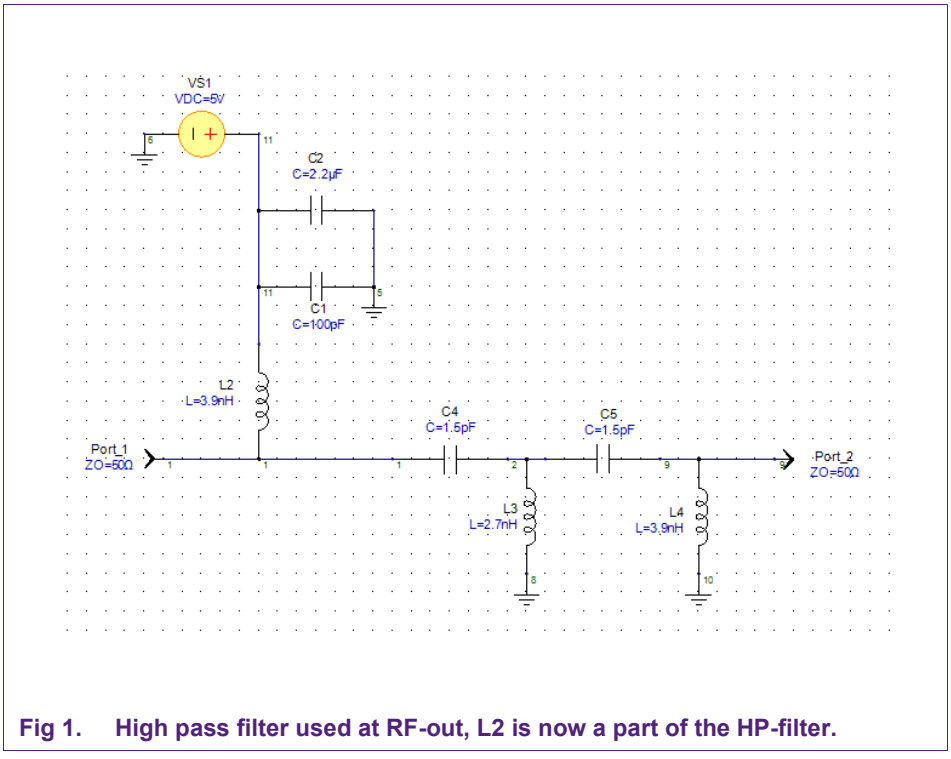

Fig 1. High pass filter used at RF-out, L2 is now a part of the HP-filter.

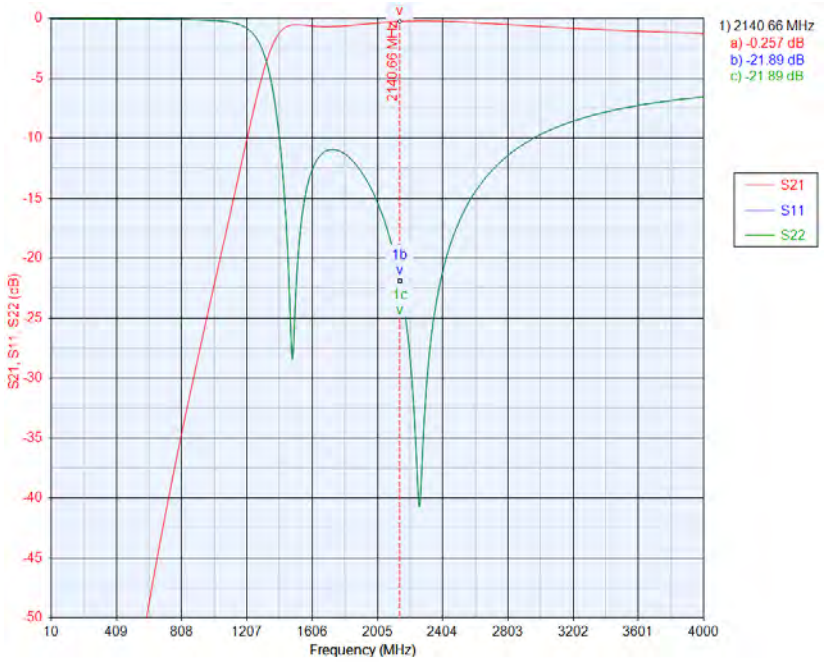

Fig 2. Simulation results of the High pass filter used at RF-out, L2 is now a part of the HP-filter.

