RF Front End Modules

Improvement of Harmonic Distortion

Harmonic performance of RF FEM over VSWR and phase

Application Note AN284

Revision: Rev. 1.0
2012-04-10

RF and Protection Devices

Edition 2012-04-10

Published by
Infineon Technologies AG
81726 Munich, Germany

Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office (**www.infineon.com**).

Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office.

Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

Application Note AN284
Revision History: 2012-04-10

Previous Revision: prev. Rev. x.x	
Page	**Subjects (major changes since last revision)**

Table of Content

List of Figures

List of Tables

1 Introduction

This application note shows the possibilities to reduce harmonic products of a RF Front End Module over VSWR antenna port mismatch with arbitrary phase by tuning the impedance termination at the RF CMOS switch input and output. Infineon`s BGS18D RF CMOS SP8T antenna switch has been used as an example.

2 Application Information

2.1 Application

The block diagram on Figure 1 shows a typical Front End Module application in RF environments of mobile phones or Base stations. The FEM is connecting the Rx path to the antenna or the antenna to Tx path.

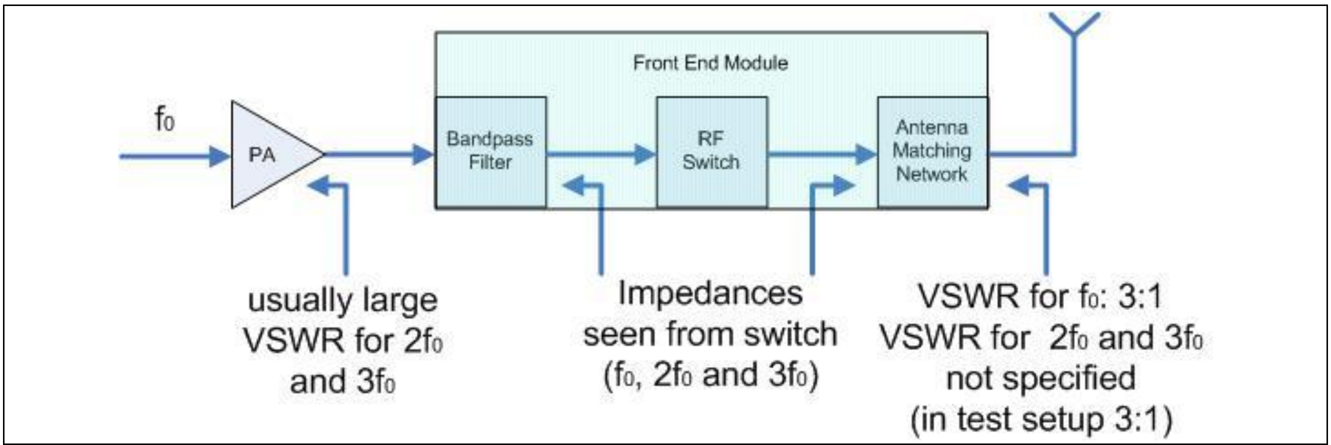

Figure 1 Application Diagram

This application describes the importance of the harmonic impedance terminations in a RF FEM. The impedances at input and output of the switch have great influences on the performance. To achieve best possible distortion results low impedance harmonic termination has to be offered at the high-power ports of the switch. To find out the perfect port conditions to reach best harmonic performance at VSWR mismatch a test setup has been developed (Figure 2, Table 1).

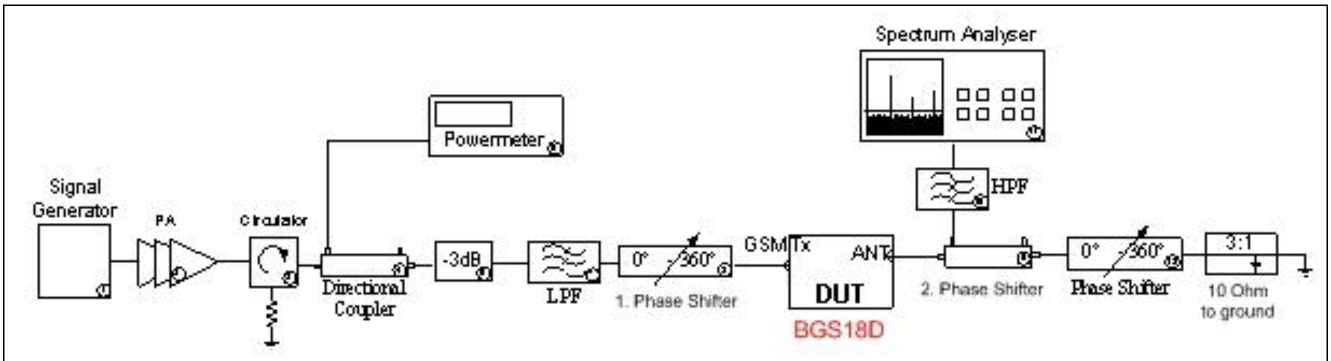

Figure 2 Harmonic Distortion Test setup

The test bench includes two phase shifters, one at the input and another at the output of the DUT (BGS18D, chip on evaluation board) to tune the phase of the impedance at the second (H2) and third harmonics (H3). The

reflections in the stopband (H2, H3) between the filter (bandpass or lowpass possible) at the TX input and the antenna at output of the DUT influence the harmonic generation in the switch itself.

