AN11991

Front end module (including PA, RX/TX switch) for IoT applications using BGA6130 as PA and BAP64-02 as switch

Rev. 1 — 31 August 2017 Application note

Document information

Info	Content
Keywords	RX/TX, Switch, BAP64-02, BGA6130, LNA
Abstract	This document explains the RX/TX pin diode switch evaluation board
Ordering info	BGA6130, BAP64-02 starter kit OM17065, 12nc 9340 713 99598
Contact information	For more information, please visit: http://www.nxp.com

Revision history

Rev	Date	Description
1.0	20170831	First publication

Contact information

For more information, please visit: http://www.nxp.com

For sales office addresses, please send an email to: salesaddresses@nxp.com

1. Introduction

IoT applications needs Front end modules (PA + RX/TX switch) which can be realized using NXP's BGA6130 and BAP64-02. A pair of PIN diodes (BAP64-02) are used in a RX/TX switch configuration and an MPA (BGA6130) is used as a gain stage to deliver a certain amount of RF power. A typical application could be an IoT range extender.

Two evaluation boards are designed to evaluate the performance of the PIN diodes with or without the use of an MPA.

The EVB contains the following parts:

- NXP Semiconductors BAP64-02 diodes
- Optional NXP Semiconductors BGA6130 amplifier
- A low pass Chebyshev filter
- Decoupling of the power supply and control signals

In this document, the application diagram, board layout, bill of materials, and typical results are given. Fig 1 shows a picture of the RX/TX switch without an MPA. Fig 2 shows a picture of the RX/TX switch with an additional MPA.

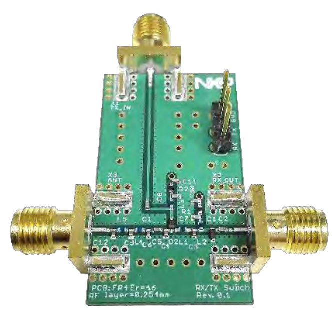


Fig 1. RX/TX Switch evaluation board

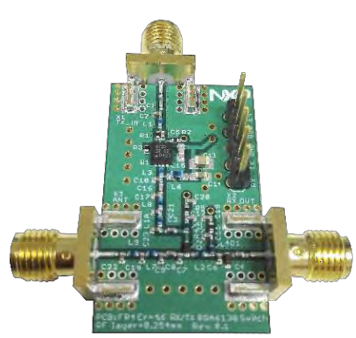


Fig 2. RX/TX Switch evaluation board with BGA6130

All information provided in this document is subject to legal disclaimers.

2. General description

The nowadays modern transceivers or radios require a way to switch the antenna to either a transmitter output or a receiver input. The switch should be robust enough to handle the RF power of the transmitter as well as exhibiting low insertion loss in the receive mode to reduce the added noise figure to the LNA.

While mechanical switches typically have a lower “ON” resistance and generate less harmonic distortion, they are larger in size, slow switching and more expensive and therefore in many cases not suitable.

The solution to overcome these drawbacks is PIN diode technology. These diodes are developed to use as an RF switch. Their “ON” resistance varies from less than a few ohms to more than several kilo ohms in the “OFF” state. These typical characteristics make them well suitable to use as an RX/TX switch.

An RX/TX switch can be constructed by using a PIN diode in series at the TX path and a parallel PIN diode construction at the RX path to avoid excessive RF power at the input of the LNA while in TX mode.

In certain applications e.g. IoT, repeaters, signal booster etc. an additional MPA is needed. A separate EVB (Evaluation Board) is available to evaluate the RX/TX switch in combination with an MPA.

Table 1 gives an overview of the different configurations. In this application note, all these different configurations are evaluated.

Table 1. Configuration overview

Configuration	Narrow band	Broad band	Filter	BGA6130	RX power consumption	Comments
1	•		•		None	Details see Par. 3
2	•				None	
3		•	•		*	
4		•			*	
5	•		•	•	None	Details see Par. 4
6	•			•	None	
7		•	•	•	*	
8		•		•	*	

*power consumption depends on bias setting

The application without the MPA is described in chapter 3. Chapter 4 describes the application with the MPA. Both chapters contains the application description and measurement results.

The customer evaluation kit “starter kit” OM17065 contains the configuration 2 (only switch), configuration 6 (switch + PA), empty boards and loose sample.

3. RX/TX switch evaluation board

The RX/TX switch evaluation board simplifies the evaluation of the BAP64-02 in a RX/TX configuration. The evaluation board enables testing of the devices RF performance and requires no additional support circuitry. The board is fully assembled with the two BAP64-02 PIN diodes and the necessary bias circuitry. The board is contains three SMA connectors for input and output connection to RF test equipment.
The BAP64-02 RX/TX switch operates with a 3.3 V single supply and consumes typical 5 or 15 mA in TX mode depending on the bias resistor. The circuit consumes zero current in RX mode (narrow bandwidth version).

Typical characteristics:

- High output power capability
- Zero current during receive mode (narrow bandwidth version)
- Low component count (depends on customer application)

3.1 Summary measurement results

Table 2. Summary measurement results

Operating conditions: V_{cc} = 3.3 V; f_c = 915 MHz; P_i = 6.5 dBm per tone; Δf =1 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	Typ.	Unit
1	Idd	Current consumption	RX mode	0.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	-1.3	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-1.1	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-22.6	dB
	IIP3	Input third-order intercept point	TX mode	40.5	dBm
	OIP3	Output third-order intercept point	TX mode	39.2	dBm
	IP1dB	Input 1dB compression point	TX mode	>40	dBm
	OP1dB	Output 1dB compression point	TX mode	>40	dBm
2	Idd	Current consumption	RX mode	0.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	-0.7	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-0.5	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-22.7	dB
	IIP3	Input third-order intercept point	TX mode	40.9	dBm
	OIP3	Output third-order intercept point	TX mode	40.2	dBm
	IP1dB	Input 1dB compression point	TX mode	>40	dBm
	OP1dB	Output 1dB compression point	TX mode	>40	dBm
3	Idd	Current consumption	RX mode	15.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	-1.0	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-0.9	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-26.1	dB
	IIP3	Input third-order intercept point	TX mode	42.4	dBm
	OIP3	Output third-order intercept point	TX mode	41.4	dBm
	IP1dB	Input 1dB compression point	TX mode	>40	dBm
	OP1dB	Output 1dB compression point	TX mode	>40	dBm
4	Idd	Current consumption	RX mode	15.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	-0.4	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-0.3	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-26.0	dB
	IIP3	Input third-order intercept point	TX mode	41.7	dBm
	OIP3	Output third-order intercept point	TX mode	41.3	dBm
	IP1dB	Input 1dB compression point	TX mode	>40	dBm

Configuration	Symbol	Parameter	Conditions	Typ.	Unit
	OP1dB	Output 1dB compression point	TX mode	>40	dBm

3.2 Application Circuit

The circuit diagram of the evaluation board without an MPA is shown in Fig 3.

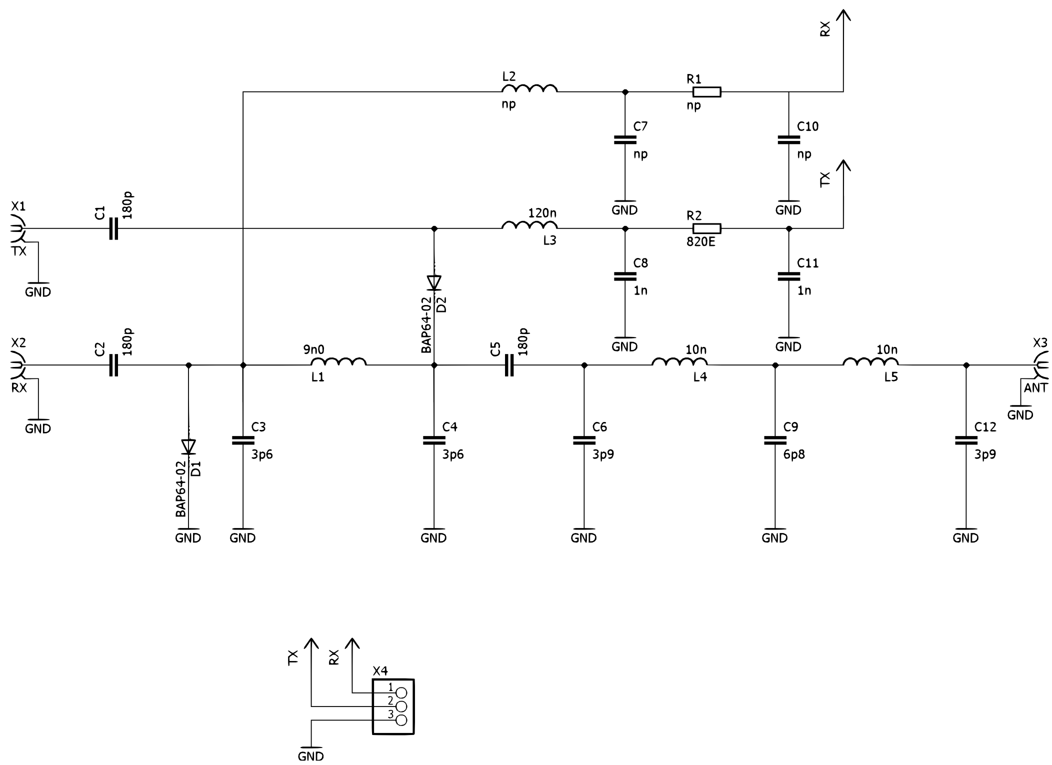


Fig 3. Circuit diagram of the RX/TX Switch evaluation board narrow band configuration

The above circuit diagram shows a simple arrangement where two PIN diodes are used to switch the antenna between the receiver and the transmitter output.
In TX mode both diodes D1 and D2 are forward biased, TX port is connected to antenna port and the RX port is shorted via D1 (open circuit at antenna port via quarter wavelength line at 915 MHz using C3, C4 and L1).
In RX mode both diodes are not biased, the TX port is isolated by the D2 and the antenna port is connected to RX port.
This method doesn't need supply voltage in RX mode but the bandwidth is limited (narrow band configuration).

No current consumption (no supply needed) in RX mode.

The circuit can also be transformed to a broadband application by moving the PIN diode D1 to L1 position and removing C3. Replace C4 by a 120 nH inductor.
Fig 4 shows the schematic of the broadband configuration. The circuit needs in both modes (TX & RX) control voltage (current consumption also in RX mode).

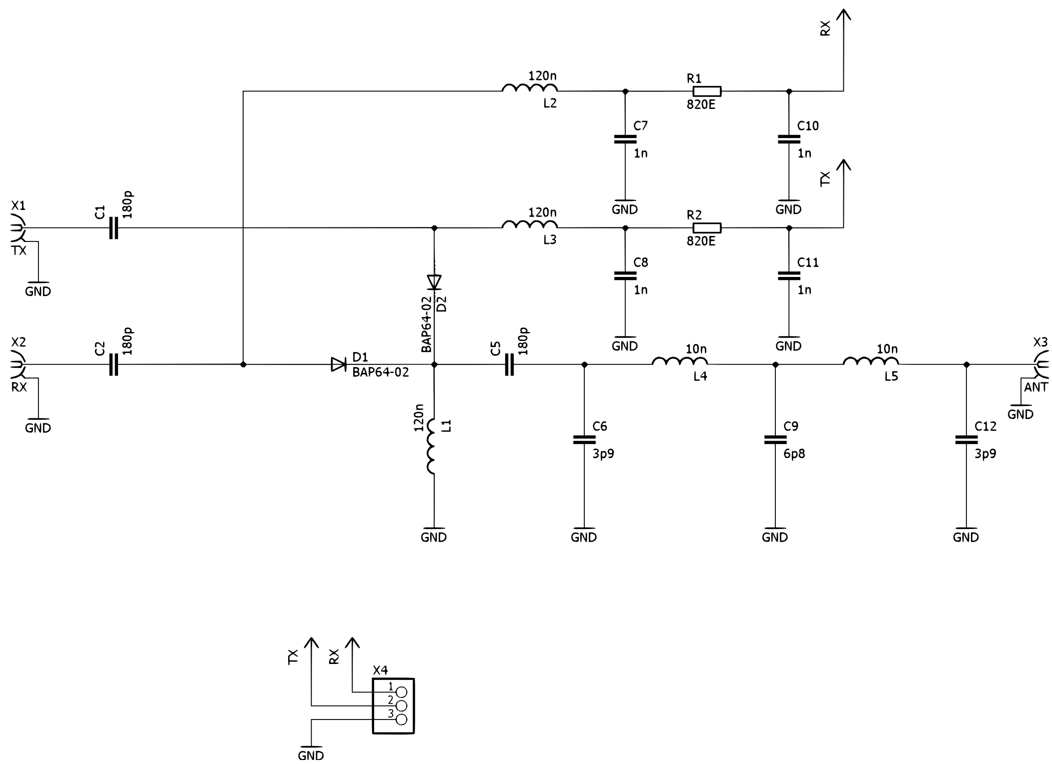


Fig 4. Circuit diagram of the RX/TX Switch evaluation board broadband configuration

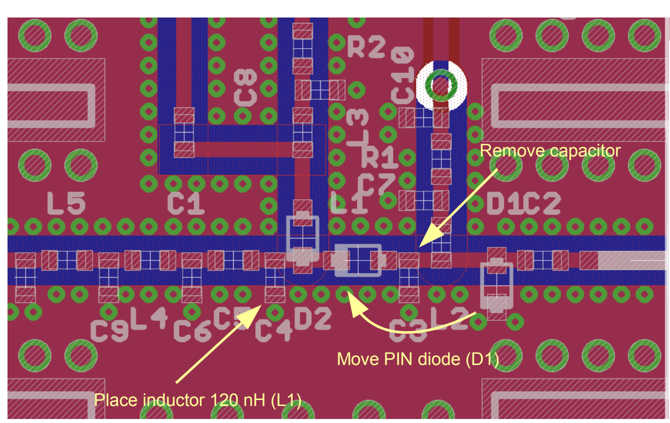


Fig 5. EVB layout broadband configuration

Remark: Notice the polarity of the PIN diodes.

3.3 PCB Layout

The layout of the RX/TX Switch PCB is given in Fig 6.

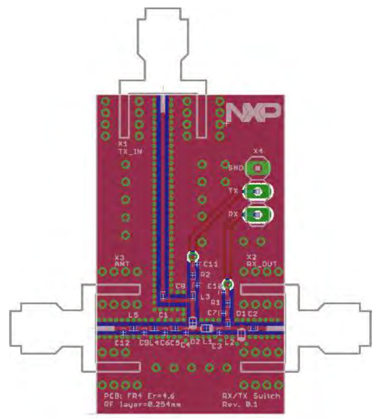


Fig 6. Printed-Circuit Board layout of the RX/TX Switch evaluation board without BGA6130.

All resistors and capacitors have a 0402 footprint.

A good PCB layout is an essential part of an RF circuit design. The evaluation board of the RX/TX Switch can serve as a guideline for laying out a board using the BAP64-02.

- Use controlled impedance lines for all high frequency inputs and outputs.
- For long bias lines it may be necessary to add decoupling capacitors along the line.
- Proper grounding of the GND pins is essential for good RF performance. Either connect the GND pins directly to the ground plane or through vias, or do both, which is recommended.
- To ensure optimal performance of the BAP64-02 in the application it is advised to simulate the overall application performance using the S-parameter and noise models of the device, the models for the external components and the models for the PCB. Models for the BAP64-02 are available via www.nxp.com.
- For good thermal behavior of the BGA6130, use thermal vias and keep the GND layer large in the middle and bottom layer.

