Wideband SP3T RF Switch for RF diversity or RF band selection applications

BGS13S2N9

About this document

Scope and purpose

This application note describes Infineon's Wideband SP3T RF Switch for RF diversity or RF band selection applications: BGS13S2N9 as switch for Mobile phones in different RF FE applications such as diversity or band selection switch.

1. This application note documents the behavior of BGS13S2N9 for different LTE bands (Band 1, 2, 3, 4, 5, 7, 12, 13, 17, 20, 25 and Band 30).
2. The BGS13S2N9 is used in this document.
3. General purpose wideband Rf switch for diversity application or as band selection switch.
4. Key Parameters:
   - 3 high-linearity TRx paths with power handling capability of up to 30 dBm
   - Low insertion loss
   - Low harmonic generation
   - High port-to-port-isolation
   - Suitable for Edge / CDMA2000 / LTE / WCDMA applications

Table of Contents

List of Figures[1]

List of figures

List of Tables

1) The graphs are generated with the simulation program AWR Microwave Office®.

1 Introduction

Infineon's RF CMOS switches are the first on the market to be based purely on standard industrial CMOS processes that offer low insertion loss, high isolation and low harmonics generation for high-volume production. They are widely used for band selection/switching or diversity switching at the antenna or different RF paths within the RF Front-End (FE).

The BGS13S2N9 RF MOS switch is specifically designed for cell phone and mobile applications. Any of the 3 ports can be used as termination of the diversity antenna handling up to 30 dBm.

This SP3T offers low insertion loss and high robustness against interferer signals at the antenna port and low harmonic generation in termination mode. The on-chip controller integrates CMOS logic and level shifters, driven by control inputs from 1.35 V to VDD. The BGS13S2N9 RF Switch is manufactured in Infineon's patented MOS technology, offering the performance of GaAs with the economy and integration of conventional CMOS including the inherent higher ESD robustness. The device has a very small size of only 1.1 x 1.1 mm2 and a maximum height of 0.375 mm.

The recent trend of smartphone and tablet users to download more and more data anytime and anywhere increases the demand for more bandwidth and for an additional receiver channel called the diversity path. To select the right receive band, a diversity switch with low insertion loss and excellent RF performance is one method of choice. Nowadays, diversity switches covering up to 7 or more different UMTS/LTE bands are becoming more and more popular in smartphones and tablets (Overview LTE Bands).