3.1 S-par and linearity measurements original versus HP-filter

Table 1. Linearity results

Measured at 2140 MHz

Symbol	Original	With HP-filter
$P_{L(1dB)}$	20 dBm	22.5 dBm
IP3o	34 dBm	34 dBm

Adding the HP-filter improves the $P_{L(1dB)}$, this can be explained by changing the output matching means improving the matching at the BGA7210 output pin.

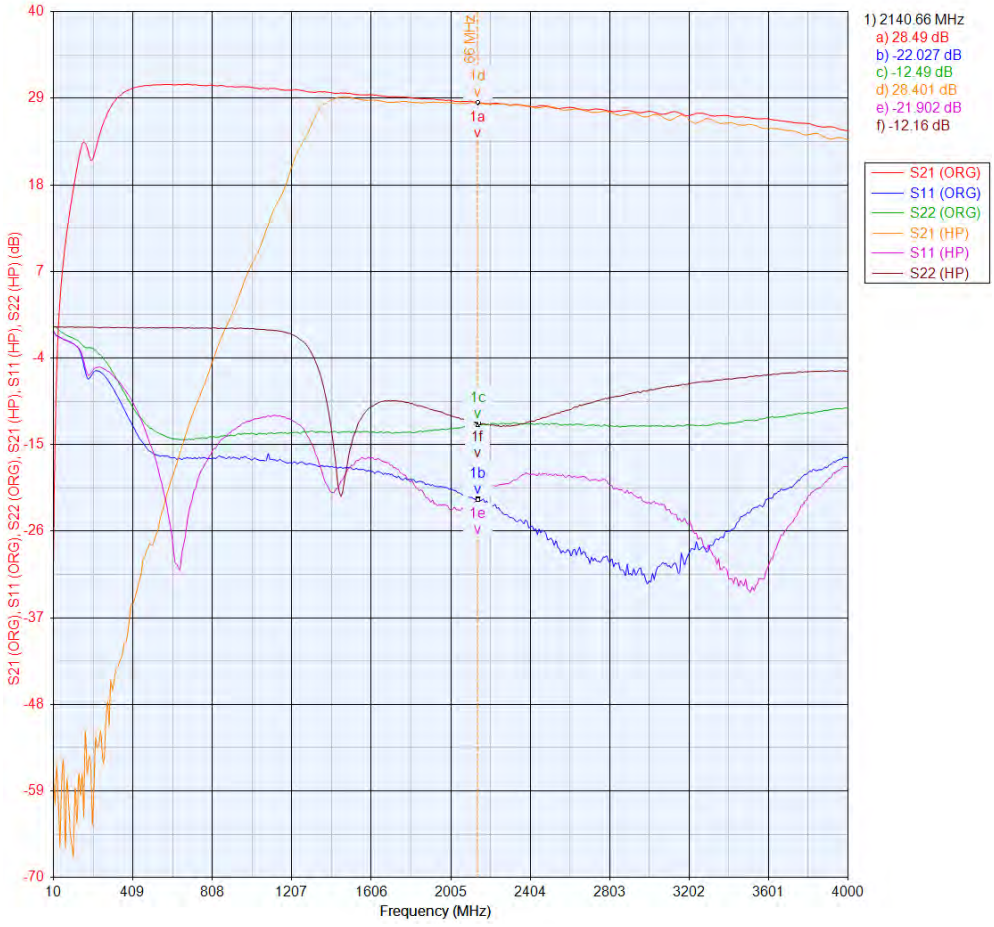

Fig 3. S-par measurement results at max gain & max current comparing original components vs. high pass filter used at RF-out, L2 is now a part of the HP-filter.

3.2 Measurements on the Spurs at RF_out using the original components and the proposed HP filter schematic

Spurs are measured with the original components and with the HP-filter which reduce the spurs.