The material that has been used for the evaluation board is FR4 using the layer stack shown in Fig 7.

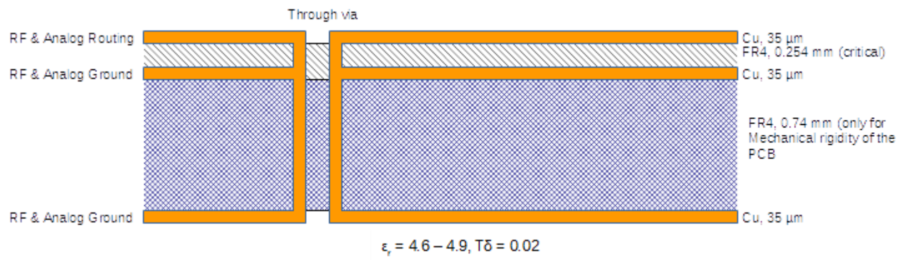


Fig 7. Stack of the PCB material

3.4 Bill of materials

With the evaluation board, several configurations are possible. The different configurations are identified as follows:

Table 3. BOM of the RX/TX switch evaluation board configuration 1 (narrow band + low pass filter)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
D1,D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R2	Resistor	0402	100 Ω /360 Ω	Yageo 2322 705 70101/70361	360 Ω /5 mA, 100 Ω /15 mA
C1,C2,C5	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C3,C4	Capacitor	0402	3.6 pF	Murata GRM1555C1H3R6CZ01D	
C6,C12	Capacitor	0402	3.9 pF	Murata GRM1555C1H3R9CZ01D	
C8,C11	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
C9	Capacitor	0402	6.8 pF	Murata GRM1555C1H6R8DZ01D	
L1	Inductor	0402	9.1 nH	Murata LQW15AN9N1G00D	
L3	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L4,L5	Inductor	0402	10 nH	Murata LQW15AN10NG00D	
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector

Table 4. BOM of the RX/TX switch evaluation board configuration 2 (narrow band)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
D1,D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R2	Resistor	0402	100 Ω /360 Ω	Yageo 2322 705 70101/70361	360 Ω /5 mA, 100 Ω /15 mA
C1,C2,C5	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C3,C4	Capacitor	0402	3.6 pF	Murata GRM1555C1H3R6CZ01D	
C8,C11	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
L1	Inductor	0402	9.1 nH	Murata LQW15AN9N1G00D	
L3	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L4,L5	Resistor	0402	0 Ω	Yageo 2322 705 91001	Jumper
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector

Table 5. BOM of the RX/TX switch evaluation board configuration 3 (broadband + low pass filter)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R1,R2	Resistor	0402	150 Ω /470 Ω	Yageo 2322 705 70151/70471	470 Ω /5 mA, 150 Ω /15 mA
C1,C2,C5	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C4	Capacitor	0402	120 nH	Murata LQW15ANR12J00D	Place inductor at C4 pos.
C6,C12	Capacitor	0402	3.9 pF	Murata GRM1555C1H3R9CZ01D	
C7,C8,C10, C11	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
C9	Capacitor	0402	6.8 pF	Murata GRM1555C1H6R8DZ01D	
L1	Inductor	0402	9.1 nH	Murata LQW15AN9N1G00D	
L2,L3	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L4,L5	Inductor	0402	10 nH	Murata LQW15AN10NG00D	
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector

Table 6. BOM of the RX/TX switch evaluation board configuration 4 (broadband)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R1,R2	Resistor	0402	150 Ω /470 Ω	Yageo 2322 705 70151/70471	470 Ω /5 mA, 150 Ω /15 mA
C1,C2,C5	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C4	Capacitor	0402	120 nH	Murata LQW15ANR12J00D	Place inductor at C4 pos.
C7,C8,C10, C11	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
L1	BAP64-02	SOD523		NXP	Place BAP64-02 at L1 pos.
L2,L3	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L4,L5	Resistor	0402	0 Ω	Yageo 2322 705 91001	Jumper
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector

3.5 Measurement results

3.5.1 S-parameters (3-port)

Because the RX/TX switch contains three RF-ports, it is desirable to have a three ports small signal S-parameter measurement. There are two situations to be analyzed. The RX/TX switch can be set in RX or TX mode. For both situations an S-parameter measurement is performed. The measurements are performed under the following conditions:

- Pin = -30 dBm
- Frequency = 10 – 6000 MHz
- Ambient temperature = 25°C

In the TX mode, the RF path between the TX input and the antenna output has a low insertion loss. In the TX mode, there is high isolation between the ANT/TX_IN connection and RX_OUT port.

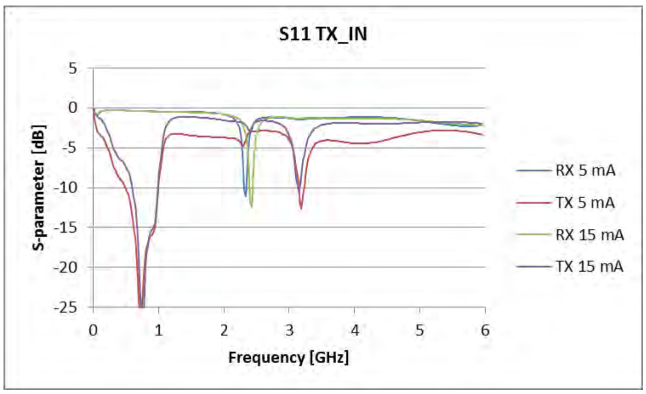
Next paragraphs shows the S-parameters graphs measured at different PIN diode currents (5 and 15 mA). The graphs shows also the low pass filter response with a cut-off frequency of 1 GHz.

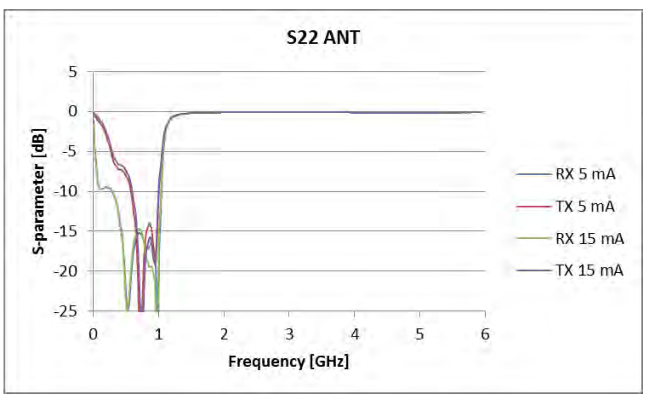
3.5.1.1 Narrow band with low-pass filter (configuration 1)

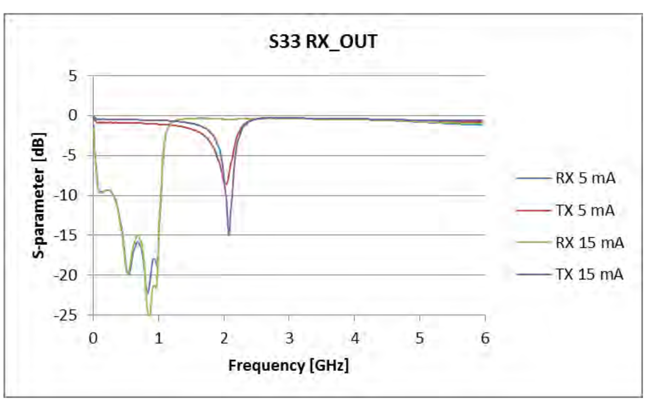
Next paragraphs show the measurement results of the narrow band application circuit with the low pass filter.

Return losses (S11, S22 and S33)

This paragraph shows the return losses of the three different RF ports:

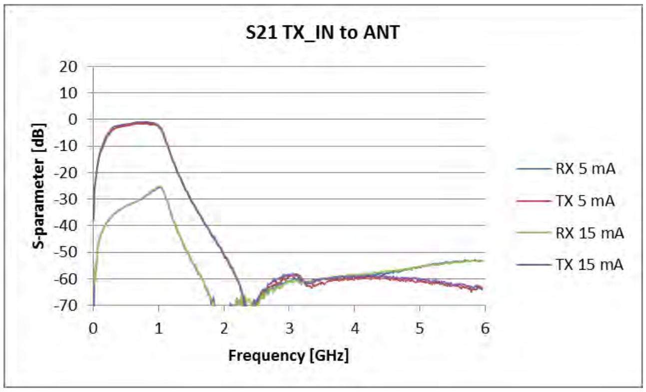


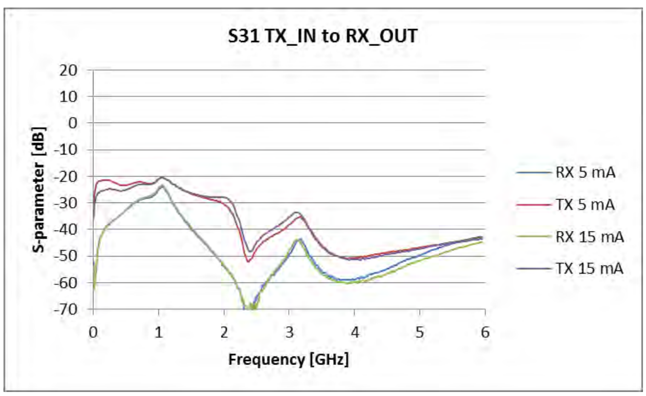


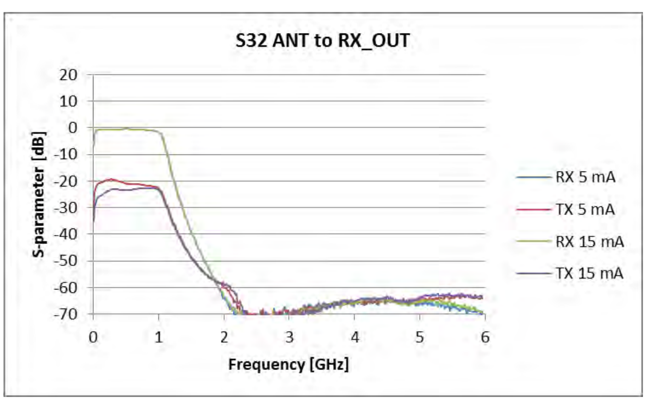


Transmission (S21, S31 and S32)

This paragraph shows the transmission between the three different RF ports:

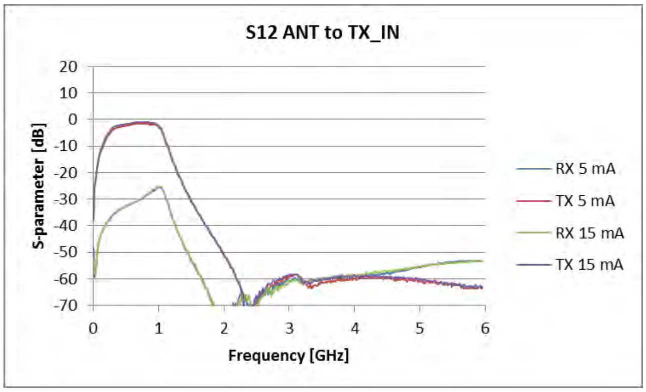


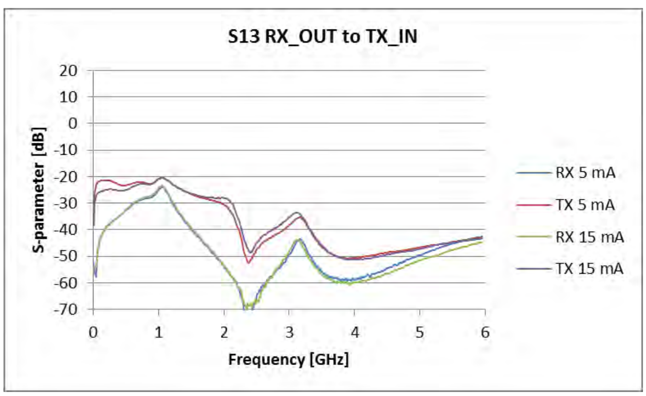


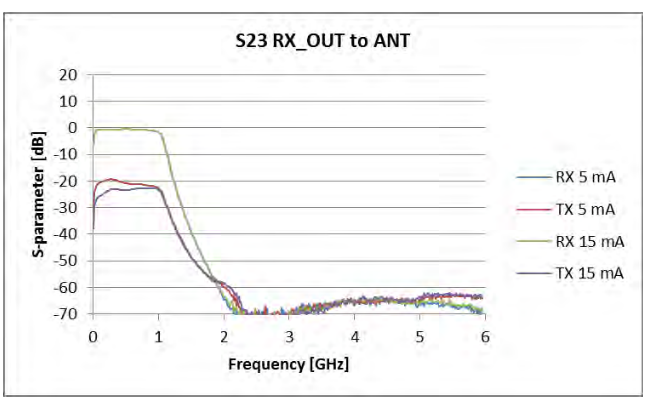


Isolation (S12, S13 and S23)

This paragraph shows the isolation between the three different RF ports:

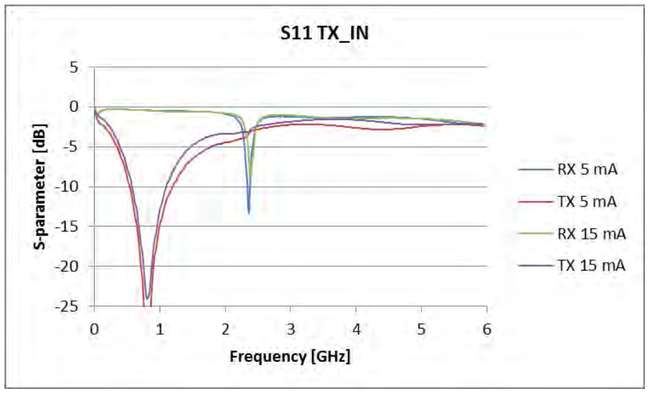


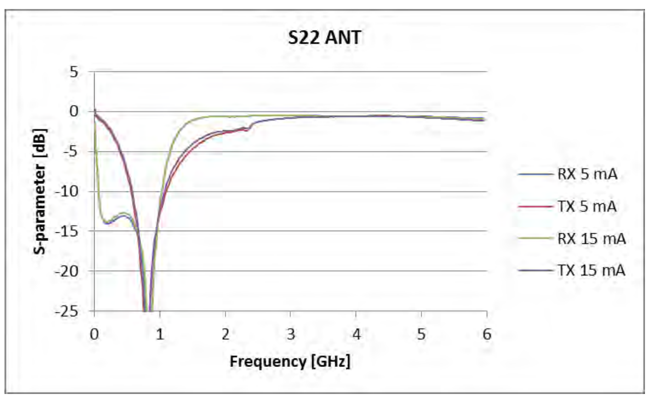


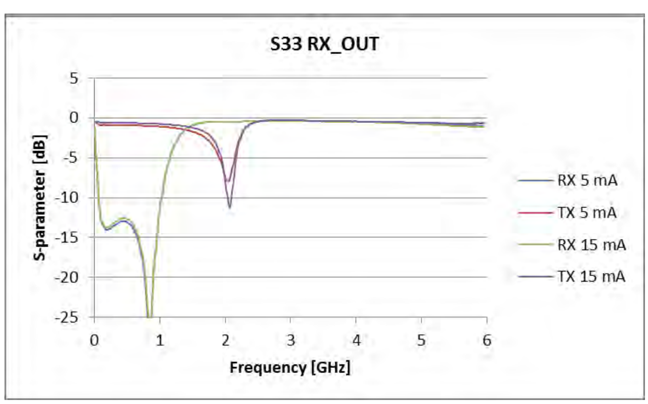


3.5.1.2 Narrow band without filter (configuration 2)

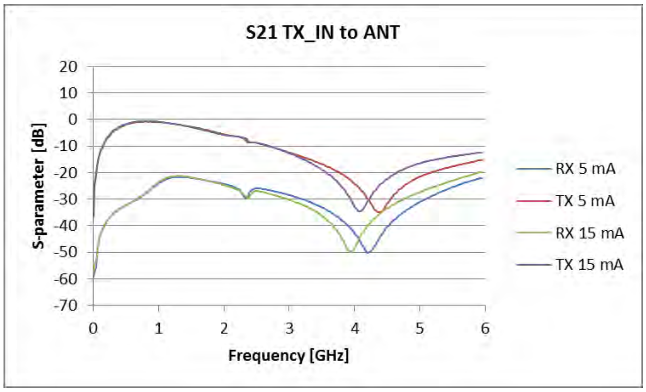
Return losses (S11, S22 and S33)