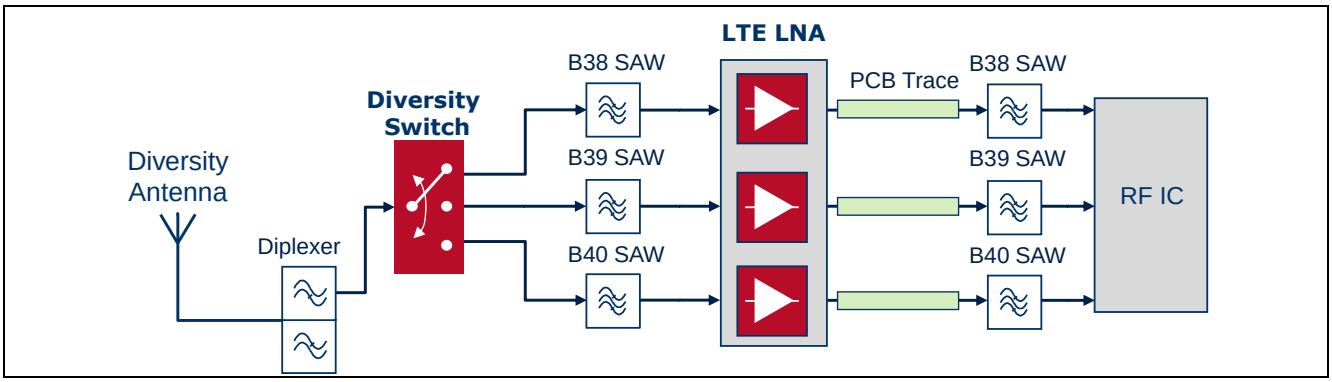


Figure 1 Excample of TD-LTE band for diversity path

Table 1 Overview LTE Bands

Band No.	Band Definition	Uplink Frequency Range	Downlink Frequency Range	FDD/TDD System	Comment
1	Mid-Band	1920-1980 MHz	2110-2170 MHz	FDD	
2	Mid-Band	1850-1910 MHz	1930-1990 MHz	FDD	
3	Mid-Band	1710-1785 MHz	1805-1880 MHz	FDD	
4	Mid-Band	1710-1755 MHz	2110-2155 MHz	FDD	
5	Low-Band	824-849 MHz	869-894 MHz	FDD	
6	Low-Band	830-840 MHz	875-885 MHz	FDD	
7	High-Band	2500-2570 MHz	2620-2690 MHz	FDD	
8	Low-Band	880-915 MHz	925-960 MHz	FDD	
9	Mid-Band	1749.9-1784.9 MHz	1844.9-1879.9 MHz	FDD	
10	Mid-Band	1710-1770 MHz	2110-2170 MHz	FDD	
11	Mid-Band	1427.9-1452.9 MHz	1475.9-1500.9 MHz	FDD	
12	Low-Band	698-716 MHz	728-746 MHz	FDD	
13	Low-Band	777-787 MHz	746-756 MHz	FDD	
14	Low-Band	788-798 MHz	758-768 MHz	FDD	
15		reserved	reserved	FDD	
16		reserved	Reserved	FDD	
17	Low-Band	704-716 MHz	734-746 MHz	FDD	
18	Low-Band	815-830 MHz	860-875 MHz	FDD	
19	Low-Band	830-845 MHz	875-890 MHz	FDD	
20	Low-Band	832-862 MHz	791-821 MHz	FDD	
21	Mid-Band	1447.9-1462.9 MHz	1495.9-1510.9 MHz	FDD	
22	High-Band	3410-3500 MHz	3510-3600 MHz	FDD	
23	Mid-Band	2000-2020 MHz	2180-2200 MHz	FDD	
24	Mid-Band	1626.5-1660.5 MHz	1525-1559 MHz	FDD	
25	Mid-Band	1850-1915 MHz	1930-1995 MHz	FDD	
26	Low-Band	814-849 MHz	859-894 MHz	FDD	
27	Low-Band	807-824 MHz	852-869 MHz	FDD	
28	Low-Band	703-748 MHz	758-803 MHz	FDD	
29	Low-Band	N/A	716-728 MHz	FDD	
30	High-Band	2305-2315 MHz	2350-2360 MHz	FDD	
31	Low-Band	452.5-457.5 MHz	462.5-467.5MHz	FDD	
32	Mid-Band	N/A	1452-1496 MHz	FDD	
33	Mid-Band	1900-1920 MHz		TDD	
34	Mid-Band	2010-2025 MHz		TDD	
35	Mid-Band	1850-1910 MHz		TDD	
36	Mid-Band	1930-1990 MHz		TDD	
37	Mid-Band	1910-1930 MHz		TDD	

Table 1 Overview LTE Bands

38	High-Band	2570-2620 MHz	TDD	
39	Mid-Band	1880-1920 MHz	TDD	
40	High-Band	2300-2400 MHz	TDD	
41	High-Band	2496-2690 MHz	TDD	
42	High-Band	3400-3600 MHz	TDD	
43	High-Band	3600-3800 MHz	TDD	
44	Low-Band	703-803 MHz	TDD	
46	Mid-Band	5150-5925 MHz	TDD	

Note: FDD: Frequency Division Duplexing; TDD: Time Division Duplexing

2 BGS13S2N9 Features

2.1 Main Features

- 3 high-linearity TRx paths with power handling capability of up to 30 dBm
- Low insertion loss
- Low harmonic generation
- High port-to-port-isolation
- Suitable for Edge / CDMA2000 / LTE / WCDMA applications
- 0.1 to 3.0 GHz coverage
- No decoupling capacitors required if no DC applied on RF lines
- On-chip control logic including ESD protection
- General Purpose Input-Output (GPIO) Interface
- Small form factor 1.1mm x 1.1mm x 0.375mm
- No power supply blocking required
- High EMI robustness
- RoHS and WEEE compliant package