Table 1 Test Setup Equipment

Description	Manufacturer	Identification number	Function
Signal Generator	Rohde & Schwarz	SMIQ 06B	
Power Amplifier	Mini Circuits	ZHL-30W-252-S+	
Circulator	MTC	C163FFF	For proper matching of the PA
Directional Coupler	PULSAR	CS20-22-436/3	Enable power measurement during the test
Attenuator	Lucas Wenschel	33-3-34 3dB/50W	Establishment of a 50 Ohm environment behind directional coupler
Power Meter	Agilent	E4419B	
Lowpass Filter	Wainwright	WLK1.0/18G-10SS	Filtering the harmonics of PA and providing mismatch at H2 and H3
TX Phase Shifter	ATM	PNR P1213D	Phase tuning of the H2,H3 impedance
Highpass Filter	Wainwright	WLK1.3/15G-10SS	Prevents overload of the spectrum analyser
Spectrum Analyser	Rohde & Schwarz	FSIQ26	
ANT Phase Shifter	ARRA	D4428C	Phase tuning at VSWR conditions

3 Measurement Procedure

1. Set **low Impedances** (only for $2f_0$ and $3f_0$) at the lowpass filter to reduce reflections by changing the phase of the TX phase shifter. The best way, to reach a good harmonic performance is to bring the Input Matching of the lowpass filter ($2f_0$ and $3f_0$) together on the left side of the Smith chart.
2. Measure $2f_0$ and $3f_0$ products concerning several phase conditions by the ANT phase shifter

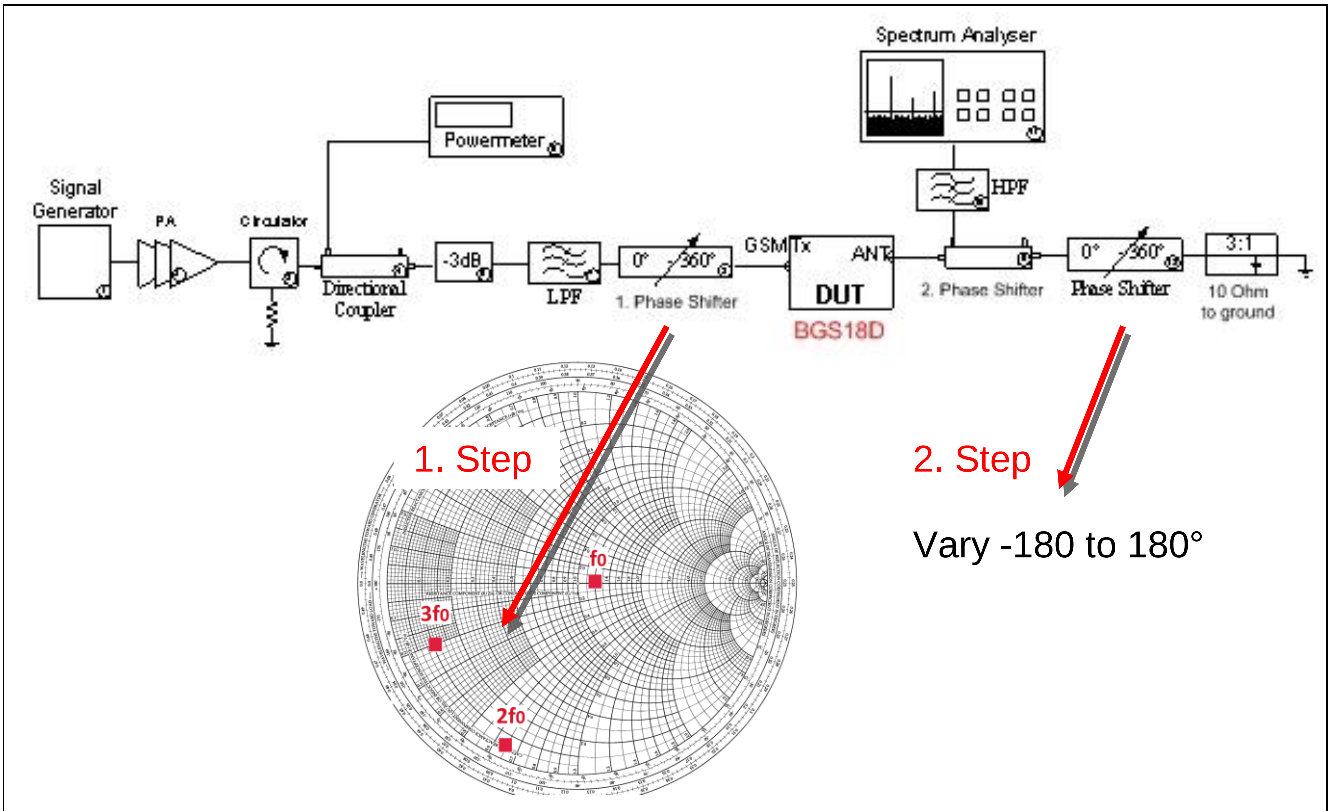

Figure 3 Measurement Procedure

Harmonic Frequencies: (2 examples)

f_0 = 824 MHz, $2f_0$ = 1648 MHz, $3f_0$ = 2472 MHz

f_0 = 915 MHz, $2f_0$ = 1830 MHz, $3f_0$ = 2745 MHz

All measurements are done at nominal operation conditions of the switch (25° room temperature).