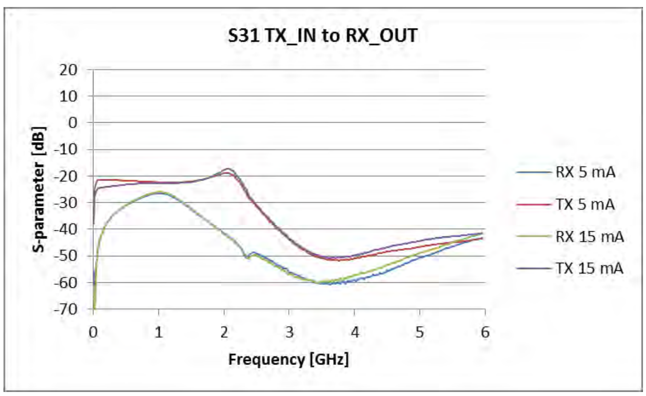


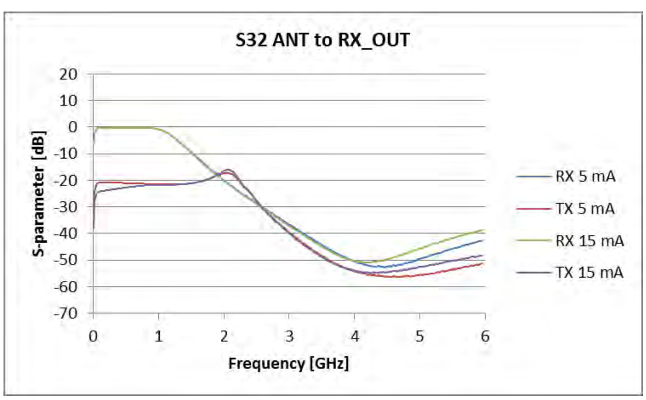




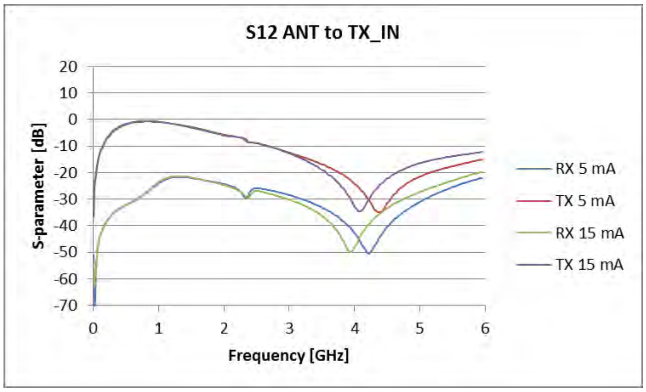
Transmission (S21, S31 and S32)

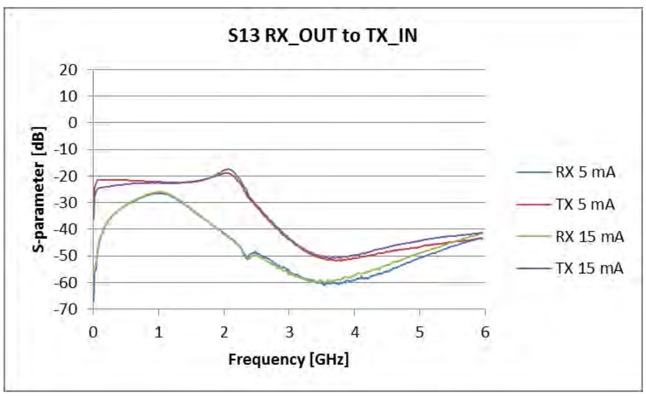


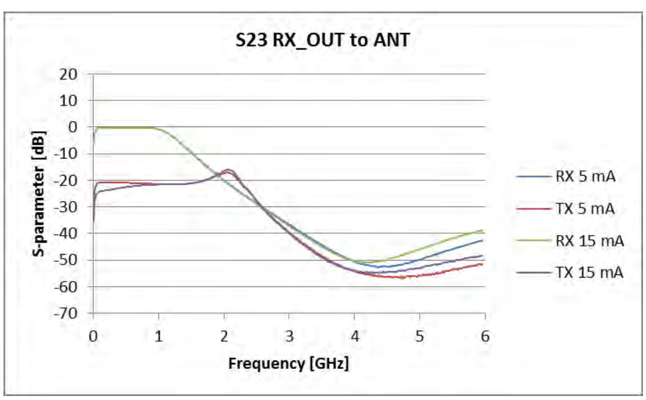




Isolation (S12, S13 and S23)

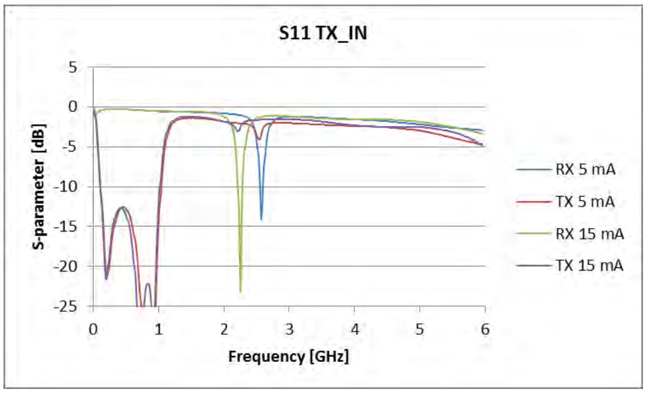


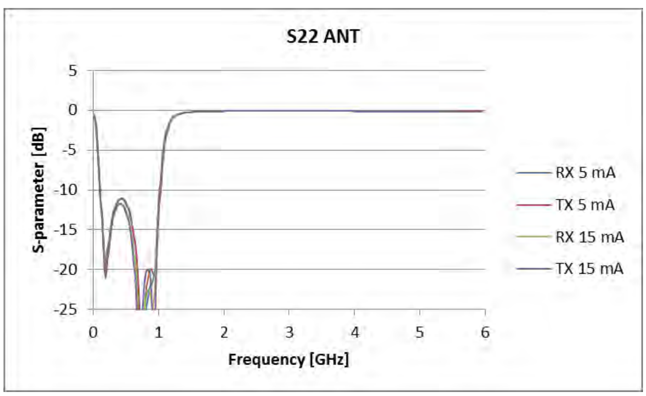


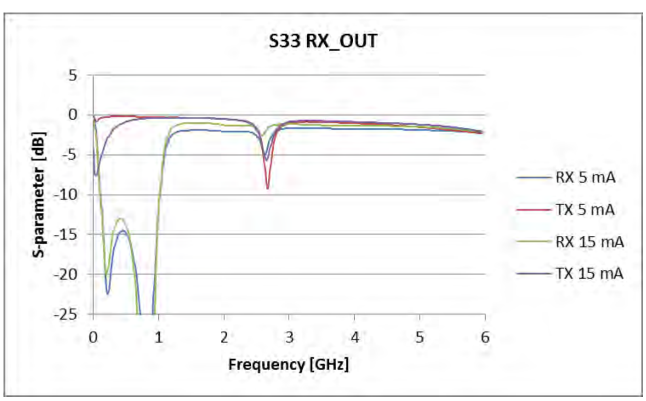


3.5.1.3 Broad band with filter (configuration 3)

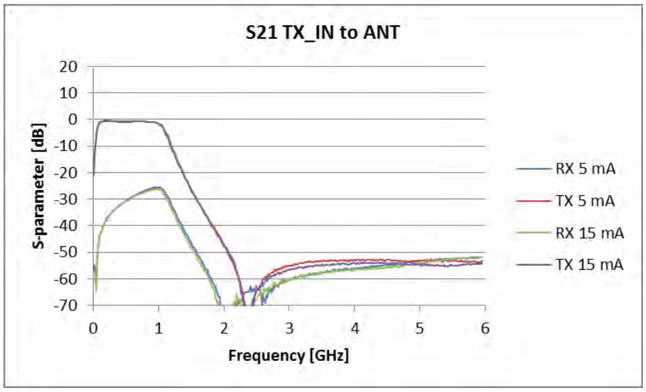
Return losses (S11, S22 and S33)

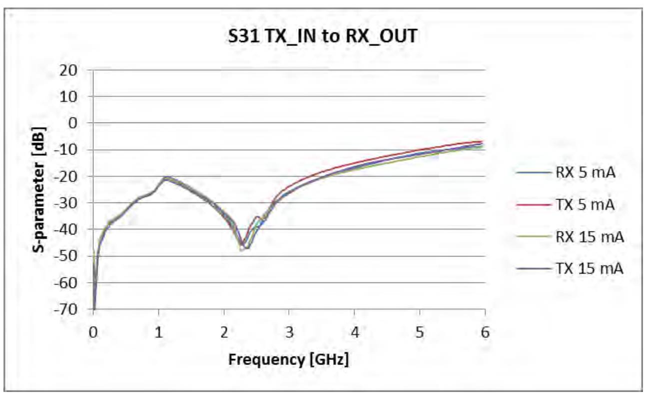


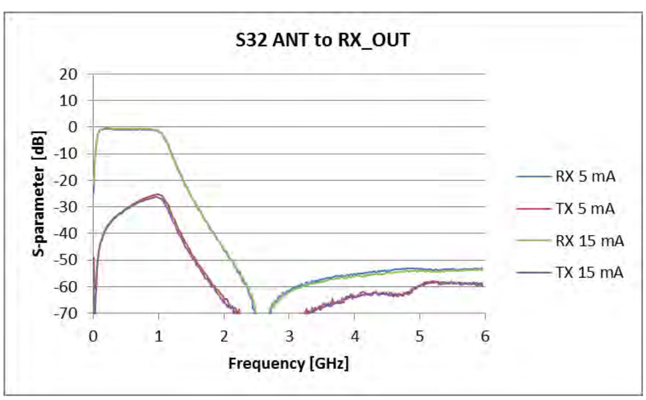




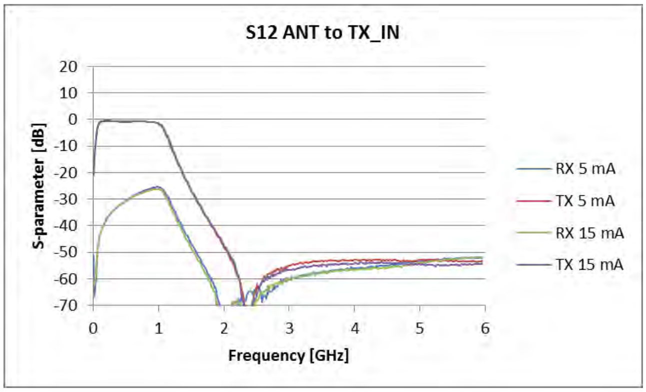
Transmission (S21, S31 and S32)

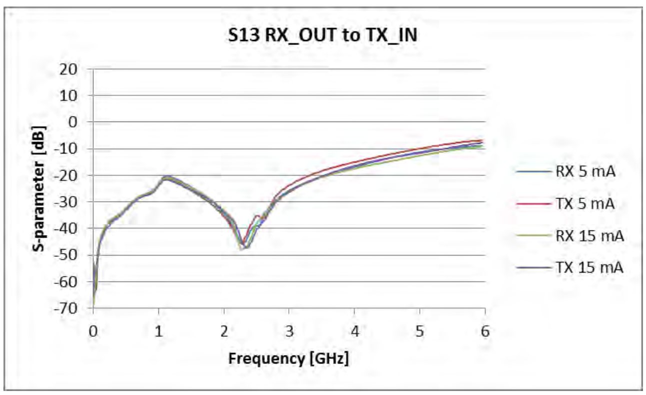


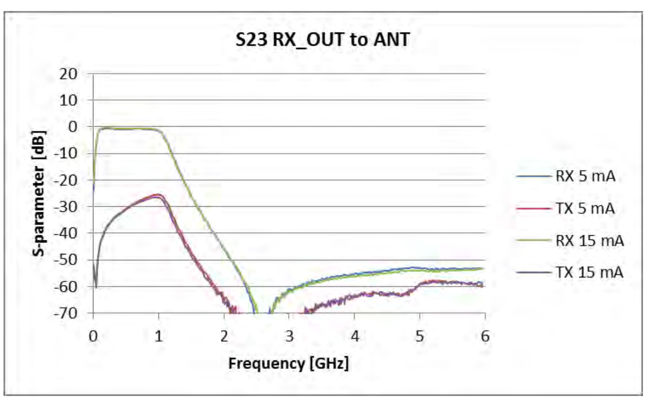




Isolation (S12, S13 and S23)