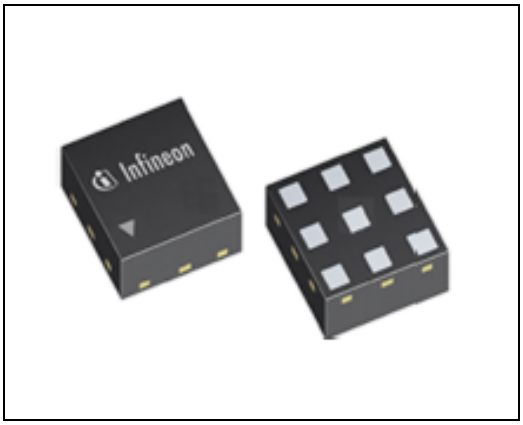


Figure 2 BGS13S2N9 package

2.2 Functional Diagram

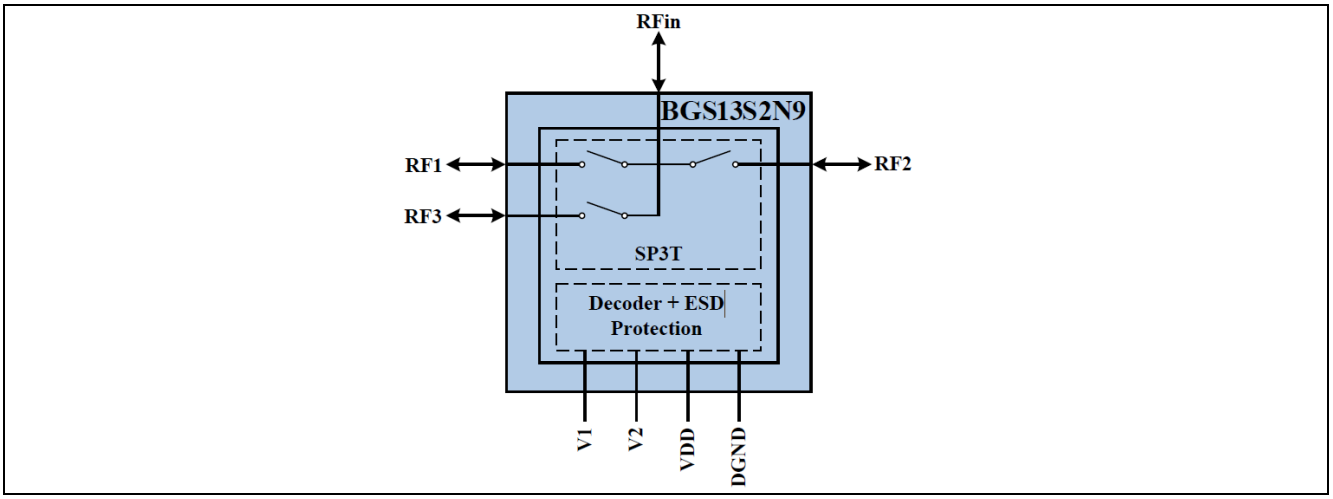


Figure 3 Equivalent Circuit Block diagram of BGS13S2N9

2.3 Signal Description

Table 2 Pin Configuration of BGS13S2N9

Pin No.	Name	Pin Type	Function
1	V1	I	Control Pin 1
2	RF3	I/O	RF-Port3
3	RF1	I/O	RF-Port1
4	RFin	I/O	RF-Input
5	RF2	I/O	RF-Port2
6	DGND	GND	Digital Ground
7	VDD	PWR	Power Supply
8	V2	I	Control Pin 2
9	GND	GND	Digital Ground

Table 3 Modes of Operation: Truth Table of BGS13S2N9

		Control Inputs				
State	Mode	V1	V2	RF1	RF2	RF3
1	Isolation	0	0	off	off	off
2	RFin – RF1	1	0	on	off	off
3	RFin – RF2	0	1	off	on	off
4	RFin – RF3	1	1	off	off	on

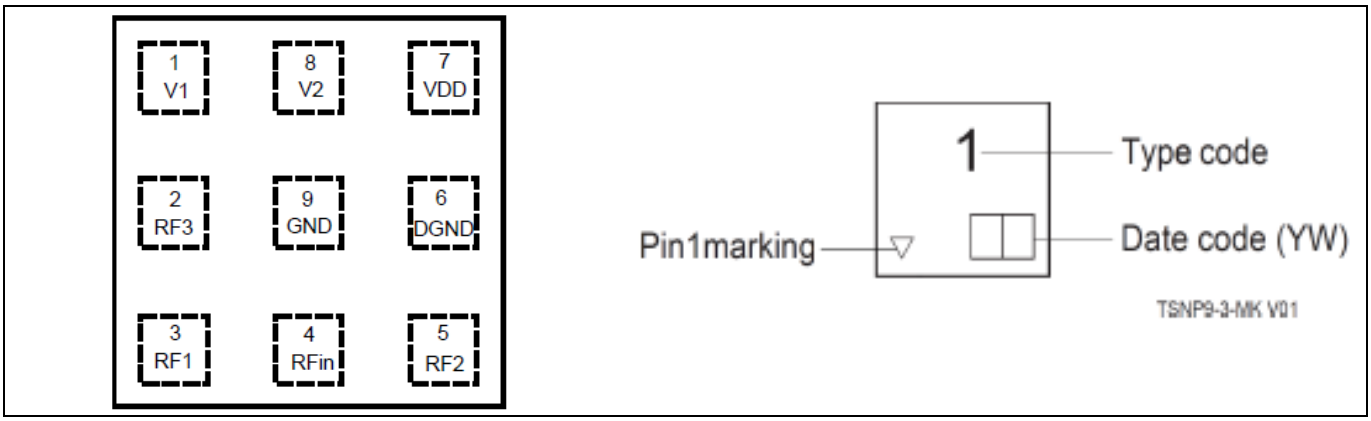


Figure 4 Package and pin connections (top view) of BGS13S2N9

3 Application Circuit and Performance Overview

In this chapter the performance of the application circuit, the schematic and bill-on-materials are presented.