3.2.1 Schematic and component list

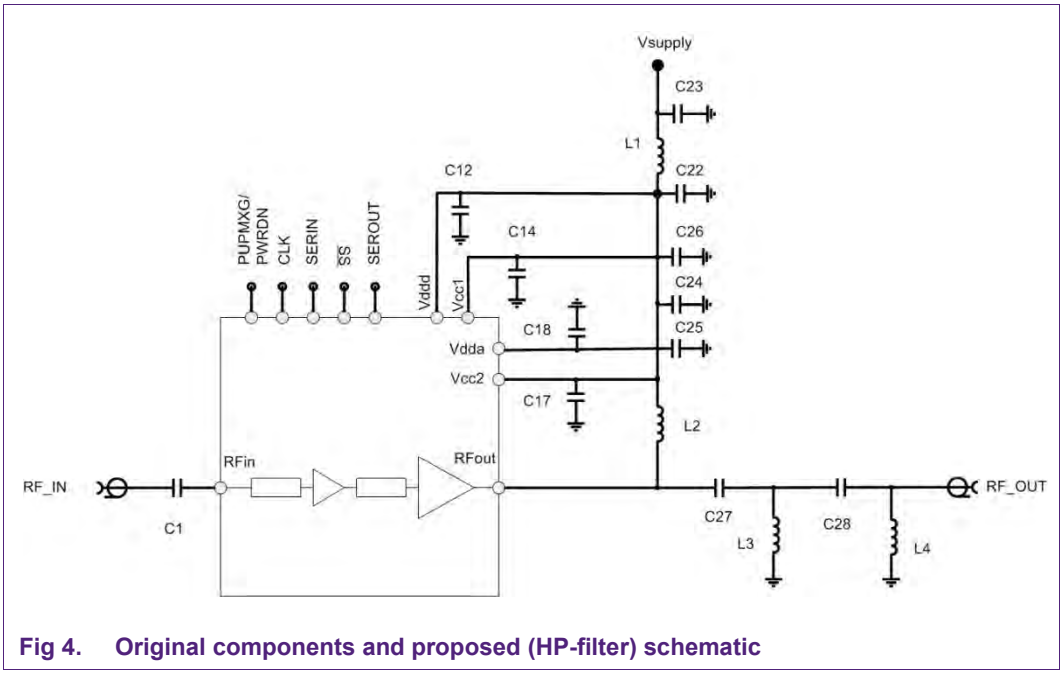

Fig 4. Original components and proposed (HP-filter) schematic

Table 2. List of components proposed in the BGA7210 Data sheet and with the HP-filter

Component	Description	Value orginal	Value HP-filter	Remarks
C1	DC blocking capacitor	100 pF	100 pF	Murata GRM
C27	DC blocking capacitor/HP-filter	100 pF	1.5 pF	Murata GRM
C12	Decoupling capacitor	100 nF	100 nF	Close to pin 19
C14	Decoupling capacitor	100 nF	100 nF	Close to pin 17
C17	Decoupling capacitor	100 nF	100 nF	Close to pin 15
C18	Decoupling capacitor	100 nF	100 nF	Close to pin 16
C22	Optional decoupling capacitor	10 µF	10 µF	Part of optional ripple filter
C23	Optional decoupling capacitor	10 µF	10 µF	Part of optional ripple filter
C24	Decoupling capacitor	100 pF	100 pF	Close to L2
C25	Decoupling capacitor	100 nF	100 nF	Close to L2
C26	Decoupling capacitor	4.7 µF	4.7 µF	Close to L2
C28	Jumper / HP-filter	0 Ω	1.5 pF	Murata GRM
L1	Optional inductor	820 nH	820 nH	Part of optional ripple filter

Component	Description	Value orginal	Value HP-filter	Remarks
L2	Inductor (biasing final stage) / HP-filter	22 nH	3.9 nH	Murata LQW 18 (close to RF-line)
L3	HP-filter	n.c.	2.7 nH	Murata LQW 18 (close to RF-line)
L4	HP-filter	n.c.	3.9 nH	Murata LQW 18 (close to RF-line)

3.2.2 Spur Measurements

This paragraph plots the spurs at RF-Out in time- and frequency-domain by switching BGA7210 on and off at max current and max gain setting. The switch on/off frequency at PUP-pin is set to 250 Hz, the input and output is terminated with 50 ohm.