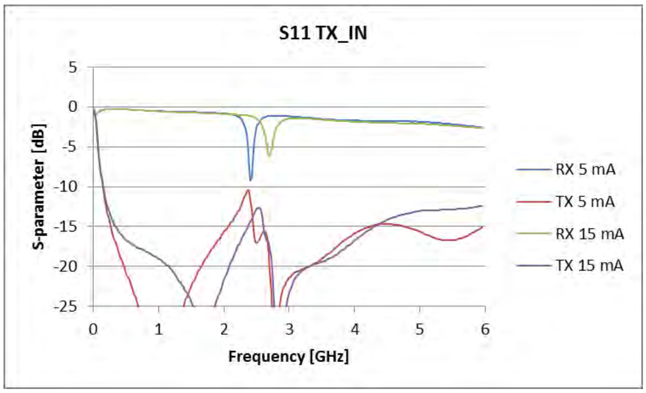


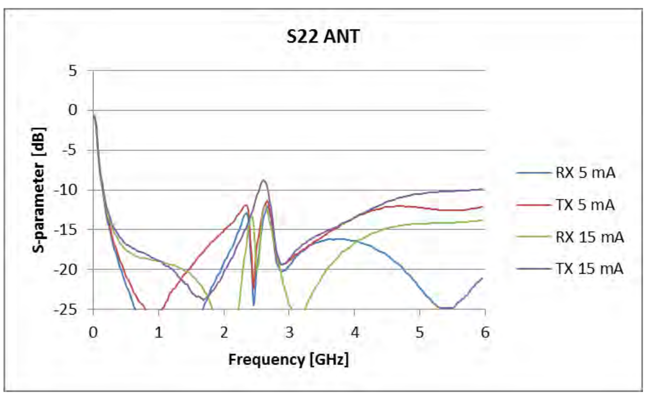


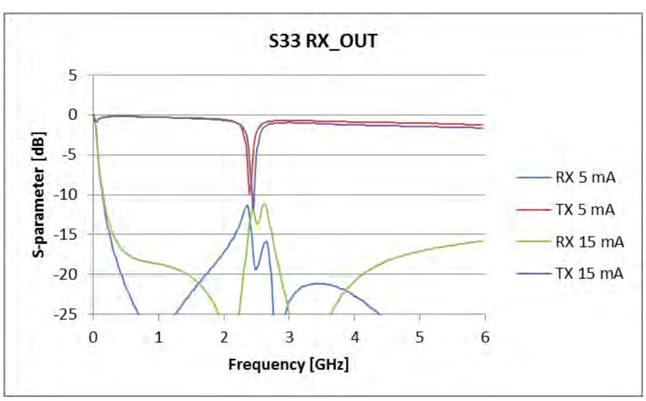


3.5.1.4 Broad band without filter (configuration 4)

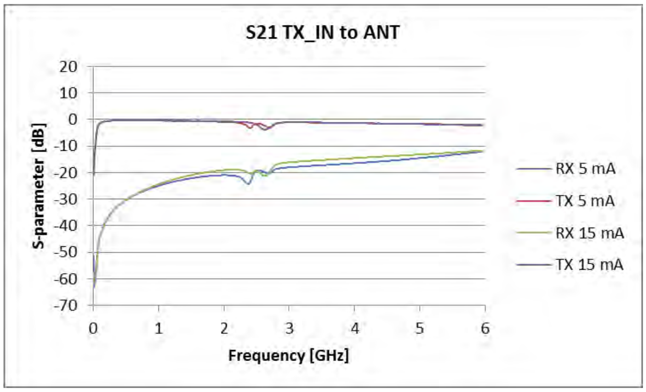
Return losses (S11, S22 and S33)

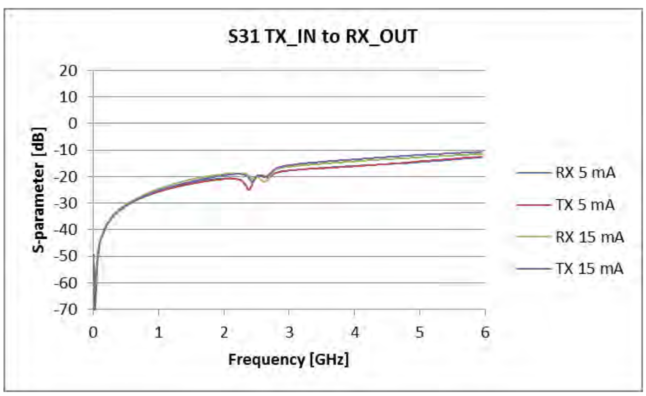


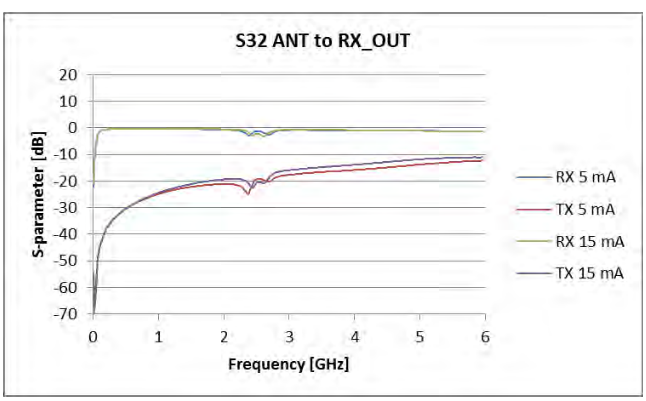




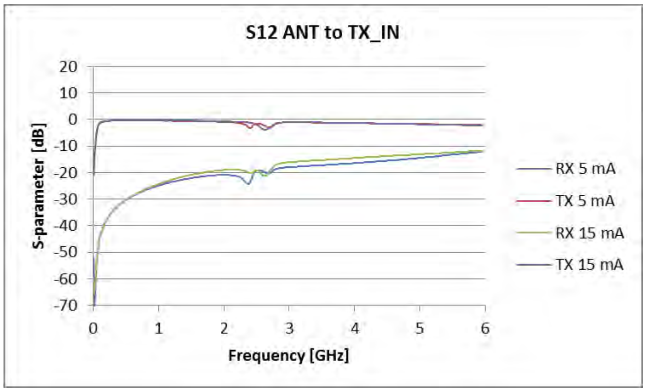
Transmission (S21, S31 and S32)

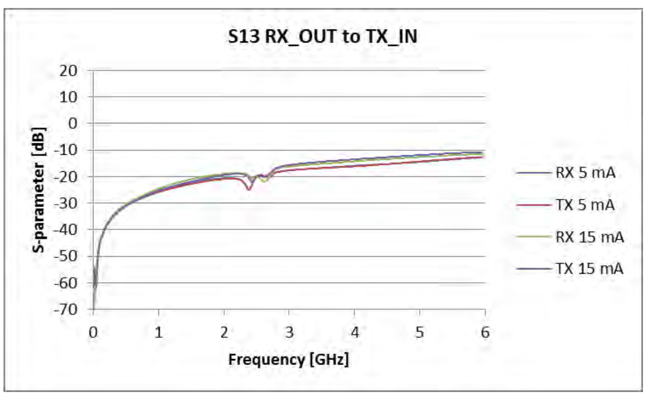






Isolation (S12, S13 and S23)





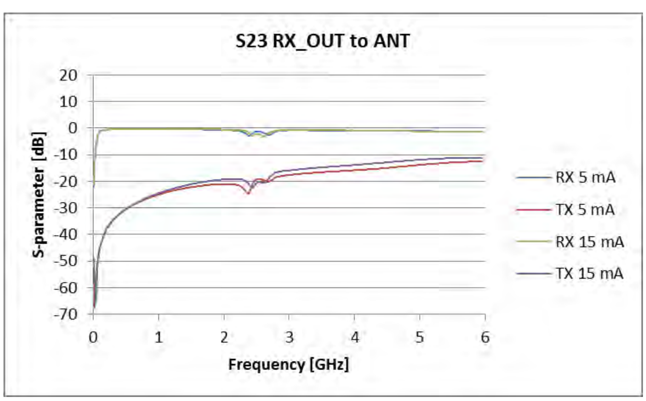


Table 7. S-parameter summary

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 3.3 V; I_{dd} = 15 mA; P_i = -30 dBm; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	900 MHz	915 MHz	930 MHz	Unit
1	RL_{TX_IN}	Return loss TX_IN	TX mode	-15.3	-15.0	-13.6	dB
	ISL	Iso Antenna to TX_IN	RX mode	-27.0	-26.4	-25.9	
	ISL	Iso RX_OUT to TX_IN	TX mode	-22.8	-22.5	-21.9	
	G_p	TX_IN to ANT	TX mode	-1.2	-1.3	-1.5	
	RL_{ANT}	Return loss ANT	RX mode	-19.4	-20.2	-24.5	
	ISL	Iso RX_OUT to ANT	TX mode	-22.7	-22.7	-22.8	
	ISL	Iso TX_IN to RX_OUT	TX mode	-22.9	-22.6	-22.0	
	G_p	ANT to RX_OUT	RX mode	-1.0	-1.1	-1.2	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-22.8	-21.3	-21.6	
2	RL_{TX_IN}	Return loss TX_IN	TX mode	-18.6	-16.7	-15.0	dB
	ISL	Iso Antenna to TX_IN	RX mode	-25.7	-25.1	-24.5	
	ISL	Iso RX_OUT to TX_IN	TX mode	-22.6	-22.6	-22.6	
	G_p	TX_IN to ANT	TX mode	-0.6	-0.7	-0.7	
	RL_{ANT}	Return loss ANT	RX mode	-23.4	-18.6	-15.4	
	ISL	Iso RX_OUT to ANT	TX mode	-21.7	-21.7	-21.7	
	ISL	Iso TX_IN to RX_OUT	TX mode	-22.7	-22.7	-22.7	
	G_p	ANT to RX_OUT	RX mode	-0.4	-0.5	-0.6	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-21.7	-17.9	-15.0	
3	RL_{TX_IN}	Return loss TX_IN	TX mode	-25.3	-28.0	-21.2	dB
	ISL	Iso Antenna to TX_IN	RX mode	-26.5	-26.3	-26.2	
	ISL	Iso RX_OUT to TX_IN	TX mode	-26.8	-26.2	-25.4	
	G_p	TX_IN to ANT	TX mode	-0.9	-1.0	-1.1	
	RL_{ANT}	Return loss ANT	RX mode	-24.2	-24.6	-19.8	
	ISL	Iso RX_OUT to ANT	TX mode	-26.8	-26.6	-26.5	
	ISL	Iso TX_IN to RX_OUT	TX mode	-26.7	-26.1	-25.3	
	G_p	ANT to RX_OUT	RX mode	-0.8	-0.9	-1.0	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-32.9	-29.9	-20.2	
4	RL_{TX_IN}	Return loss TX_IN	TX mode	-18.6	-18.6	-18.8	dB
	ISL	Iso Antenna to TX_IN	RX mode	-25.3	-25.0	-24.8	
	ISL	Iso RX_OUT to TX_IN	TX mode	-26.3	-26.1	-25.8	
	G_p	TX_IN to ANT	TX mode	-0.4	-0.4	-0.4	
	RL_{ANT}	Return loss ANT	RX mode	-18.8	-18.9	-18.9	
	ISL	Iso RX_OUT to ANT	TX mode	-25.5	-25.2	-25.7	
	ISL	Iso TX_IN to RX_OUT	TX mode	-26.3	-26.0	-25.7	
	G_p	ANT to RX_OUT	RX mode	-0.3	-0.3	-0.3	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-18	-18.6	-18.6	

3.5.2 In-band 1dB gain compression

The 1 dB compression level determines the power handling capability of the RX/TX switch. This capability is only for interest in the TX mode due to the high power level normally used in the transmit mode.

The 1dB gain compression is determined by applying an RF-power sweep at the input of the TX and measure the output power at the antenna output. The application is first set into the transmit mode before applying the power sweep.

During the P1dB measurement of the application without the BGA6130, no degradation on linearity was observed up to 40 dBm input power.

3.5.3 Intermodulation distortion (IP3)

When receiving or transmitting RF signals, intermodulation can be caused by the non-linear behavior of the PIN diodes.

To determine this influence, the application is excited with two RF signals and its output will be monitored for third order harmonics. The IP3 performance of the different configurations and on different modes can be found in the tables below.

Table 8. IP3 TX_IN to ANT path (TX mode)

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 3.3 V; f_c = 915 MHz; P_i = 6.5 dBm per tone; Δf =1 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	IIP3	OIP3	I_{supply}
1	IP3	Third-order intercept point	Idd = 5 mA	41.2 dBm	39.2 dBm	5 mA
			Idd = 15 mA	40.2 dBm	38.9 dBm	16.2 mA
2	IP3	Third-order intercept point	Idd = 5 mA	41.1 dBm	40.2 dBm	4.9 mA
			Idd = 15 mA	39.6 dBm	38.9 dBm	16.3 mA
3	IP3	Third-order intercept point	Idd = 5 mA	42.5 dBm	41.4 dBm	5.4 mA
			Idd = 15 mA	39.4 dBm	38.4 dBm	16.2 mA
4	IP3	Third-order intercept point	Idd = 5 mA	41.8 dBm	41.3 dBm	5.4 mA
			Idd = 15 mA	39.3 dBm	38.9 dBm	16.2 mA

Remark: Idd = PIN diode(s) current.

Table 9. IP3 ANT to RX_OUT path (RX mode)

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 3.3 V; f_c = 915 MHz; P_i = 6.5 dBm per tone; Δf =1 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	IIP3	OIP3	I_{supply}
1	IP3	Third-order intercept point	Idd = 0 mA	46.2 dBm	45.0 dBm	0 mA
2	IP3	Third-order intercept point	Idd = 0 mA	46.4 dBm	45.9 dBm	0 mA
3	IP3	Third-order intercept point	Idd = 5 mA	44.7 dBm	43.7 dBm	5.4 mA
			Idd = 15 mA	44.7 dBm	43.7 dBm	16.2 mA
4	IP3	Third-order intercept point	Idd = 5 mA	44.4 dBm	44.1 dBm	5.4 mA
			Idd = 15 mA	44.6 dBm	44.3 dBm	16.1 mA

Remark: Idd = PIN diode(s) current.

4. RX/TX switch with MPA evaluation board

There are two versions of the evaluation board available. The difference of these two versions is an additional medium power amplifier (MPA). This paragraph describes the version with the additional MPA in more detail.

Typical characteristics:

- High output power capability
- High gain
- Zero current during receive mode with MPA disabled (narrow bandwidth version)
- Low component count (depends on customer application)

4.1 Summary measurement results

Table 10. Summary measurement results

Operating conditions: V_{cc} = 3.3 V; f_c = 915 MHz; P_i = 6.5 dBm per tone; Δf =1 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	Typ.	Unit
5	Idd	Current consumption	RX mode	0.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	11.5	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-1.2	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-9.9	dB
	IIP3	Input third-order intercept point	TX mode	27.4	dBm
	OIP3	Output third-order intercept point	TX mode	38.9	dBm
	IP1dB	Input 1dB compression point	TX mode	15.5	dBm
	OP1dB	Output 1dB compression point	TX mode	26.2	dBm
6	Idd	Current consumption	RX mode	0.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	12.8	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-0.5	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-9.2	dB
	IIP3	Input third-order intercept point	TX mode	26.1	dBm
	OIP3	Output third-order intercept point	TX mode	38.9	dBm
	IP1dB	Input 1dB compression point	TX mode	15.3	dBm
	OP1dB	Output 1dB compression point	TX mode	27.1	dBm
7	Idd	Current consumption	RX mode	15.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	11.8	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-1.0	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-13.7	dB
	IIP3	Input third-order intercept point	TX mode	26.6	dBm
	OIP3	Output third-order intercept point	TX mode	38.4	dBm
	IP1dB	Input 1dB compression point	TX mode	15.3	dBm
	OP1dB	Output 1dB compression point	TX mode	26.3	dBm
8	Idd	Current consumption	RX mode	15.0	mA
			TX mode	15.0	mA
	G_p	Transmission TX_IN to ANT	TX mode	13.1	dB
	G_p	Transmission ANT to RX_OUT	RX mode	-0.3	dB
	ISL	Isolation TX_IN to RX_OUT	TX mode	-12.9	dB
	IIP3	Input third-order intercept point	TX mode	25.8	dBm
	OIP3	Output third-order intercept point	TX mode	38.9	dBm
	IP1dB	Input 1dB compression point	TX mode	14.8	dBm

Configuration	Symbol	Parameter	Conditions	Typ.	Unit
	OP1dB	Output 1dB compression point	TX mode	27.0	dBm

4.2 Application Circuit

Fig 8 shows the RX/TX switch with a power amplifier BGA6130 placed in the TX path. For more details about the BGA6130 see the associated datasheet.