Device: **BGS13S2N9**

Application: **Wideband RF S3PT Switch**

PCB Marking: **BGS13xN9**

3.1 Summary of Measurement Results

All measurement results of this application note are measured with a typical device of the BGS13S2N9 on an application board. The measurement procedure is shown in chapters Intermodulation, Harmonic Generation and Evaluation Board and Layout Information including the needed de-embedding.

The small signal characteristics are measured at 25 °C, -5 dBm P_{in}, 2.8V V_{dd}, 2.8V V_{crlt} up to 3GHz with a Network Analyzer connected to an automatic multiport switch box in single ended mode.

In the following tables and graphs the most important RF parameter of the BGS13S2N9 are shown. The markers are set to the most important frequencies of the WCDMA system.

3.2 Insertion Loss

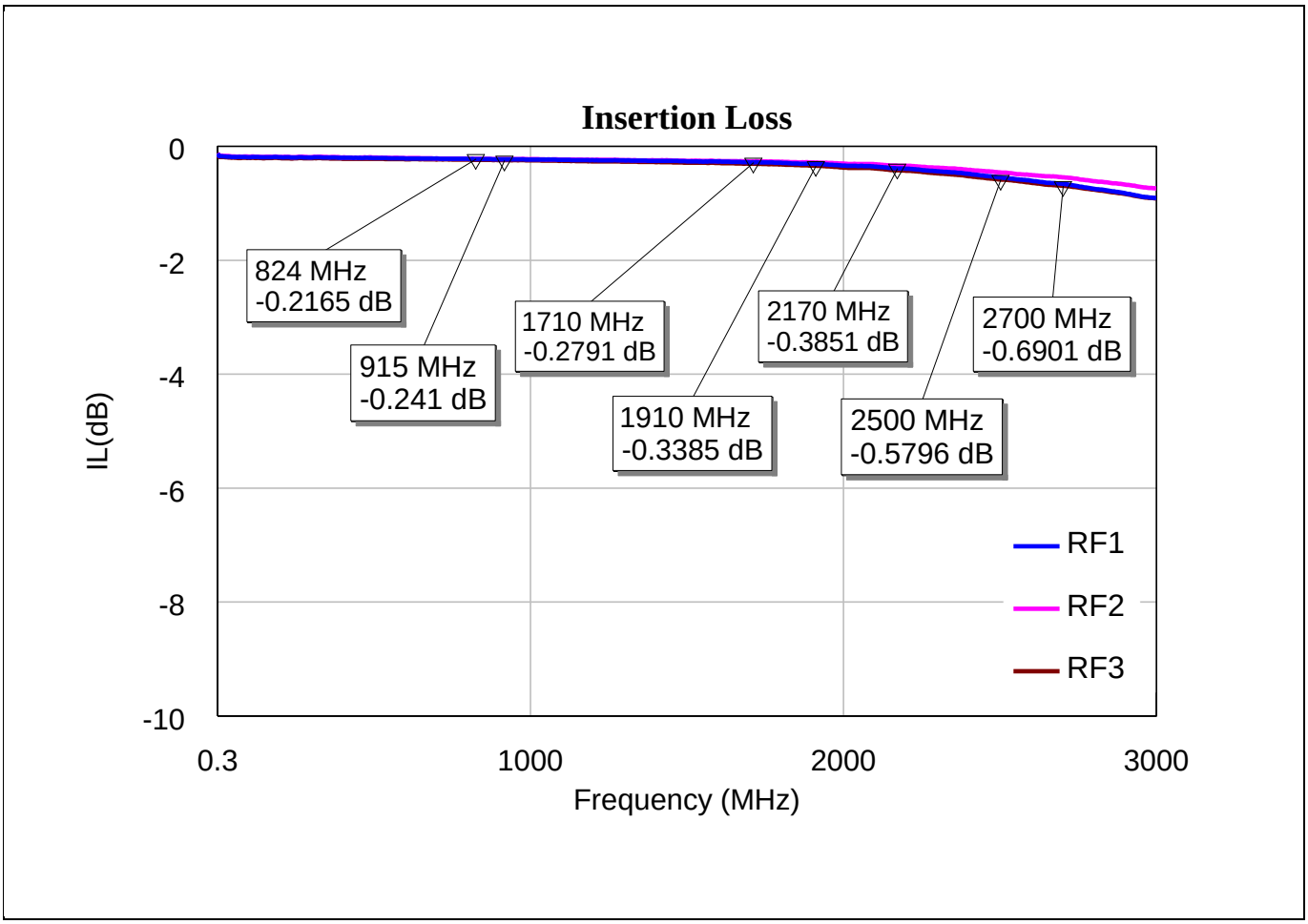


Figure 5 Insertion Loss in dB up to 3GHz

Table 4 Insertion Loss in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF1	0.22	0.23	0.28	0.31	0.39	0.54	0.66
RF2	0.22	0.22	0.26	0.28	0.34	0.45	0.54
RF3	0.23	0.24	0.31	0.34	0.42	0.58	0.69

3.3 Antenna Return Loss

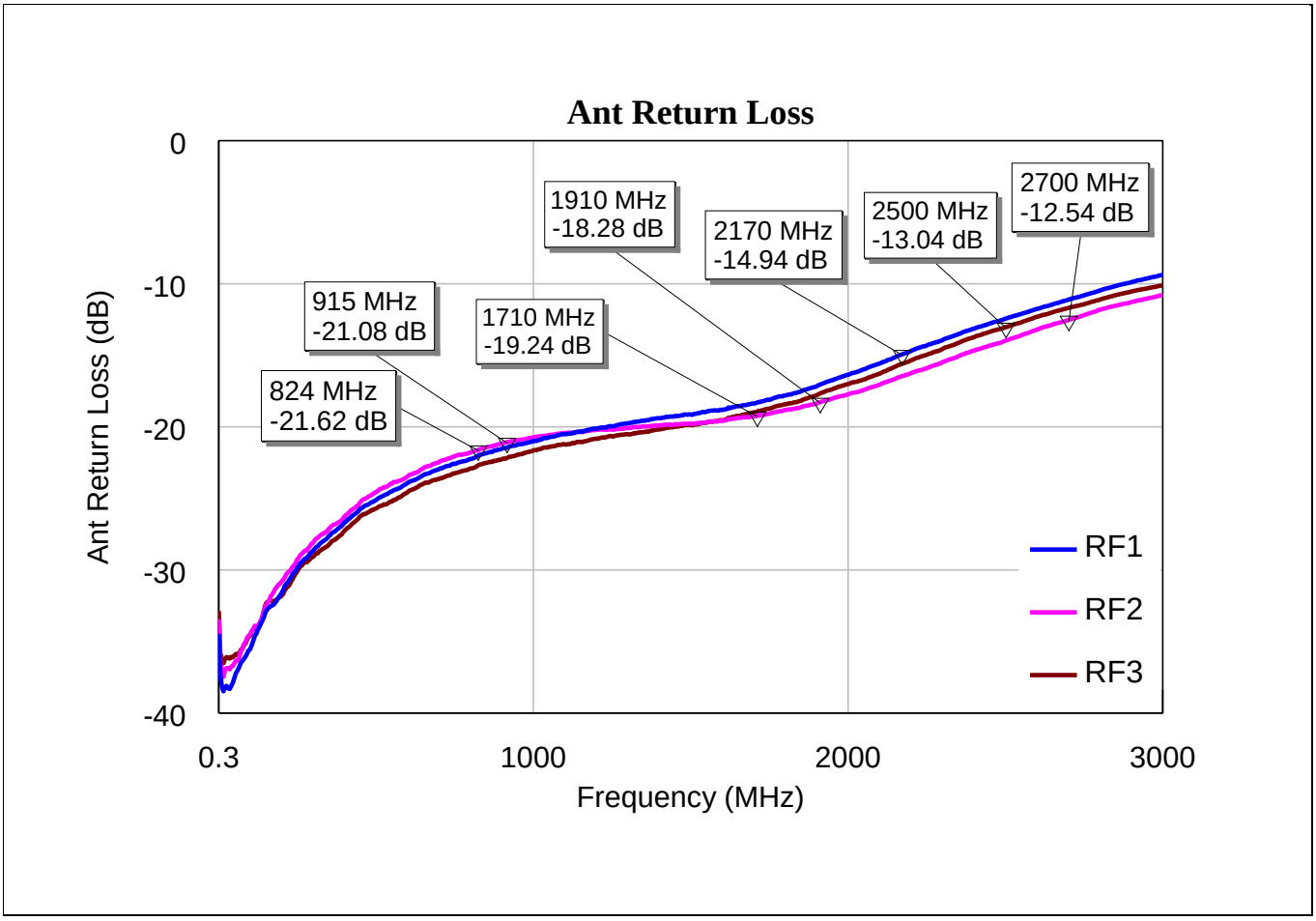


Figure 6 RF matching @ Ant Port in dB

Table 5 Antenna Return Loss in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF1	22.04	21.46	18.33	17.06	14.95	12.44	11.11
RF2	21.62	21.09	19.24	18.28	16.48	13.99	12.54
RF3	22.71	22.20	18.96	17.67	15.61	13.04	11.69