P_{IN} = 35 dBm, VDD = 3.5V

4 Measurement Results

The measurement results manifest the dependence of the harmonic degeneration and input / output VSWR including phase. As an example for such a harmonic improvement both corners of GSM850 and GSM900 have been chosen (824MHz and 915MHz).

4.1 Measurement results with f_0 = 824 MHz

4.1.1 Worst case harmonic results

Table 2 Worst case harmonics with f_0 = 824 MHz

Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	-57	-61	-54	-42,1	-25,6	-26,2	-29	-32,6	-34,6	-34,7	-41	-57
H3 (dBm)	-54	-49,5	-44	-35,1	-25,8	-25,6	-23,7	-21,8	-28,4	-34,1	-37	-54

*2 phase shifter in front of antenna

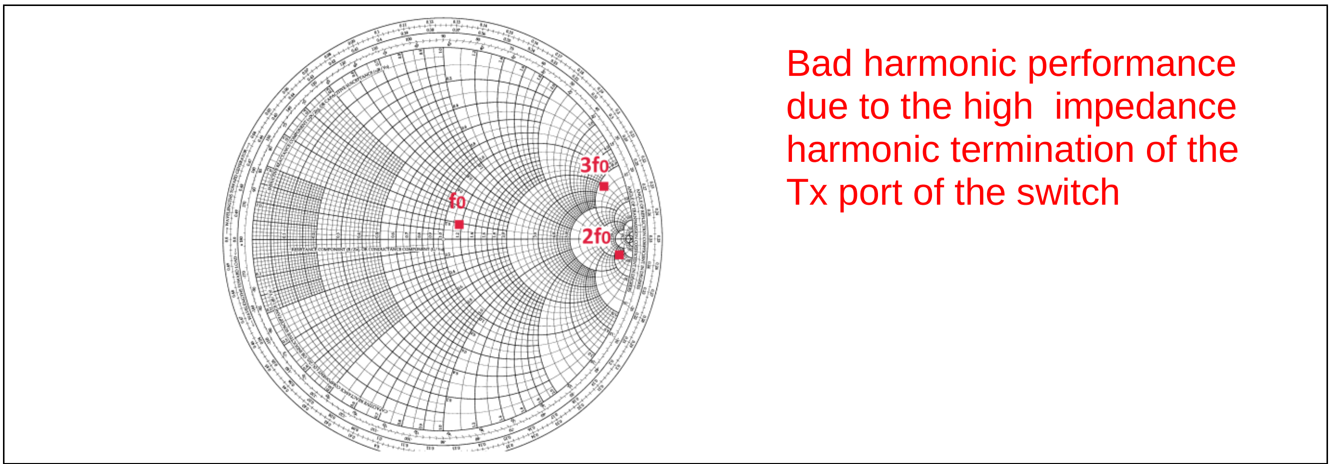

Figure 4 Example of high impedance termination at Tx port

4.1.2 H2 optimised harmonic results

Table 3 H2 optimized harmonics at f_0 = 824 MHz

Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	-56	-65	-49,8	-48	-50,5	-50	-47	-43,6	-39,9	-40,8	-47,2	-56
H3 (dBm)	-35,4	-32	-33,1	-40,5	-38,9	-35	-40,4	-45,2	-41,3	-35,8	-36,7	-35,4

*2 phase shifter in front of antenna

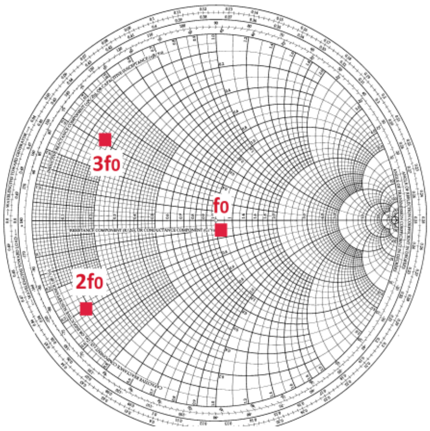

Figure 5 H2 optimized impedance termination of Tx port

4.1.3 H3 optimised harmonic results

Table 4 H3 optimized harmonics at f_0 = 824 MHz

Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	-50,3	-52,1	-52,4	-47	-35,3	-30,1	-30,1	-35,7	-41,4	-46,6	-52,5	-50,3
H3 (dBm)	-35,4	-32	-33,1	-40,5	-38,9	-35	-40,4	-45,2	-41,3	-35,8	-36,7	-35,4

*2 phase shifter in front of antenna

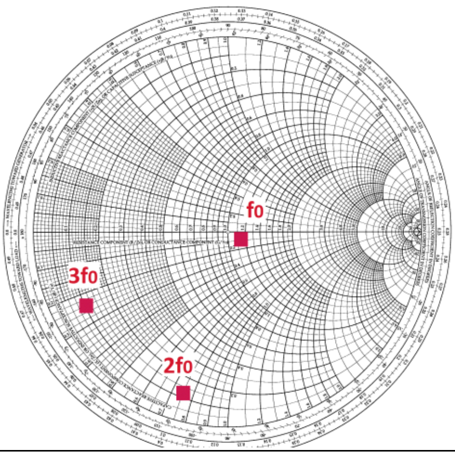

Figure 6 H3 optimized impedance termination of Tx port

4.1.4 Summary of measurement results with f_0 = 824 MHz

Table 5 Summary of the harmonic measurements at f_0 = 824 MHz

	Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	H3 optimized	-50,3	-52,1	-52,4	-47	-35,3	-30,1	-30,1	-35,7	-41,4	-46,6	-52,5	-50,3
	High Tx impedance	-57	-61	-54	-42,1	-25,6	-26,2	-29	-32,6	-34,6	-34,7	-41	-57
	H2 optimized	-56	-65	-49,8	-48	-50,5	-50	-47	-43,6	-39,9	-40,8	-47,2	-56
	50 ohm	-57	-62	-54	-41,7	-26	-27	-29,5	-32	-34	-33	-41	-57

	Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H3 (dBm)	H3 optimized	-35,4	-32	-33,1	-40,5	-38,9	-35	-40,4	-45,2	-41,3	-35,8	-36,7	-35,4
	High Tx impedance	-54	-49,5	-44	-35,1	-25,8	-25,6	-23,7	-21,8	-28,4	-34,1	-37	-54
	H2 optimized	-33,9	-28,4	-35,4	-35,3	-31,8	-35,9	-39,9	-37,5	-32,3	-35,7	-36,2	-33,9
	50 ohm	-44	-53	-43	-32,9	-26	-25	-22,2	-22	-29	-32	-33	-44

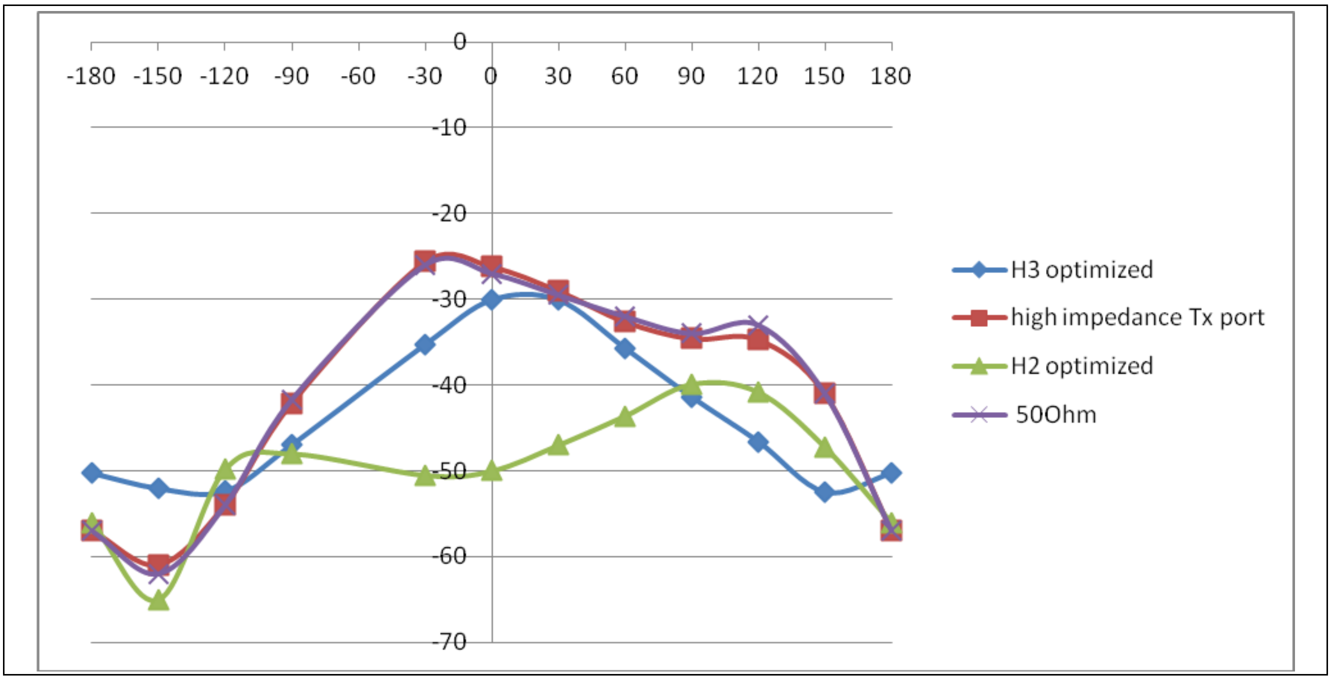

Figure 7 2 nd Harmonic Results at f_0 = 824MHz

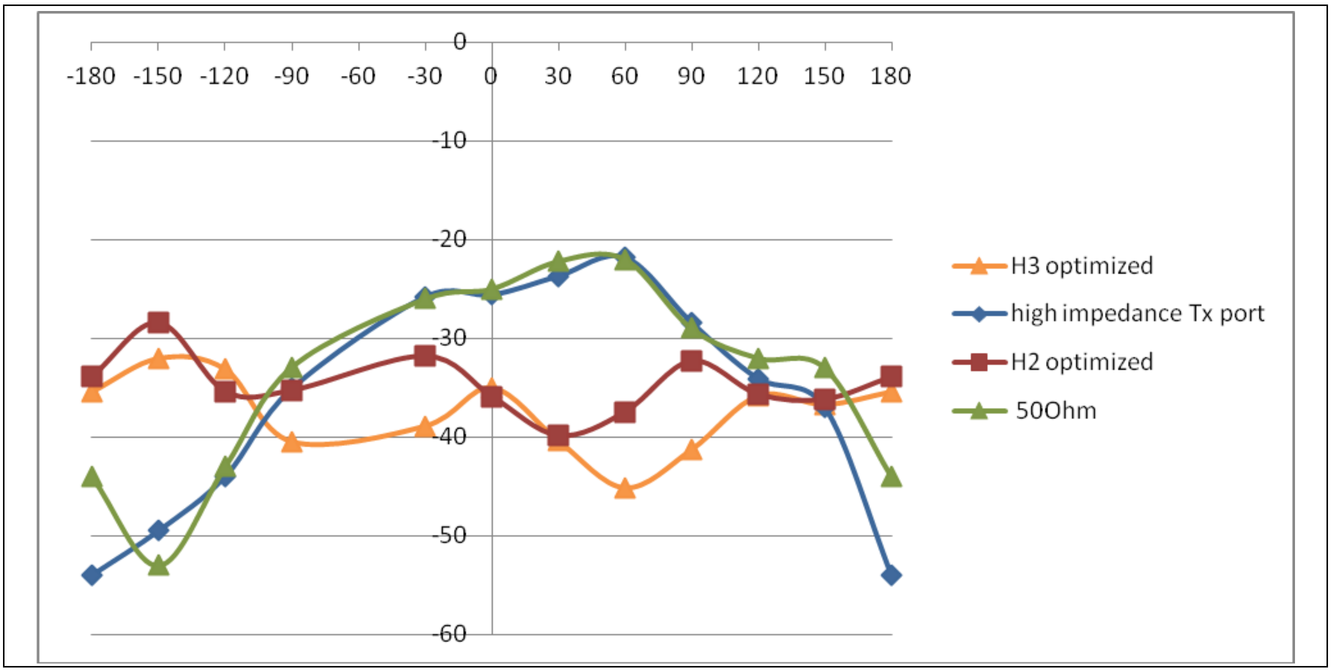

Figure 8 3 rd Harmonic Results at f_0 = 824MHz

4.2 Measurement results at f_0 = 915 MHz

4.2.1 Worst case harmonic results

Table 6 Worst case harmonics at f_0 = 915 MHz

Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	-33	-35	-37	-36	-40	-51	-60	-54	-40	-29	-30	-33
H3 (dBm)	-30	-30	-29	-37	-45	-56	-44	-45	-41	-29	-28	-30