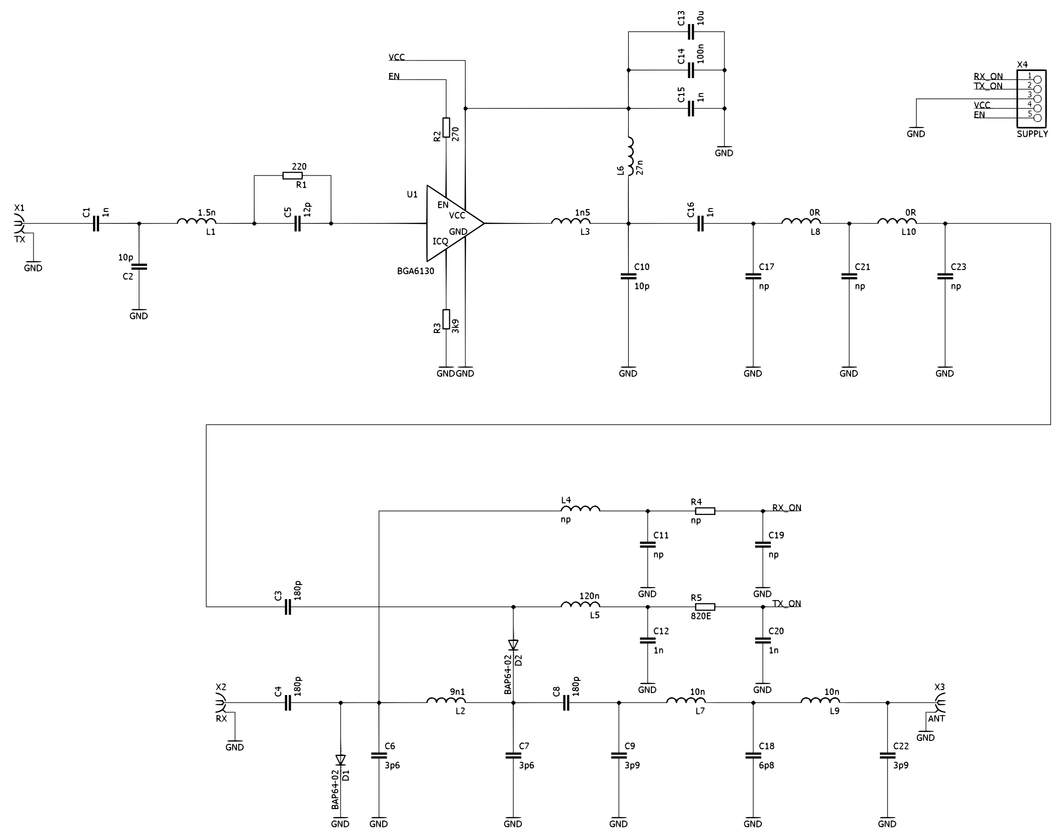


Fig 8. Circuit diagram of the RX/TX Switch with BGA6130 evaluation board narrow band configuration

The RX/TX switch part can be configured for broadband applications. Therefore the location of D4 is changed and an inductor is added to enable the DC current path. Fig 9 shows the circuit diagram for broadband usage.

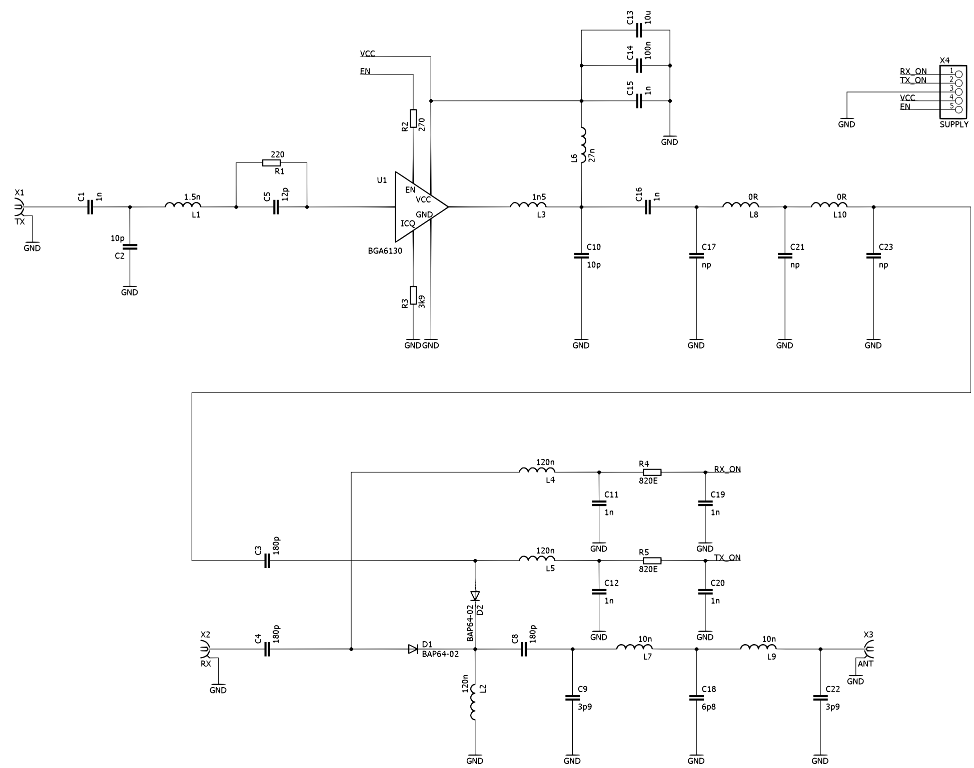


Fig 9. Circuit diagram of the RX/TX Switch with BGA6130 evaluation board broadband configuration

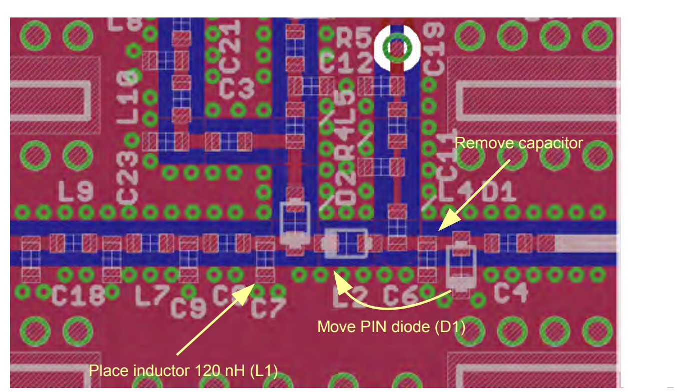


Fig 10. EVB layout broadband configuration

Remark: Notice the polarity of the PIN diodes.

4.3 PCB Layout

Both evaluation boards have the same form factor. The version that accommodates a BGA6130 has additional connector pins for applying the supply voltage and the MPA enable signal. When the MPA is disabled, the supply current of the MPA drops to 4 μA.

Most of the lumped components have a 0402 footprint except the voltage decoupling capacitors of the BGA6130. The PCB of Fig 11 accommodates an MPA in the TX_IN path.

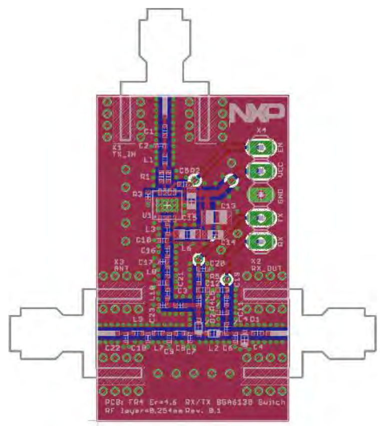


Fig 11. Printed-Circuit Board layout of the RX/TX Switch evaluation board with BGA6130.

A good PCB layout is an essential part of an RF circuit design. The evaluation board of the RX/TX Switch can serve as a guideline for laying out a board using the BAP64-02.

- Use controlled impedance lines for all high frequency inputs and outputs.
- For long bias lines it may be necessary to add decoupling capacitors along the line.
- Proper grounding of the GND pins is essential for good RF performance. Either connect the GND pins directly to the ground plane or through vias, or do both, which is recommended.
- To ensure optimal performance of the BAP64-02 in the application it is advised to simulate the overall application performance using the S-parameter and noise models of the device, the models for the external components and the models for the PCB. Models for the BAP64-02 are available via www.nxp.com.
- For good thermal behavior of the BGA6130, use thermal vias and keep the GND layer large in the middle and bottom layer (see layout example).

Fig 12 shows a recommended thermal via placement for the BGA6130 MPA (U1).

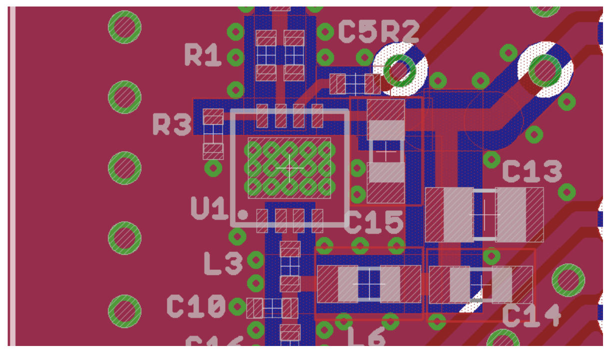


Fig 12. Recommended BGA6130 thermal via placement

The material that has been used for the evaluation board is FR4 using the layer stack shown in Fig 13.

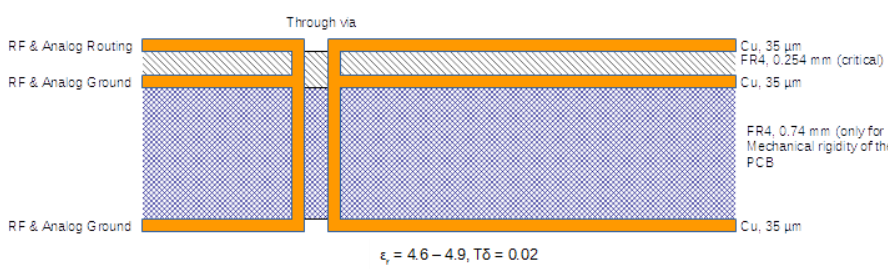


Fig 13. Stack of the PCB material

4.4 Bill of materials

Table 11. BOM of the RX/TX switch evaluation board configuration 5 (narrow band + MPA + low pass filter)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
D1,D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R1	Resistor	0402	220 Ω	Yageo 2322 705 70221	
R2	Resistor	0402	270 Ω	Yageo 2322 705 70271	
R3	Resistor	0402	3.9 kΩ	Yageo 2322 705 70392	
R5	Resistor	0402	100 Ω /360 Ω	Yageo 2322 705 70101/70361	360 Ω /5 mA, 100 Ω /15 mA
C1,C12, C16,C19, C20	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
C2	Capacitor	0402	12 pF	Murata GRM1555C1H120JZ01D	
C3,C4,C8	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C5	Capacitor	0402	8.2 pF	Murata GRM1555C1H8R2DZ01D	
C6,C7	Capacitor	0402	3.6 pF	Murata GRM1555C1H3R6CZ01D	
C9, C17,C22, C23	Capacitor	0402	3.9 pF	Murata GRM1555C1H3R9CZ01D	
C10	Capacitor	0402	10 uF	Murata GRM1555C1H100JZ01D	
C13	Capacitor	0805	10 uF	Murata GRM21BR61A106KE19L	
C14	Capacitor	0603	100 nF	Murata GRM188F51E104ZA01D	
C15	Capacitor	0603	1 nF	Murata GRM1885C1H102JA01D	
C18,C21	Capacitor	0402	6.8 pF	Murata GRM1555C1H6R8DZ01D	
L1	Inductor	0402	4.1 nH	Murata LQW15AN4N1C00D	
L2	Inductor	0402	9.1 nH	Murata LQW15AN9N1G00D	
L3	Inductor	0402	2.7 nH	Murata LQW15AN2N7C00D	
L5	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L6	Inductor	0603	27 nH	Murata LQW18AN27NJ00D	
L7,L8,L9,L10	Inductor	0402	10 nH	Murata LQW15AN10NG00D	
U1	HPA	SOT908-3		NXP BGA6130	
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 5 way 90121-0765	Bias connector

Table 12. BOM of the RX/TX switch evaluation board configuration 6 (narrow band + MPA)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
D1,D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R1	Resistor	0402	220 Ω	Yageo 2322 705 70221	
R2	Resistor	0402	270 Ω	Yageo 2322 705 70271	
R3	Resistor	0402	3.9 kΩ	Yageo 2322 705 70392	
R5	Resistor	0402	100 Ω /360 Ω	Yageo 2322 705 70101/70361	360 Ω /5 mA, 100 Ω /15 mA
C1,C12, C16,C19, C20	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
C2	Capacitor	0402	12 pF	Murata GRM1555C1H120JZ01D	
C3,C4,C8	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C5	Capacitor	0402	8.2 pF	Murata GRM1555C1H8R2DZ01D	
C6,C7	Capacitor	0402	3.6 pF	Murata GRM1555C1H3R6CZ01D	
C10	Capacitor	0402	10 pF	Murata GRM1555C1H100JZ01D	
C13	Capacitor	0805	10 uF	Murata GRM21BR61A106KE19L	
C14	Capacitor	0603	100 nF	Murata GRM188F51E104ZA01D	
C15	Capacitor	0603	1 nF	Murata GRM1885C1H102JA01D	
L1	Inductor	0402	4.1 nH	Murata LQW15AN4N1C00D	
L2	Inductor	0402	9.1 nH	Murata LQW15AN9N1G00D	
L3	Inductor	0402	2.7 nH	Murata LQW15AN2N7C00D	
L5	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L6	Inductor	0603	27 nH	Murata LQW18AN27NJ00D	
L7,L8,L9,L10	Resistor	0402	0 Ω	Yageo 2322 705 91001	Jumper
U1	HPA	SOT908-3		NXP BGA6130	
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 5 way 90121-0765	Bias connector

Table 13. BOM of the RX/TX switch evaluation board configuration 7 (broad band + MPA + low pass filter)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
L2,D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R1	Resistor	0402	220 Ω	Yageo 2322 705 70221	
R2	Resistor	0402	270 Ω	Yageo 2322 705 70271	
R3	Resistor	0402	3.9 kΩ	Yageo 2322 705 70392	
R4,R5	Resistor	0402	150 Ω /470 Ω	Yageo 2322 705 70151/70471	470 Ω /5 mA, 150 Ω /15 mA
C1,C11,C12, C16,C19, C20	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
C2	Capacitor	0402	12 pF	Murata GRM1555C1H120JZ01D	
C3,C4,C8	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C5	Capacitor	0402	8.2 pF	Murata GRM1555C1H8R2DZ01D	
C6	Capacitor	0402	3.6 pF	Murata GRM1555C1H3R6CZ01D	
C9, C17,C22, C23	Capacitor	0402	3.9 pF	Murata GRM1555C1H3R9CZ01D	
C10	Capacitor	0402	10 pF	Murata GRM1555C1H100JZ01D	
C13	Capacitor	0805	10 uF	Murata GRM21BR61A106KE19L	
C14	Capacitor	0603	100 nF	Murata GRM188F51E104ZA01D	
C15	Capacitor	0603	1 nF	Murata GRM1885C1H102JA01D	
C18,C21	Capacitor	0402	6.8 pF	Murata GRM1555C1H6R8DZ01D	
L1	Inductor	0402	4.1 nH	Murata LQW15AN4N1C00D	
L3	Inductor	0402	2.7 nH	Murata LQW15AN2N7C00D	
C7,L4,L5	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L6	Inductor	0603	27 nH	Murata LQW18AN27NJ00D	
L7,L8,L9,L10	Inductor	0402	10 nH	Murata LQW15AN10NG00D	
U1	HPA	SOT908-3		NXP BGA6130	
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 5 way 90121-0765	Bias connector