3.4 Port Return Loss

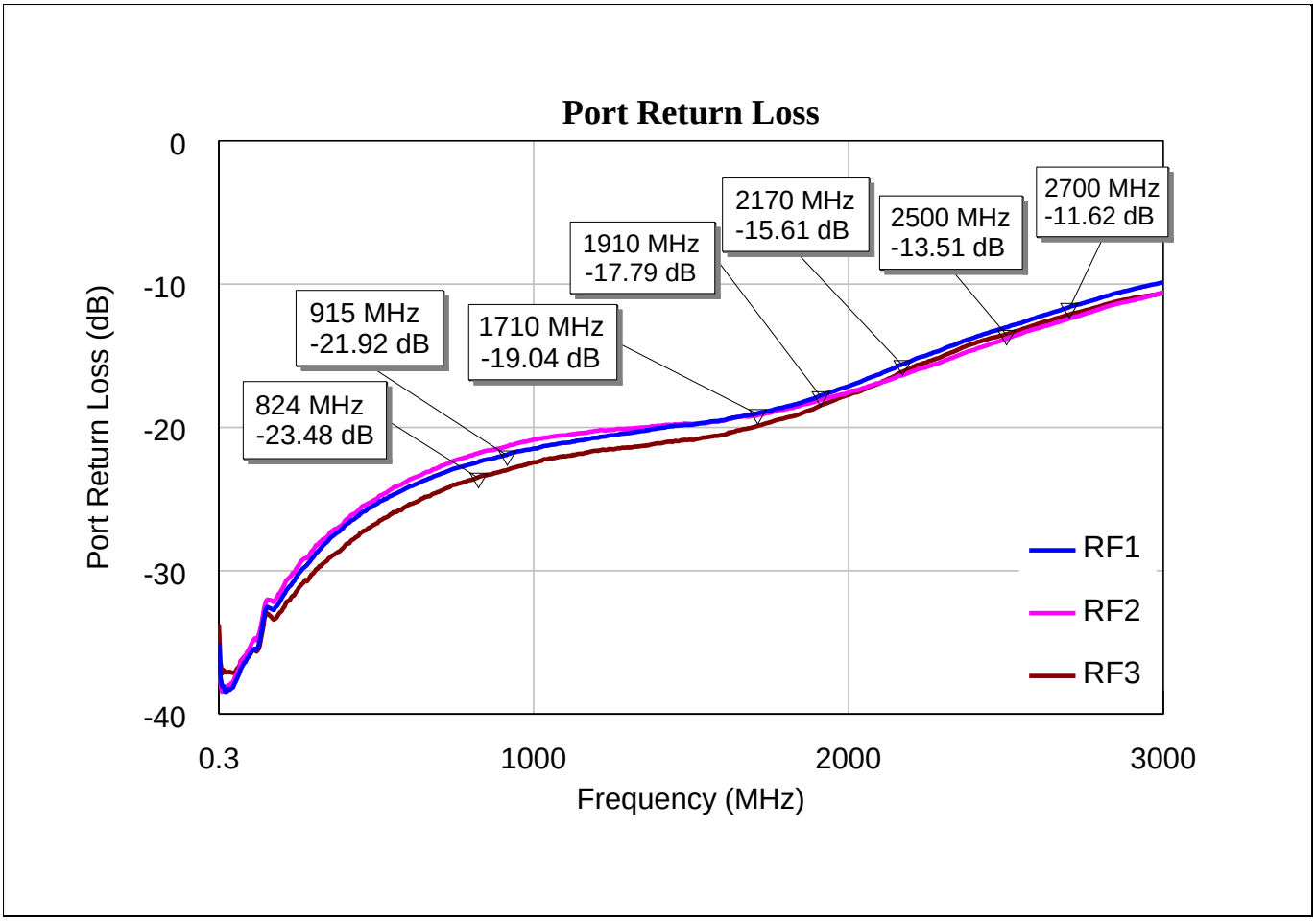


Figure 7 RF matching @ RFx Ports in dB

Table 6 Port Return Loss in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF1	22.42	21.92	19.04	17.79	15.62	13.02	11.62
RF2	21.81	21.34	19.17	18.09	16.37	13.83	12.42
RF3	23.48	22.98	19.91	18.48	16.14	13.51	12.13