*2 phase shifter in front of antenna

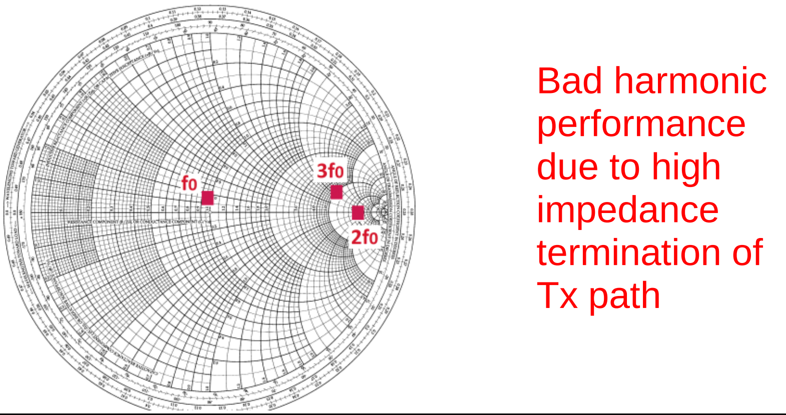

Figure 9 High impedance termination of Tx port

4.2.2 Best case harmonic results

Table 7 Best case harmonic at f_0 = 915 MHz

Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	-36	-41	-48	-56	-62	-55	-51	-53	-49	-43	-38	-36
H3 (dBm)	-43	-45	-41	-35	-40	-42	-39	-36	-43	-44	-38	-43

*2 phase shifter in front of antenna

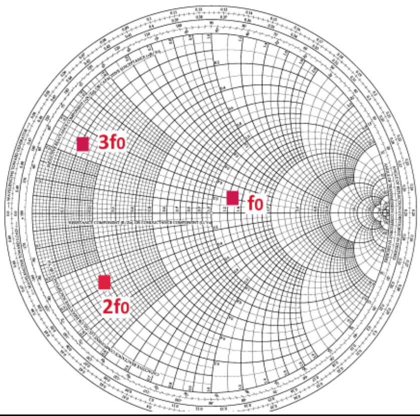

Figure 10 Low impedance termination of Tx port

4.2.3 Summary of measurement results at f_0 = 915 MHz

Table 8 Summary of harmonic measurements at f_0 = 915 MHz

	Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H2 (dBm)	High Tx impedance	-33	-35	-37	-36	-40	-51	-60	-54	-40	-29	-30	-33
	Low Tx impedance	-36	-41	-48	-56	-62	-55	-51	-53	-49	-43	-38	-36
	50 ohm	-34	-39	-44	-48	-52	-53	-51	-52	-45	-39	-33	-34