Table 14. BOM of the RX/TX switch evaluation board configuration 8 (broad band + MPA)

Designator	Description	Footprint	Value	Supplier Name/type	Comment
L2,D2	BAP64-02	SOD523		NXP	PIN diode
PCB		20.57 x 35 mm		RX/TX Switch EV Kit	
R1	Resistor	0402	220 Ω	Yageo 2322 705 70221	
R2	Resistor	0402	270 Ω	Yageo 2322 705 70271	
R3	Resistor	0402	3.9 kΩ	Yageo 2322 705 70392	
R4,R5	Resistor	0402	150 Ω /470 Ω	Yageo 2322 705 70151/70471	470 Ω /5 mA, 150 Ω /15 mA
C1,C11,C12, C16,C19, C20	Capacitor	0402	1 nF	Murata GRM1555C1H102JA01D	
C2	Capacitor	0402	12 pF	Murata GRM1555C1H120JZ01D	
C3,C4,C8	Capacitor	0402	180 pF	Murata GRM1555C1H181JA01D	
C5	Capacitor	0402	8.2 pF	Murata GRM1555C1H8R2DZ01D	
C10	Capacitor	0402	10 pF	Murata GRM1555C1H100JZ01D	
C13	Capacitor	0805	10 uF	Murata GRM21BR61A106KE19L	
C14	Capacitor	0603	100 nF	Murata GRM188F51E104ZA01D	
C15	Capacitor	0603	1 nF	Murata GRM1885C1H102JA01D	
C18,C21	Capacitor	0402	6.8 pF	Murata GRM1555C1H6R8DZ01D	
L1	Inductor	0402	4.1 nH	Murata LQW15AN4N1C00D	
L3	Inductor	0402	2.7 nH	Murata LQW15AN2N7C00D	
C7,L4,L5	Inductor	0402	120 nH	Murata LQW15ANR12J00D	
L6	Inductor	0603	27 nH	Murata LQW18AN27NJ00D	
L7,L8,L9,L10	Resistor	0402	0 Ω	Yageo 2322 705 91001	Jumper
U1	HPA	SOT908-3		NXP BGA6130	
X1,X2,X3	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X4	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 5 way 90121-0765	Bias connector

4.5 Measurement results

The measurements are performed at a supply voltage of Vcc=3.3 V at an ambient temperature of 25 °C unless stated otherwise.

4.5.1 S-parameters (3-port)

Because the RX/TX switch contains three RF-ports, it is desirable to have a three ports small signal S-parameter measurement. There are two situations to be analyzed. The RX/TX switch can be set in RX or TX mode. For both situations an S-parameter measurement is performed. The measurements are performed under the following conditions:

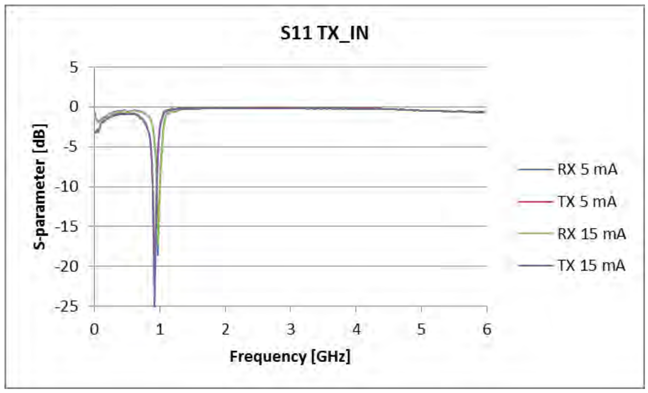
- Pin = -30 dBm
- Frequency = 10 – 6000 MHz
- Ambient temperature = 25 °C

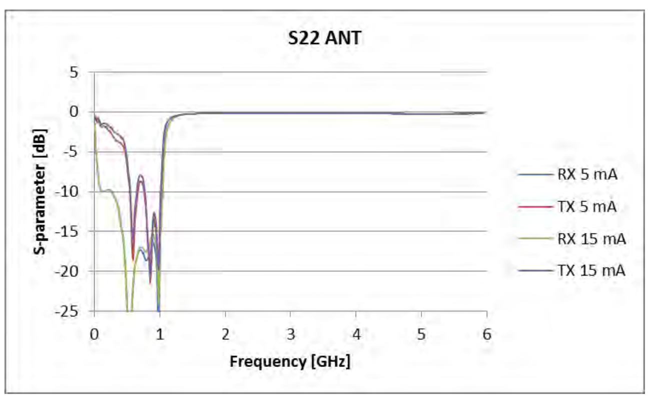
In the TX mode, the RX_OUT port is isolated from the TX_IN and ANT port.

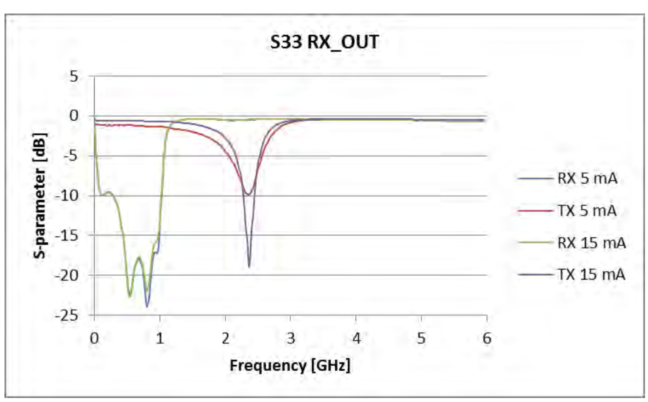
Next graphs shows the S-parameters measured at different PIN diode currents (Idd). The graphs also shows the low-pass filter response. It has a cut-off frequency of approximately 1 GHz.

4.5.1.1 Narrow band with BGA6130 and filter (configuration 5)

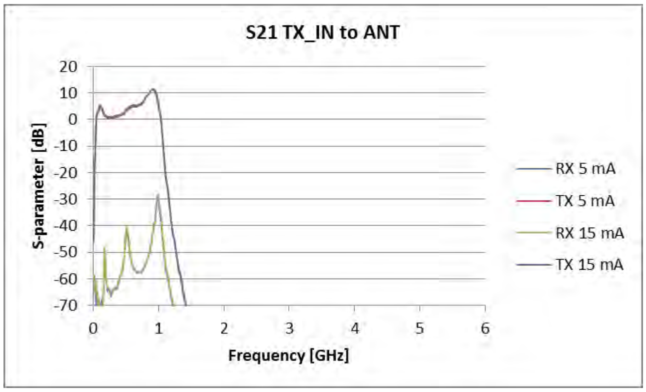
Return losses (S11, S22 and S33)

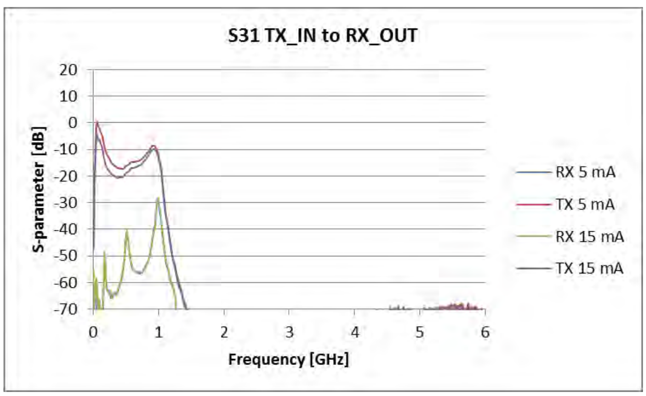


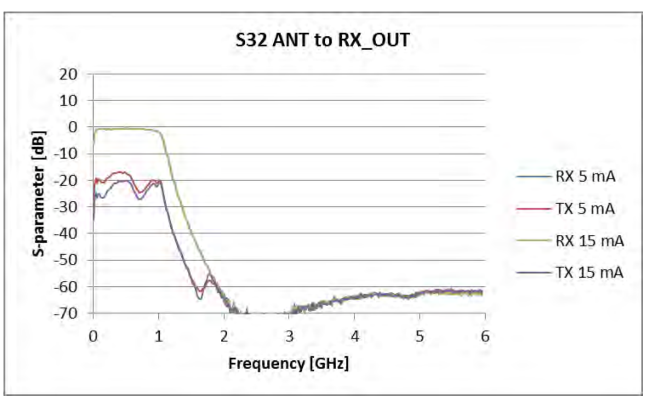




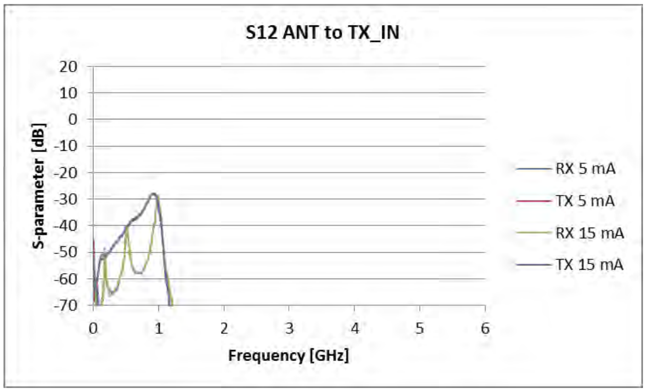
Transmission (S21, S31 and S32)

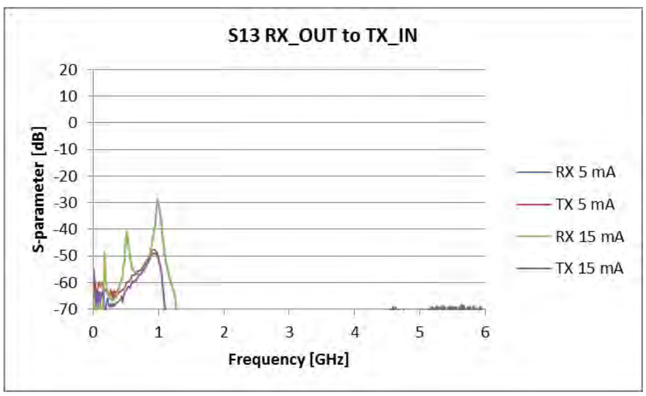


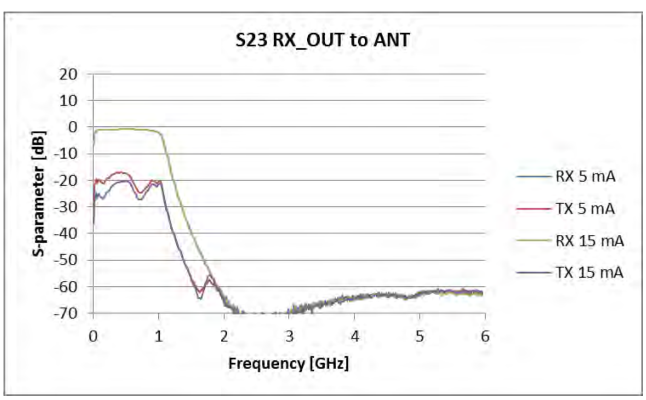




Isolation (S12, S13 and S23)

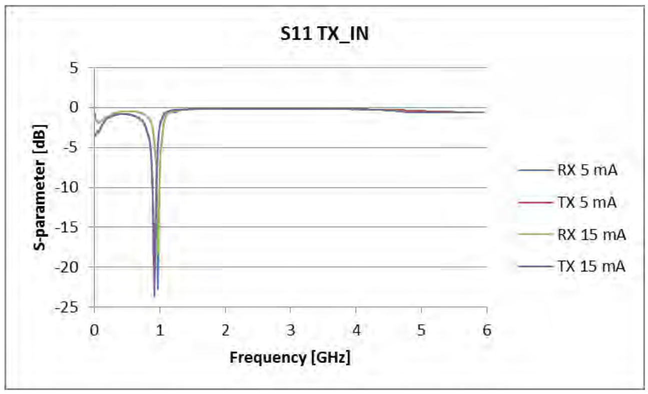


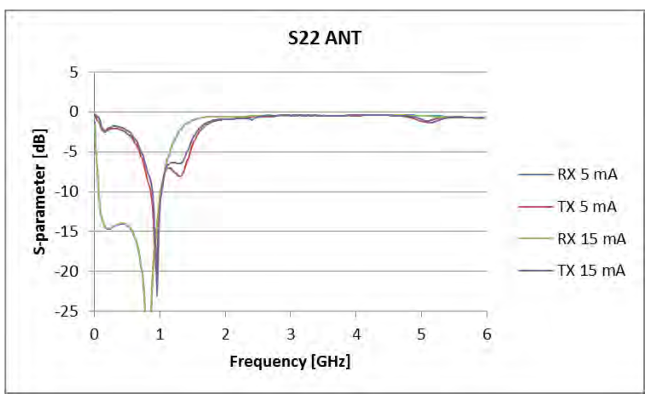


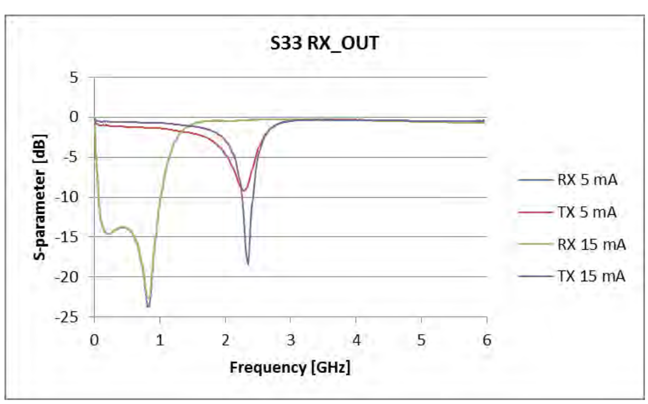


4.5.1.2 Narrow band with BGA6130 without filter (configuration 6)

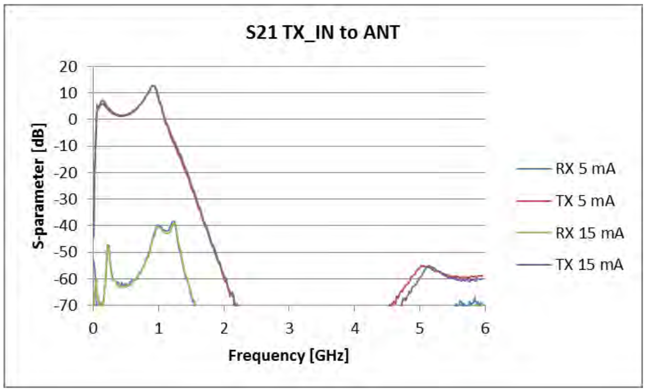
Return losses (S11, S22 and S33)