3.2.2.1 Spurs in time domain

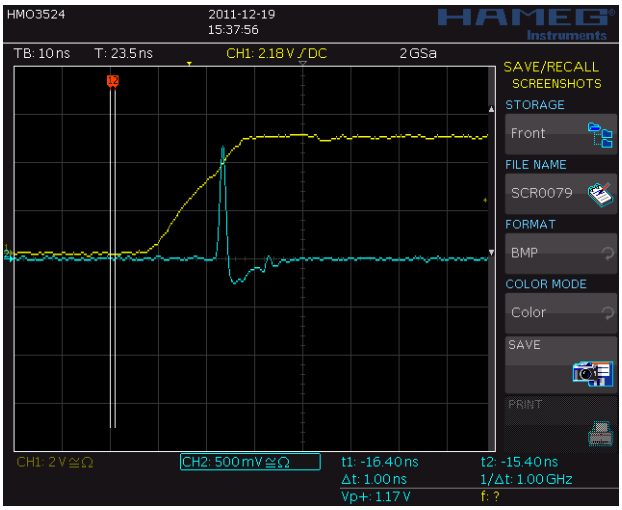

Fig 5. Original : Spur (blue 1.17Vp) at RFout (application board) during switch off sequence (yellow line is switch off signal)

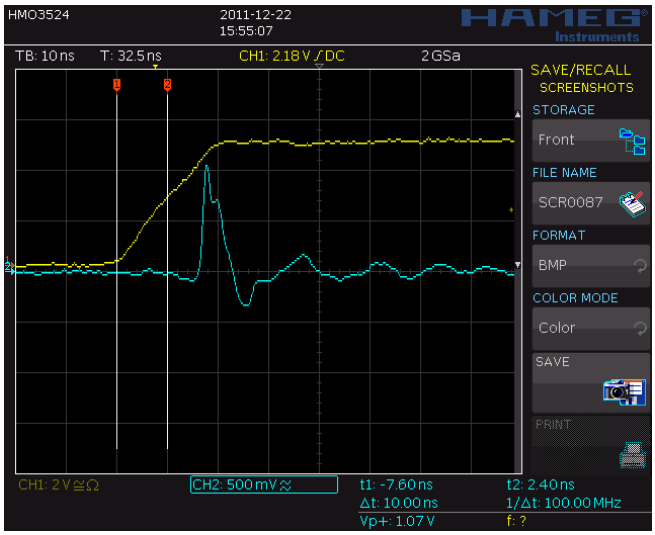

Fig 6. Original : Spur (blue 1.07Vp) at BGA7210 RFout pin during switch off sequence (yellow line is switch off signal)

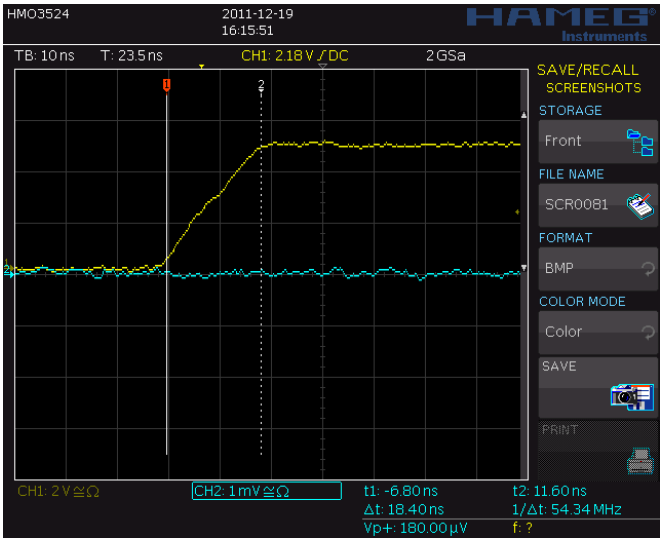

Fig 7. HP-filter : Spur (blue 0V) at RFout (application board) during the switch off sequence (yellow line is switch off signal)