	Phase (°)*	-180	-150	-120	-90	-30	0	30	60	90	120	150	180
H3 (dBm)	High Tx impedance	-30	-30	-29	-37	-45	-56	-44	-45	-41	-29	-28	-30
	Low Tx impedance	-43	-45	-41	-35	-40	-42	-39	-36	-43	-44	-38	-43
	50 ohm	-29	-28	-29	-34	-39	-45	-56	-45	-37	-29	-28	-29

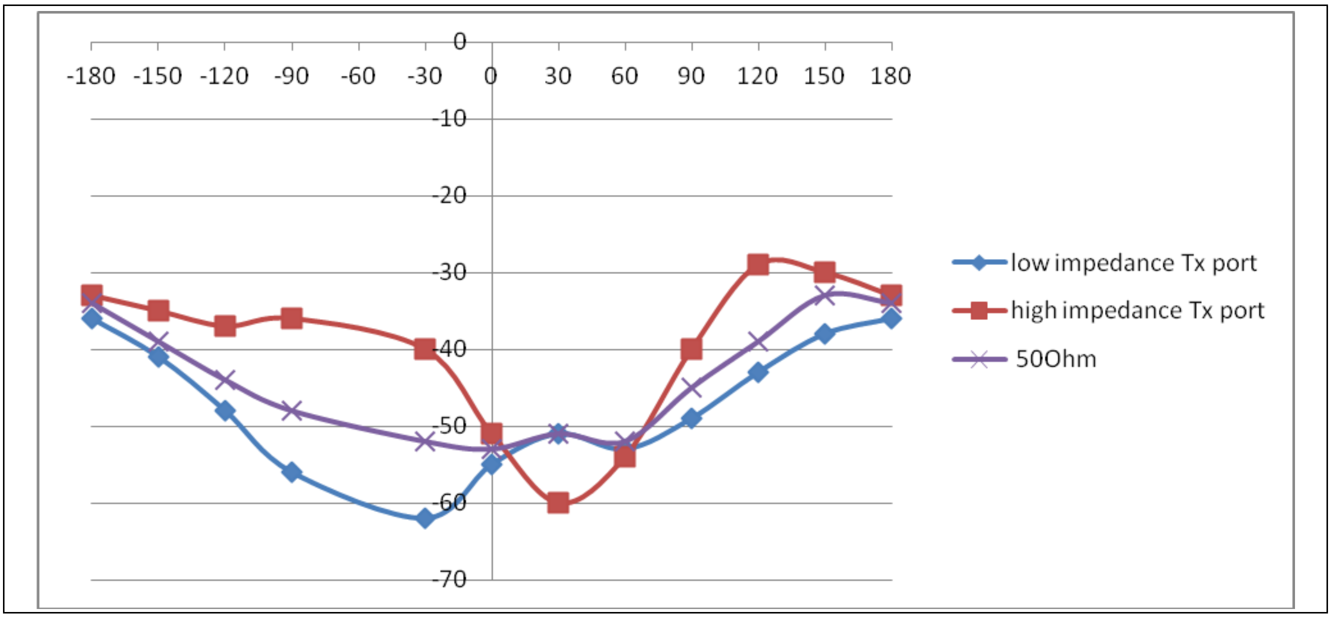

Figure 11 2 rd Harmonic Results at f_0 = 915MHz

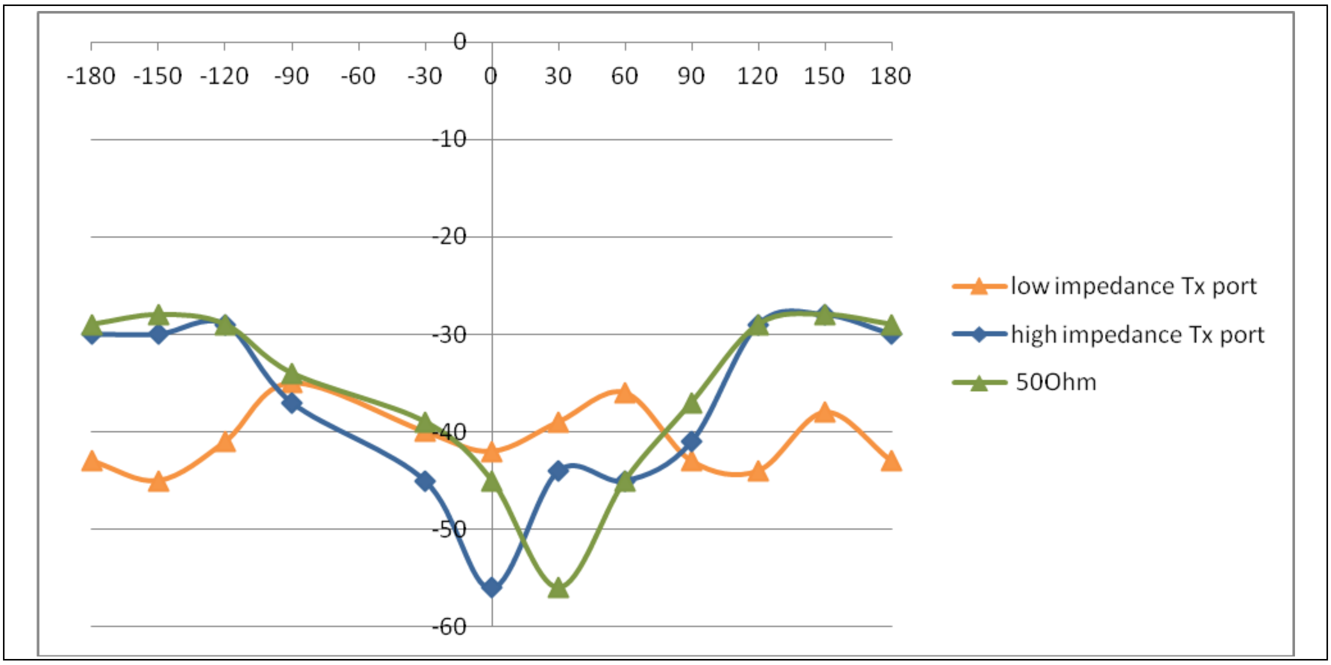

Figure 12 3 rd Harmonic Results at f_0 = 915MHz

5 Antenna matching influences the harmonic performance

To avoid the worst case phase condition at the antenna port of the module a properly chosen matching circuit is recommend.

Simple example is given on Figure 13. The results of such an antenna matching are shown on Figure 14.