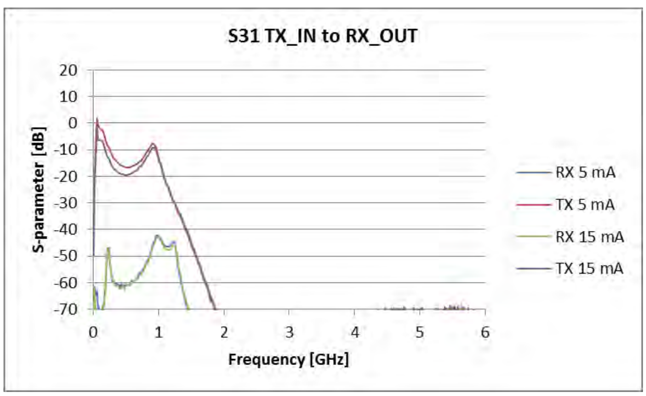


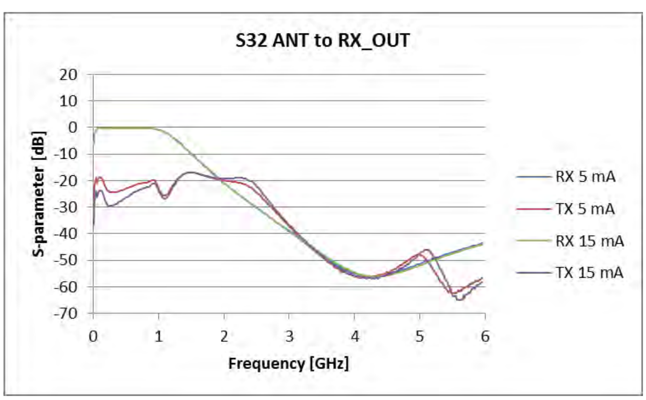




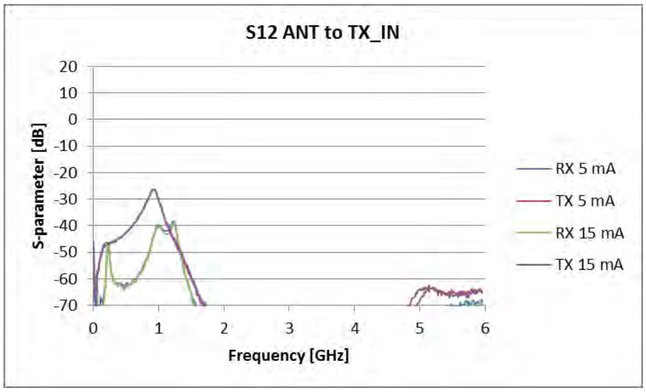
Transmission (S21, S31 and S32)

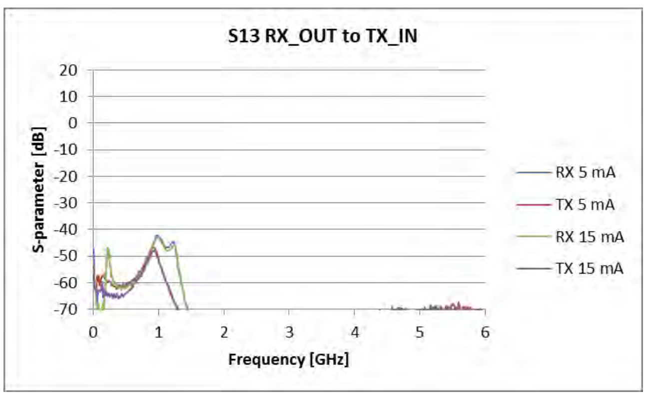


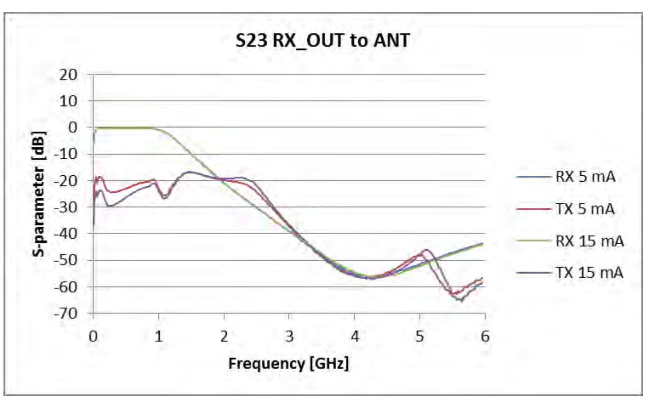




Isolation (S12, S13 and S23)

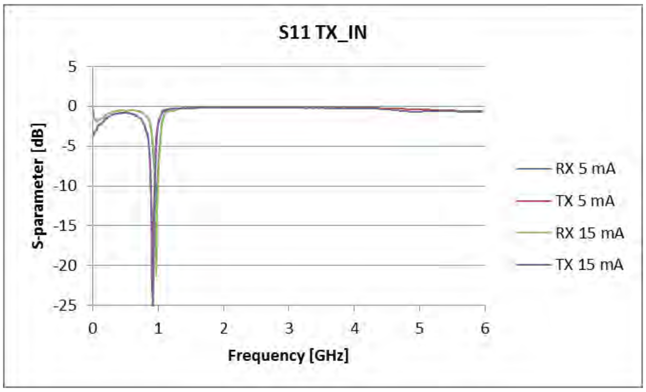


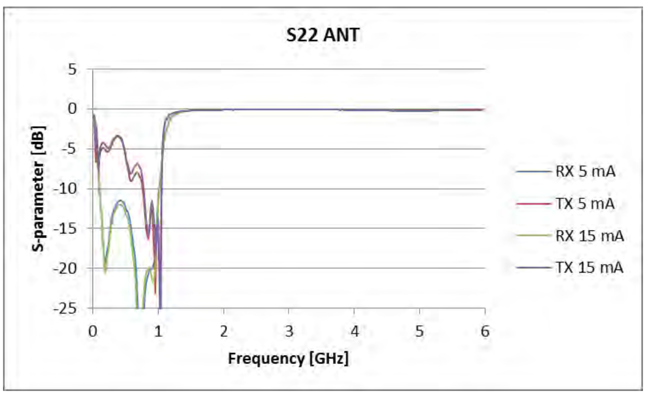


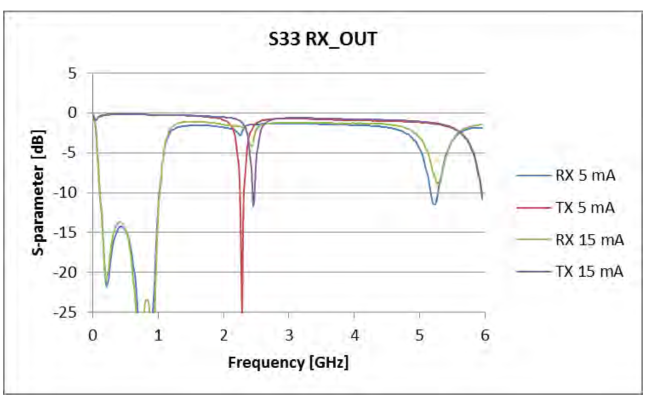


4.5.1.3 Board band with BGA6130 with filter (configuration 7)

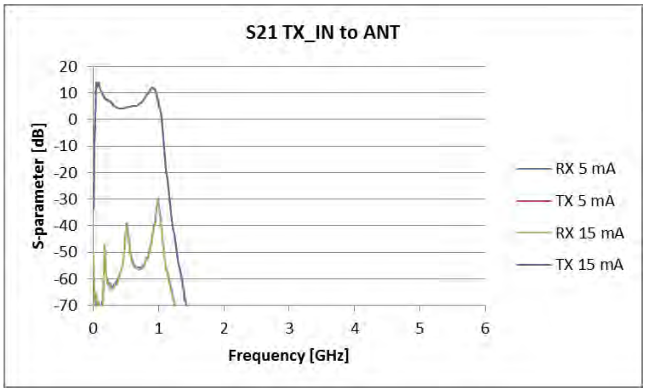
Return losses (S11, S22 and S33)

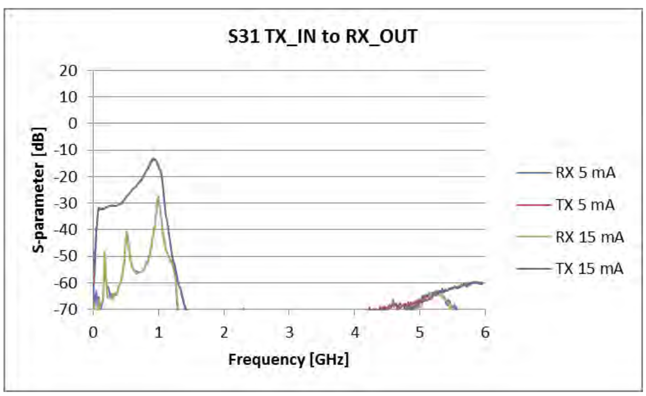


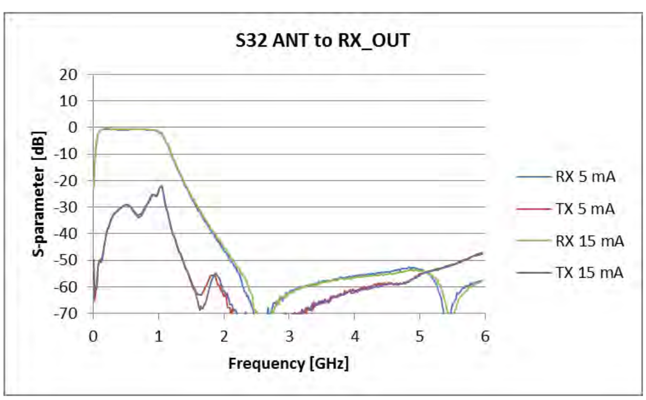




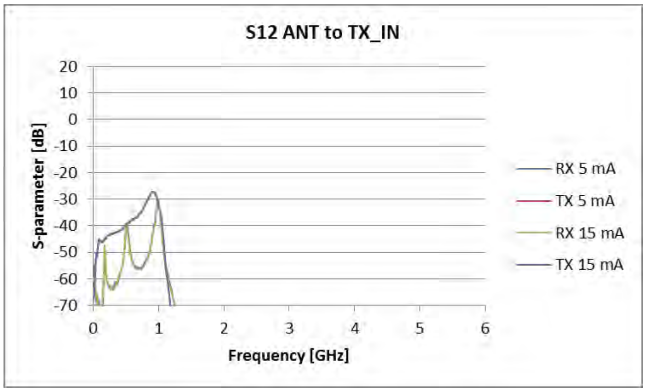
Transmission (S21, S31 and S32)

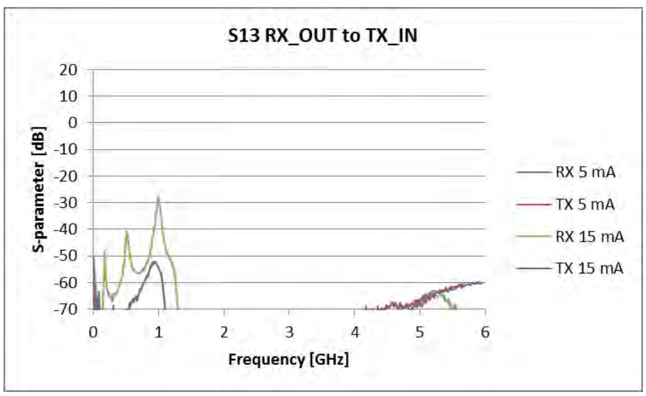


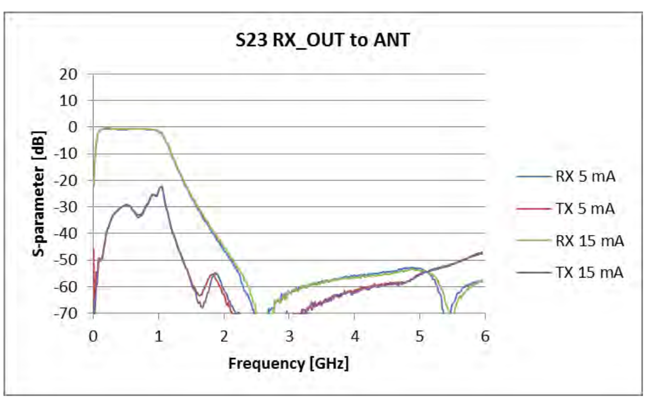




Isolation (S12, S13 and S23)

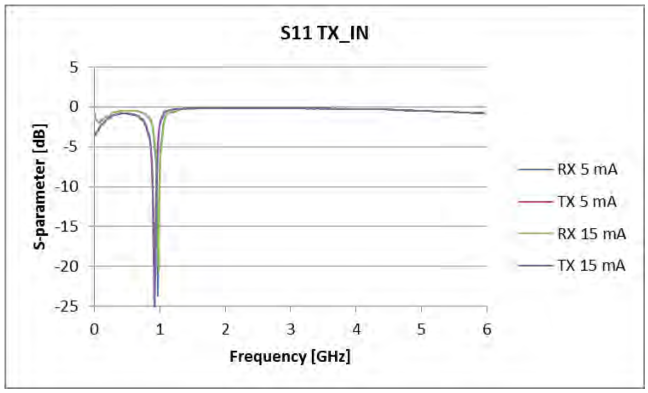


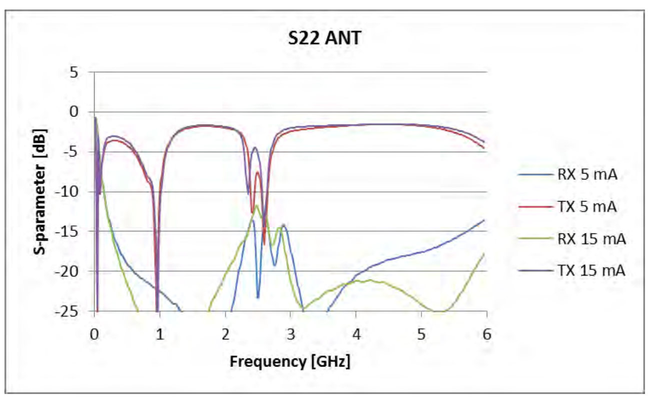


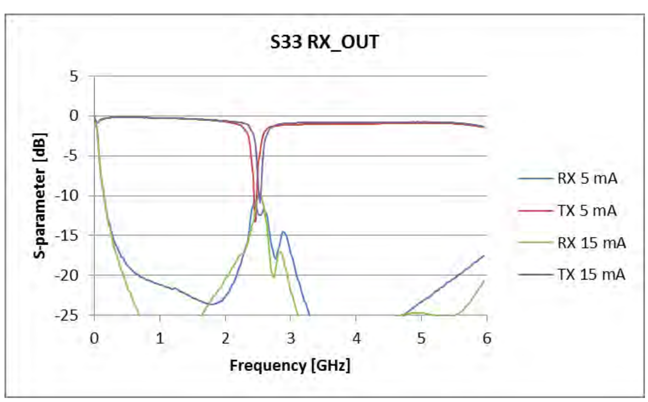


4.5.1.4 Broad band with BGA6130 without filter (configuration 8)

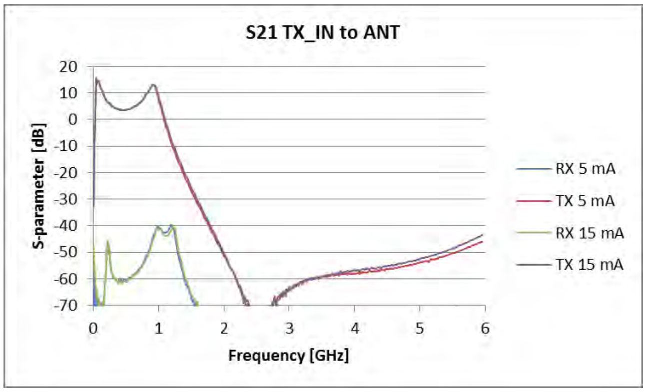
Return losses (S11, S22 and S33)