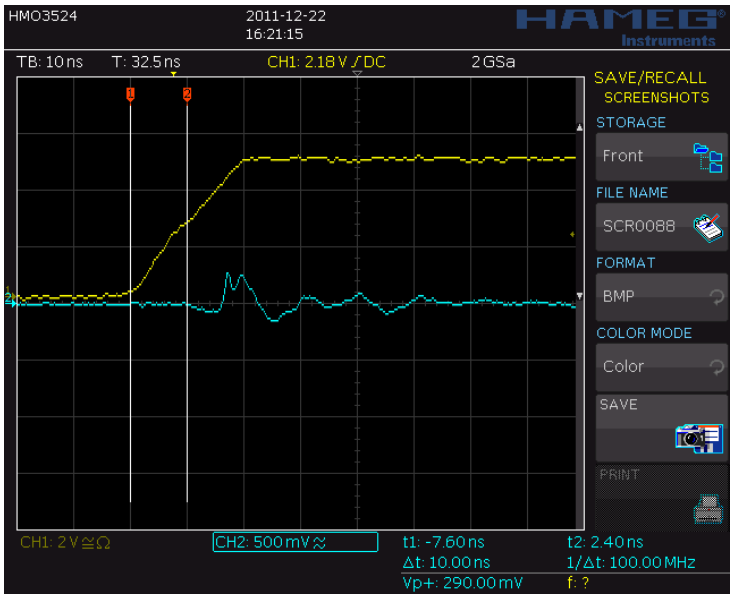

Fig 8. HP-filter : Spur (blue 0.29Vp) at BGA7210 RFout pin during switch off sequence (yellow line is switch off signal)

3.2.2.2 Spurs in frequency domain

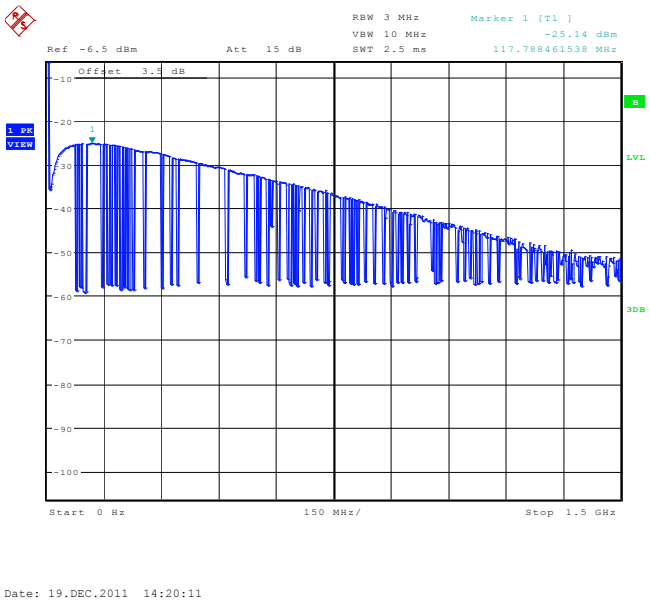

Fig 9. Original : Spur up to -25dBm at RFout (application board) during switch off sequence

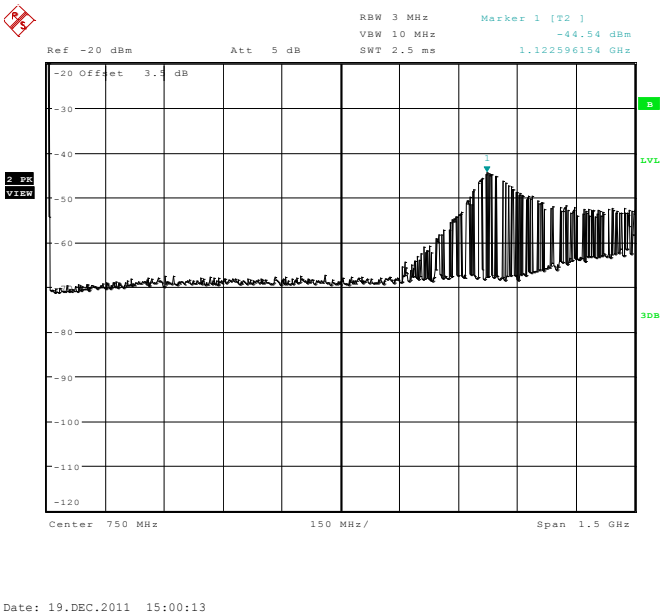

Fig 10. HP-filter : Spur up to -44 dBm at RFout (application board) during switch off sequence