3.5 Isolation Antenna to Port

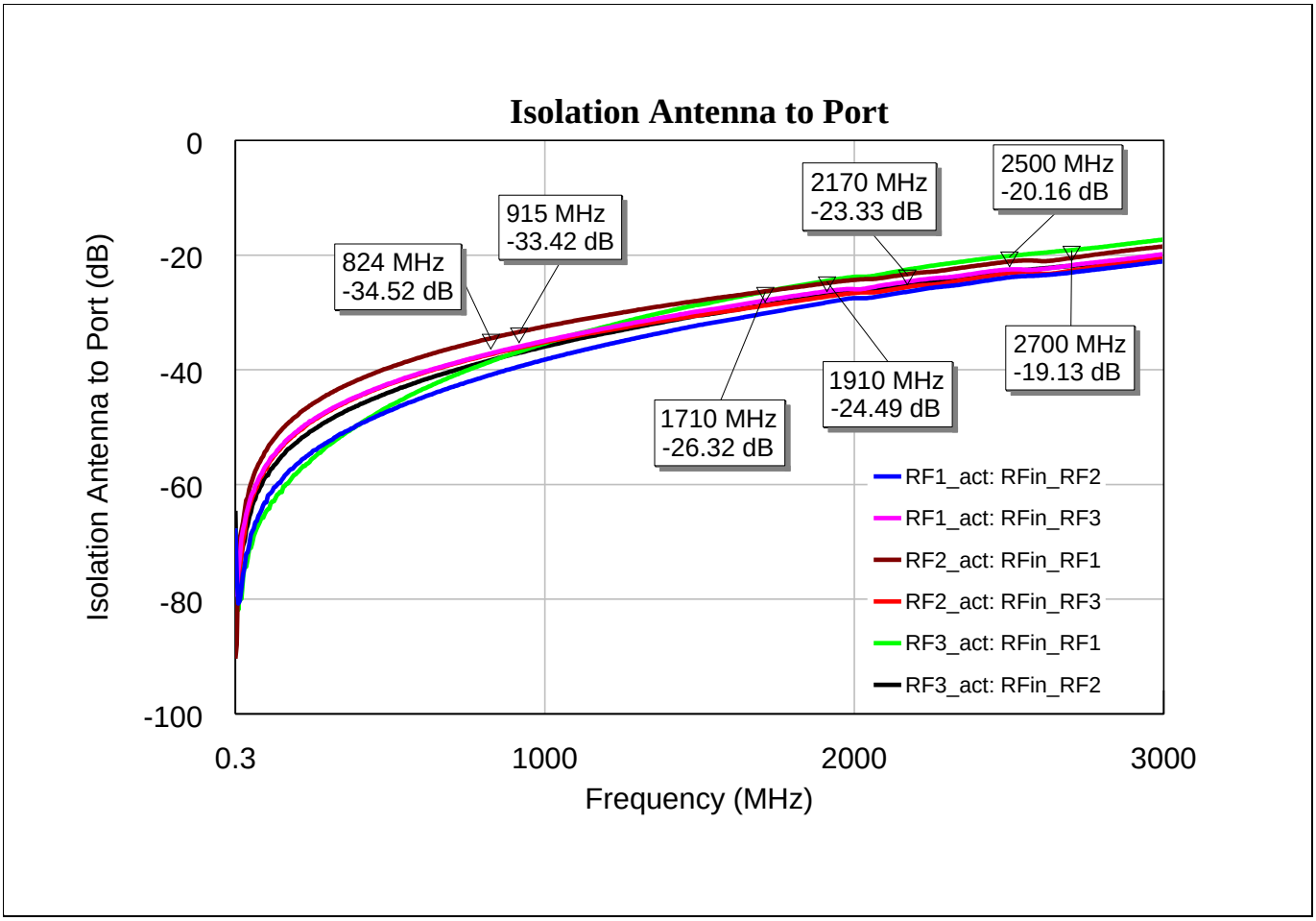


Figure 8 Isolation Antenna to Port in dB

Table 7 Isolation Antenna to Port in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF1_act: RFin_RF2	40.90	39.46	30.17	28.26	26.39	23.88	23.05
RF1_act: RFin_RF3	37.16	35.96	27.92	26.30	24.63	22.51	21.78
RF2_act: RFin_RF1	34.53	33.42	26.33	24.88	23.33	21.13	20.50
RF2_act: RFin_RF3	37.33	36.18	28.81	27.23	25.59	23.13	22.72
RF3_act: RFin_RF1	38.58	36.88	26.38	24.50	22.54	20.16	19.13
RF3_act: RFin_RF2	38.34	37.07	28.68	26.94	25.21	22.87	21.88