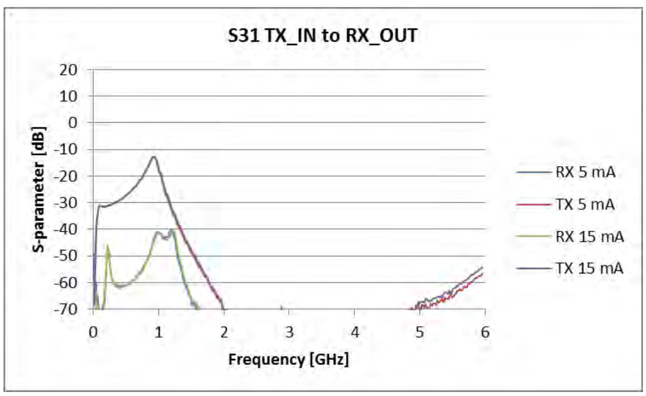


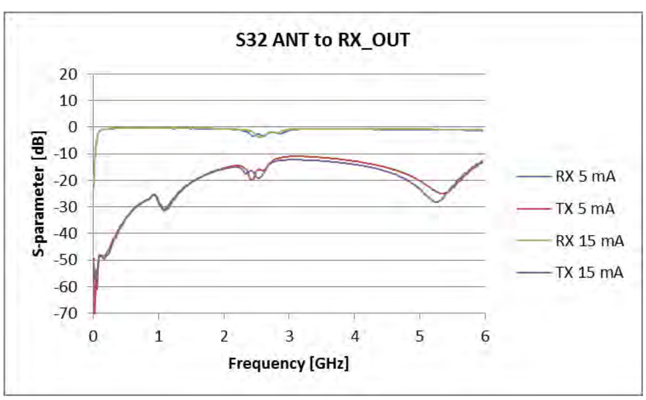




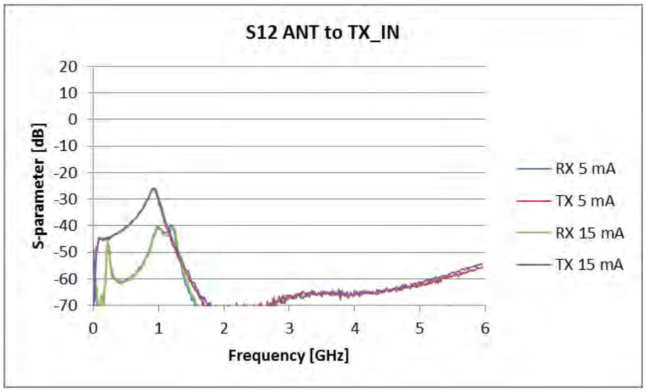
Transmission (S21, S31 and S32)

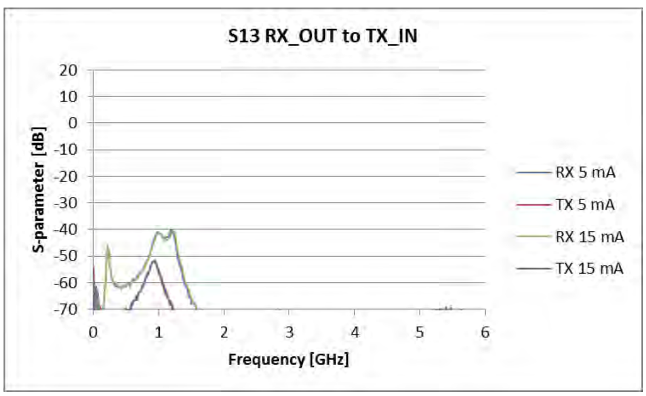






Isolation (S12, S13 and S23)





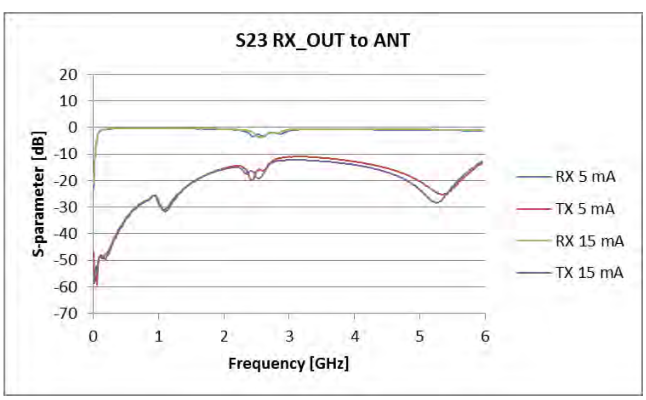


Table 15. S-parameter summary

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 3.3 V; I_{dd} = 15 mA; I_{QMPA} = 70 mA; P_i = -30 dBm; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	900 MHz	915 MHz	930 MHz	Unit
5	RL_{TX_IN}	Return loss TX_IN	TX mode	-9.8	-25.2	-9.3	dB
	ISL	Iso Antenna to TX_IN	RX mode	-46.3	-41.6	-35.6	
	ISL	Iso RX_OUT to TX_IN	TX mode	-49.6	-48.9	-48.9	
	G_p	TX_IN to ANT	TX mode	11.4	11.5	10.4	
	RL_{ANT}	Return loss ANT	RX mode	-15.3	-15.7	-18.1	
	ISL	Iso RX_OUT to ANT	TX mode	-21.4	-21.2	-21.9	
	ISL	Iso TX_IN to RX_OUT	TX mode	-10.4	-9.9	-10.3	
	G_p	ANT to RX_OUT	RX mode	-1.0	-1.2	-1.3	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-16.9	-15.9	-15.6	
6	RL_{TX_IN}	Return loss TX_IN	TX mode	-10.3	-23.6	-7.7	dB
	ISL	Iso Antenna to TX_IN	RX mode	-47.2	-44.6	-42.0	
	ISL	Iso RX_OUT to TX_IN	TX mode	-49.0	-48.2	-48.8	
	G_p	TX_IN to ANT	TX mode	12.4	12.8	11.9	
	RL_{ANT}	Return loss ANT	RX mode	-20.1	-16.6	-14.0	
	ISL	Iso RX_OUT to ANT	TX mode	-21.4	-21.0	-21.5	
	ISL	Iso TX_IN to RX_OUT	TX mode	-9.7	-9.2	-10.0	
	G_p	ANT to RX_OUT	RX mode	-0.4	-0.5	-0.6	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-18.4	-15.8	-13.5	
7	RL_{TX_IN}	Return loss TX_IN	TX mode	-10.4	-28.3	-8.0	dB
	ISL	Iso Antenna to TX_IN	RX mode	-46.4	-42.2	-36.7	
	ISL	Iso RX_OUT to TX_IN	TX mode	-53.9	-52.8	-52.8	
	G_p	TX_IN to ANT	TX mode	11.7	11.8	10.7	
	RL_{ANT}	Return loss ANT	RX mode	-20.8	-21.8	-19.6	
	ISL	Iso RX_OUT to ANT	TX mode	-25.9	-25.4	-25.7	
	ISL	Iso TX_IN to RX_OUT	TX mode	-14.5	-13.7	-13.8	
	G_p	ANT to RX_OUT	RX mode	-0.9	-1.0	-1.1	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-29.6	-37.4	-22.1	
8	RL_{TX_IN}	Return loss TX_IN	TX mode	-9.4	-27.8	-8.5	dB
	ISL	Iso Antenna to TX_IN	RX mode	-47.3	-44.8	-42.5	
	ISL	Iso RX_OUT to TX_IN	TX mode	-53.2	-52.0	-52.0	
	G_p	TX_IN to ANT	TX mode	12.6	13.1	12.3	
	RL_{ANT}	Return loss ANT	RX mode	-29.9	-30.6	-31.2	
	ISL	Iso RX_OUT to ANT	TX mode	-26.2	-25.6	-25.7	
	ISL	Iso TX_IN to RX_OUT	TX mode	-13.8	-12.9	-13.4	
	G_p	ANT to RX_OUT	RX mode	-0.3	-0.3	-0.3	
	RL_{RX_OUT}	Return loss RX_OUT	RX mode	-28.6	-29.1	-29.5	

4.5.2 In-band 1dB gain compression

The 1 dB compression level determines the power capability of the RX/TX switch. This capability is only for interest in the TX mode due to the high power level normally used in the transmit mode.

The 1dB gain compression is determined by applying an RF-power sweep at the input of the TX and measure the output power at the antenna output. The application is first set into the transmit mode before applying the power sweep.

Table 16 shows the P1dB of the TX to antenna path of this application:

Table 16. TX_INT to ANT path with BGA6130 (TX mode)

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 3.3 V; f_c = 915 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	IP1dB	OP1dB	I_{supply}
5	P1dB	1dB compression point	Idd = 5 mA	15.4 dBm	25.9 dBm	351 mA
			Idd = 15 mA	15.5 dBm	26.2 dBm	365 mA
6	P1dB	1dB compression point	Idd = 5 mA	15.3 dBm	27.1 dBm	370 mA
			Idd = 15 mA	15.2 dBm	27.1 dBm	370 mA
7	P1dB	1dB compression point	Idd = 5 mA	15.3 dBm	26.3 dBm	363 mA
			Idd = 15 mA	14.8 dBm	25.8 dBm	370 mA
8	P1dB	1dB compression point	Idd = 5 mA	14.8 dBm	27.0 dBm	370 mA
			Idd = 15 mA	14.7 dBm,	26.9 dBm	370 mA

Remark: Idd = PIN diode(s) current. I_{supply} = Idd + I_{QMPA} (MPA quiescent current = 70 mA).

4.5.3 Intermodulation distortion (IP3)

When receiving or transmitting RF signals, intermodulation can be caused by the non-linear behavior of the PIN diodes. In TX mode, intermodulation can also be generated by the BGA6130.

To determine this influence, the application is excited with two RF signals and its output will be monitored for third order harmonics. The IP3 performance of the different configurations and on different modes can be found in the tables below.

Table 17. IP3 TX_IN to ANT path (TX mode)

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 3.3 V; f_c = 915 MHz; P_i = 6.5 dBm; Δf = 1 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	IIP3	OIP3	I_{supply}
5	IP3	Third-order intercept point	Idd = 5 mA	27.7 dBm	39.2 dBm	197.7 mA
			Idd = 15 mA	27.2 dBm	38.9 dBm	209.4 mA
6	IP3	Third-order intercept point	Idd = 5 mA	27.4 dBm	40.2 dBm	213.2 mA
			Idd = 15 mA	26.0 dBm	38.9 dBm	212.9 mA
7	IP3	Third-order intercept point	Idd = 5 mA	29.4 dBm	41.4 dBm	221.7 mA
			Idd = 15 mA	26.4 dBm	38.4 dBm	233.1 mA
8	IP3	Third-order intercept point	Idd = 5 mA	28.1 dBm	41.3 dBm	229.4 mA
			Idd = 15 mA	25.7 dBm	38.9 dBm	235.9 mA

Remark: Idd = PIN diode(s) current. I_{supply} = Idd + I_{QMPA} (MPA quiescent current = 70 mA).

Table 18. IP3 ANT to RX_OUT path (RX mode)

Operating conditions: V_{cc} = 3.3 V; V_{enable} = 0.0 V; f_c = 915 MHz; P_i = 6.5 dBm; Δf = 1 MHz; T_{amb} = 25 °C; unless otherwise specified.

Configuration	Symbol	Parameter	Conditions	IIP3	OIP3	I_{supply}
5	IP3	Third-order intercept point	Idd = 0 mA	46.2 dBm	45.0 dBm	0 mA
6	IP3	Third-order intercept point	Idd = 0 mA	46.4 dBm	45.9 dBm	0 mA
7	IP3	Third-order intercept point	Idd = 5 mA	44.7 dBm	43.7 dBm	5.4 mA
			Idd = 15 mA	44.7 dBm	43.7 dBm	16.2 mA
8	IP3	Third-order intercept point	Idd = 5 mA	44.4 dBm	44.1 dBm	5.4 mA
			Idd = 15 mA	44.6 dBm	44.3 dBm	16.1 mA

Remark: Idd = PIN diode(s) current. I_{supply} = Idd + I_{QMPA} (MPA quiescent current = 70 mA) current.

5. Connections and setup

A two port network analyzer is used to measure the S-parameters of the application. Due the fact that the application has three different RF ports and a two port VNA is used, two different test setups are needed to characterize the application. The unused RF port should be terminated with 50 ohm during the measurements. Next pictures (see Fig 14 and Fig 15) depicts the two different test setups with their RF connections, 50 ohms termination and DC power supply/control voltage.

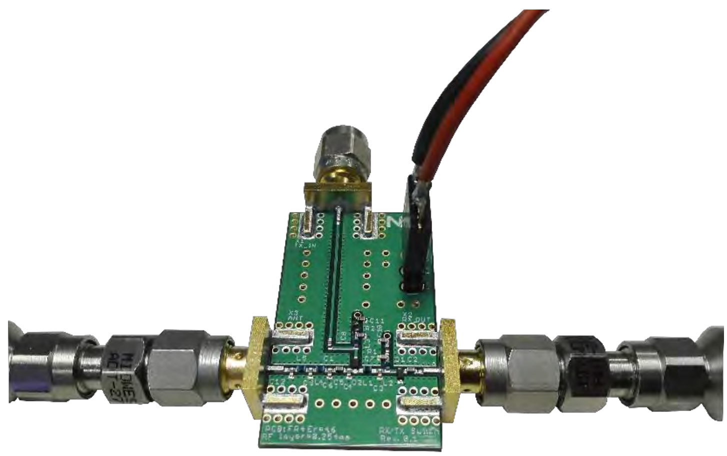


Fig 14. RX/TX Switch evaluation board connection to measure the ANT – RX_OUT path

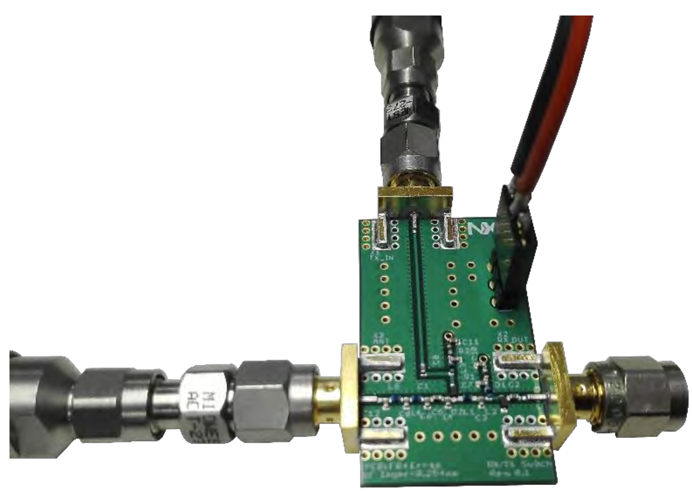


Fig 15. RX/TX Switch evaluation board connection to measure the TX_IN - ANT path

6. Legal information

6.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

6.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

6.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are property of their respective owners.

7. List of figures

8. List of tables

9. Contents

Date of release: 31 August 2017
Document identifier: AN11991