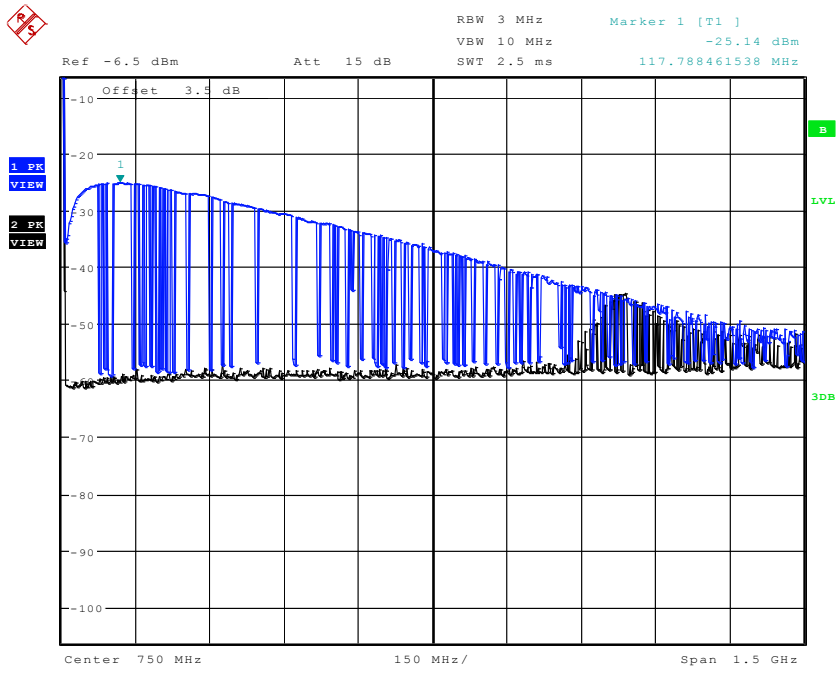

Fig 11. Original (blue) and HP-filter (black) : Spur at RFout (application board) during switch off sequence

3.2.3 Spurs in Time domain at -20dBm at RFin

This paragraph plots the spurs at RF-Out in time- domain by switching BGA7210 off at max current and max gain setting. The PUP-pin is triggered with 250 Hz, the RF input is set to -20dBm and the output signal is 8.5 dBm measured with a 50 ohm RF-detector.

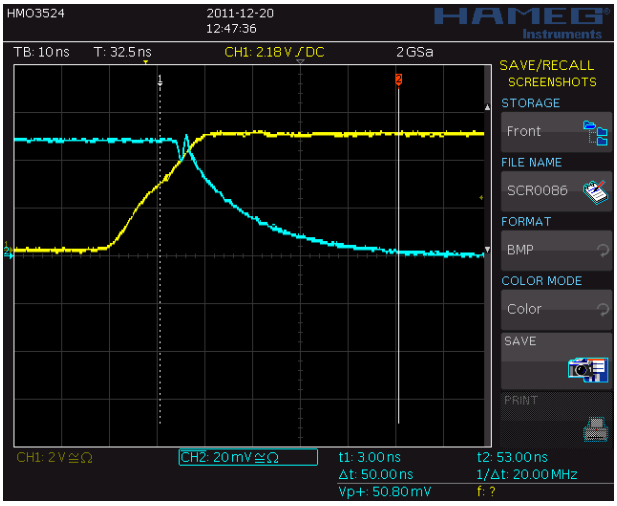

Fig 12. Original : Spur (blue) at RFout (application board) during switch off sequence (yellow line is switch off signal)

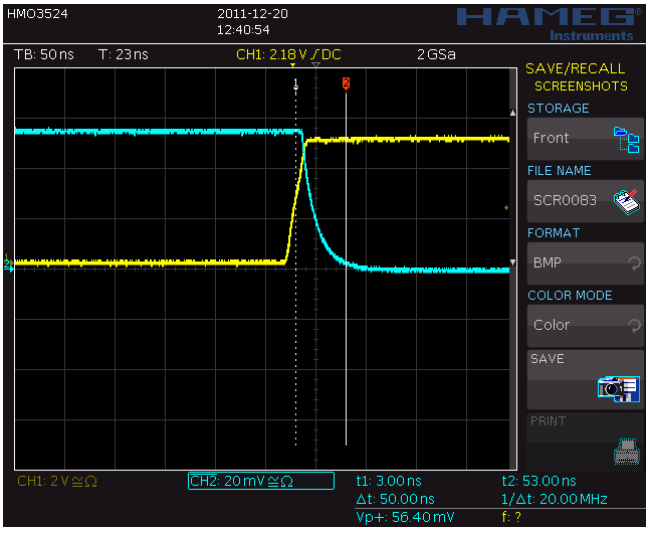

Fig 13. HP-filter : No Spur (blue) at RFout (application board) visible during switch off sequence (yellow line is switch off signal)