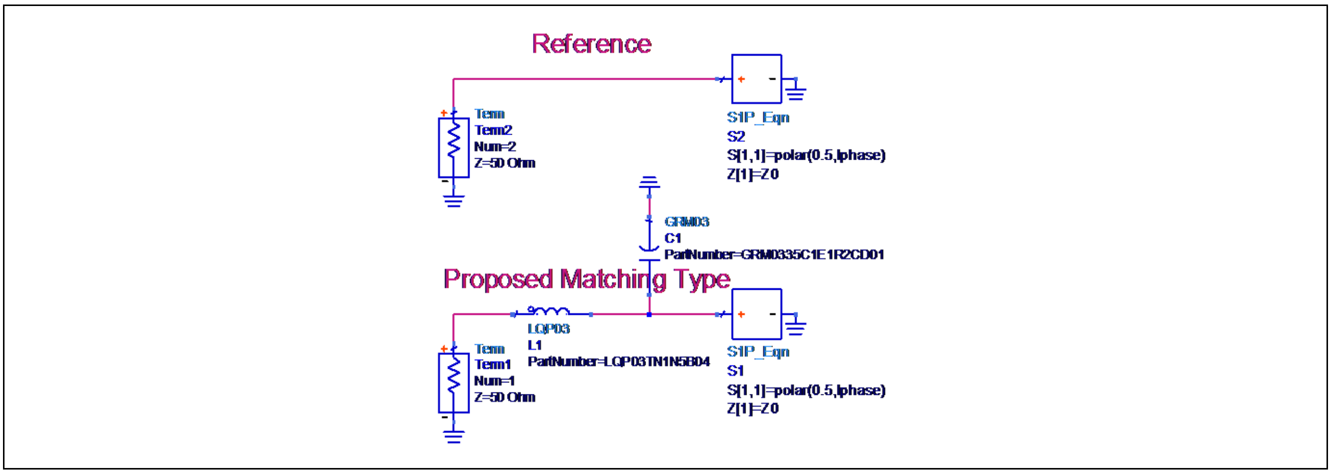

Figure 13 Proposal for an antenna matching

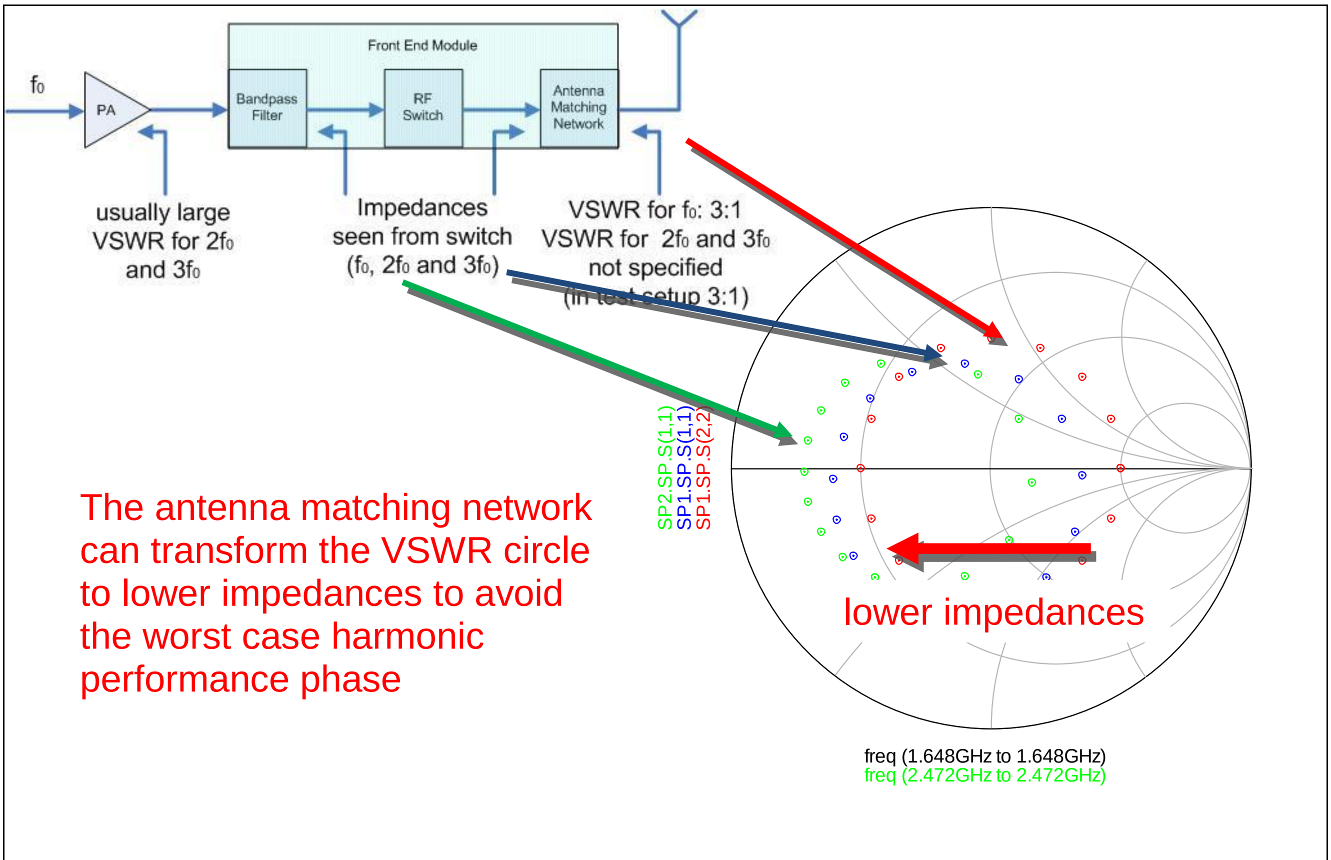

Figure 14 Impact of the Antenna Matching

6 Conclusion

The overall harmonic performance of a RF Front End Module has been improved in this example by well chosen termination impedances of the TX filter Figure 15.

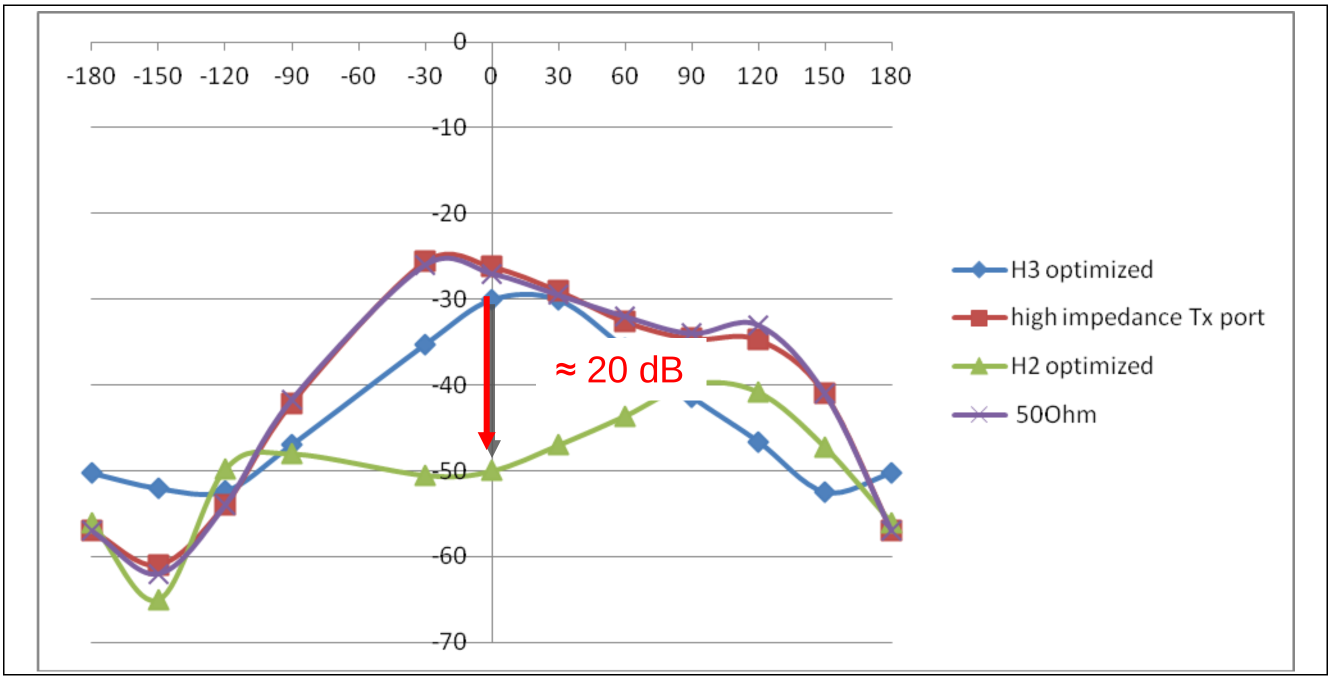

Figure 15 2 nd Harmonic improvement by low harmonic termination of the Tx path

An additional improvement of the harmonic distortion could be achieved by an antenna matching network in the module or on PCB transforming the VSWR impedance in order to reduce VSWR high impedance seen from the RF switch at the critical phase angle.

Authors

Nikolay Ilkov, RF CMOS Switch Product Development

André Dewai, Application Engineer of Business Unit “RF and Protection Devices”

Klaus Hoenninger, RF CMOS Switch Product Development

w w w . i n f i n e o n . c o m

Published by Infineon Technologies AG AN284