4. Picture proposed EVB (include HP-filter)

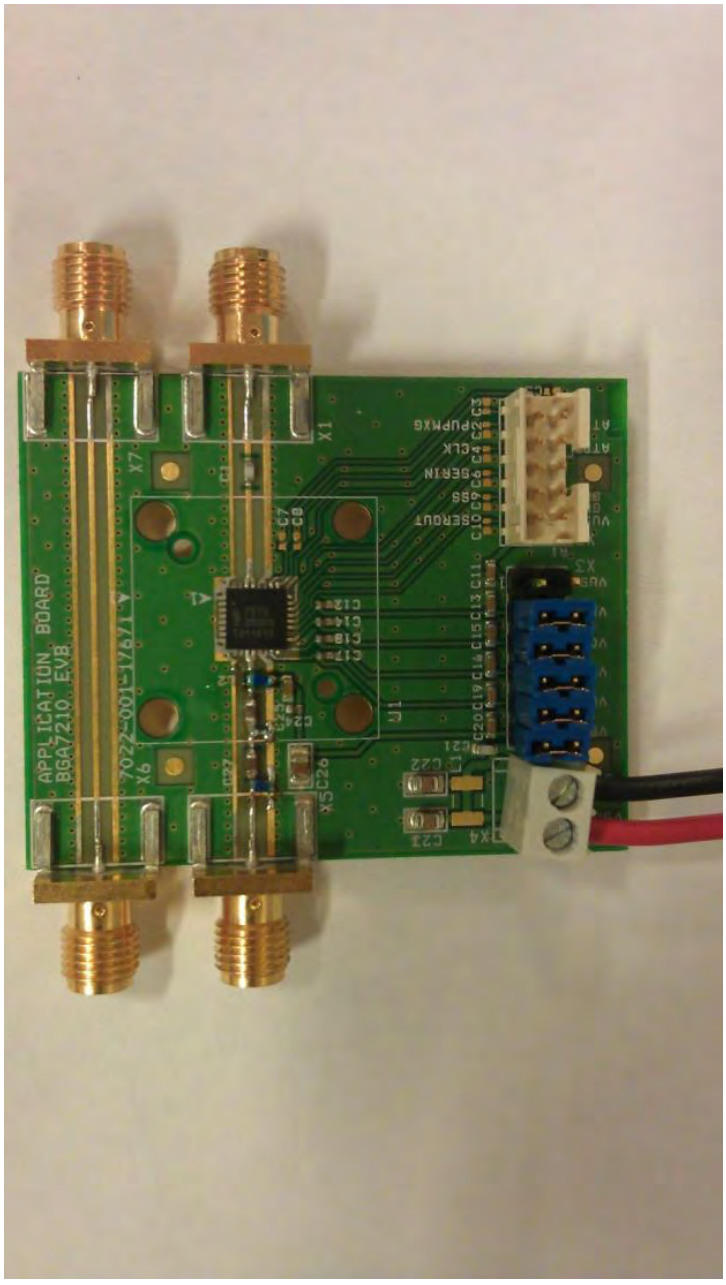

Fig 14. Picture printed circuit board of the BGA7210 with the HP-filter at the RFout.

5. Conclusion

Changing the biasing of the BGA7210 final stage (adding HP-filter) will improve the P1dB and reduce the spurs at RFout (both at VGA RF-out pin and after the HP-filter).

Other parameters like Spar and OIP3 will be not affected at 2 GHz.

The HP-filter in this App-Note is optimized for frequencies between 1.5 GHz and 2.5 GHz.

In case of using other frequencies the HP-filter should be adapted for your own requirements.

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