3.6 Isolation Port to Port

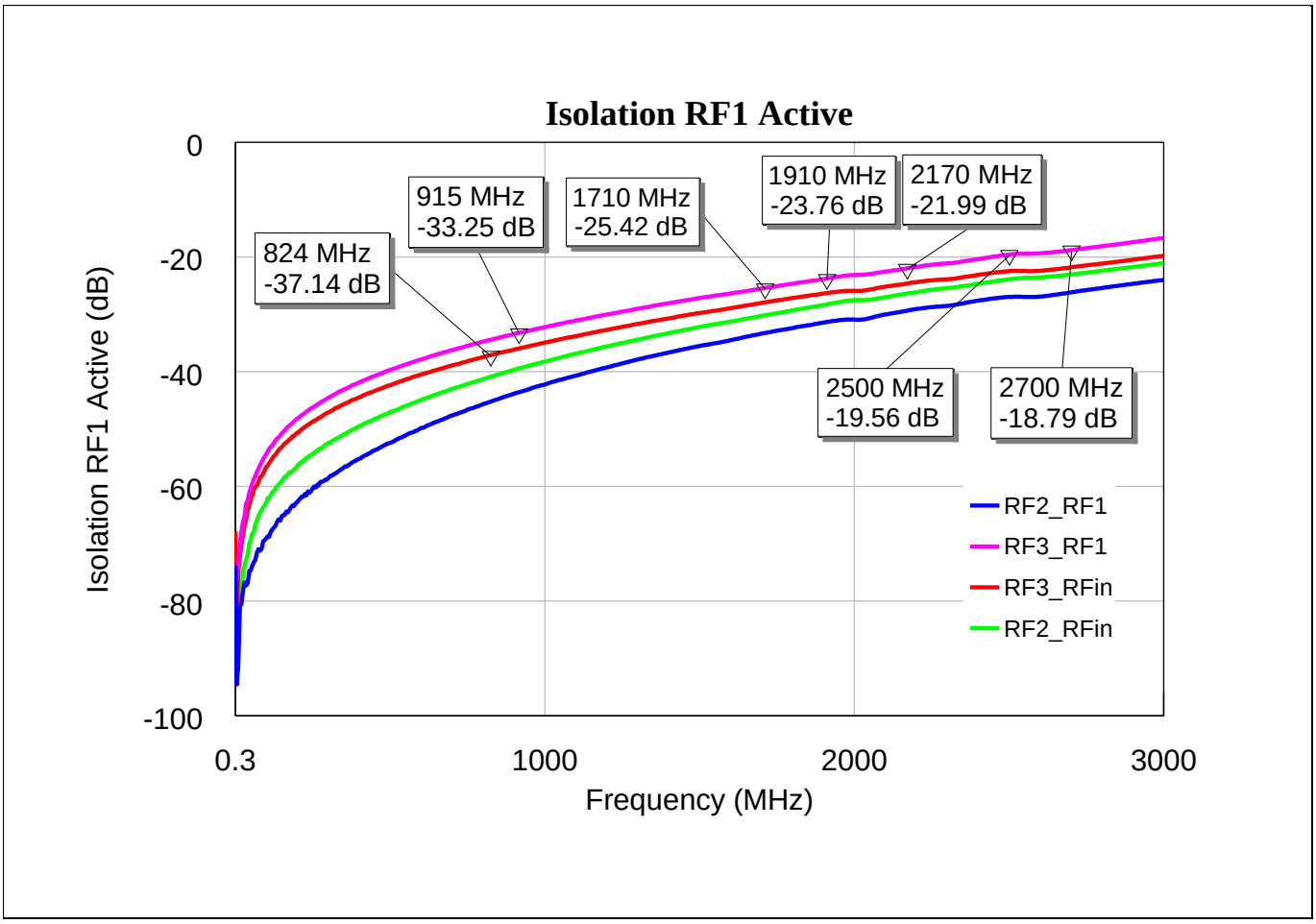


Figure 9 Isolation Port to Port with RF1 active in dB

Table 8 Isolation Port to Port with RF1 active in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF2_RF1	45.25	43.60	33.27	31.36	29.36	26.96	26.17
RF3_RF1	34.45	33.25	25.42	23.76	21.99	19.56	18.79
RF3_RFin	37.14	35.96	27.91	26.30	24.63	22.46	21.79
RF2_RFin	40.89	39.46	30.17	28.27	26.38	23.88	23.04

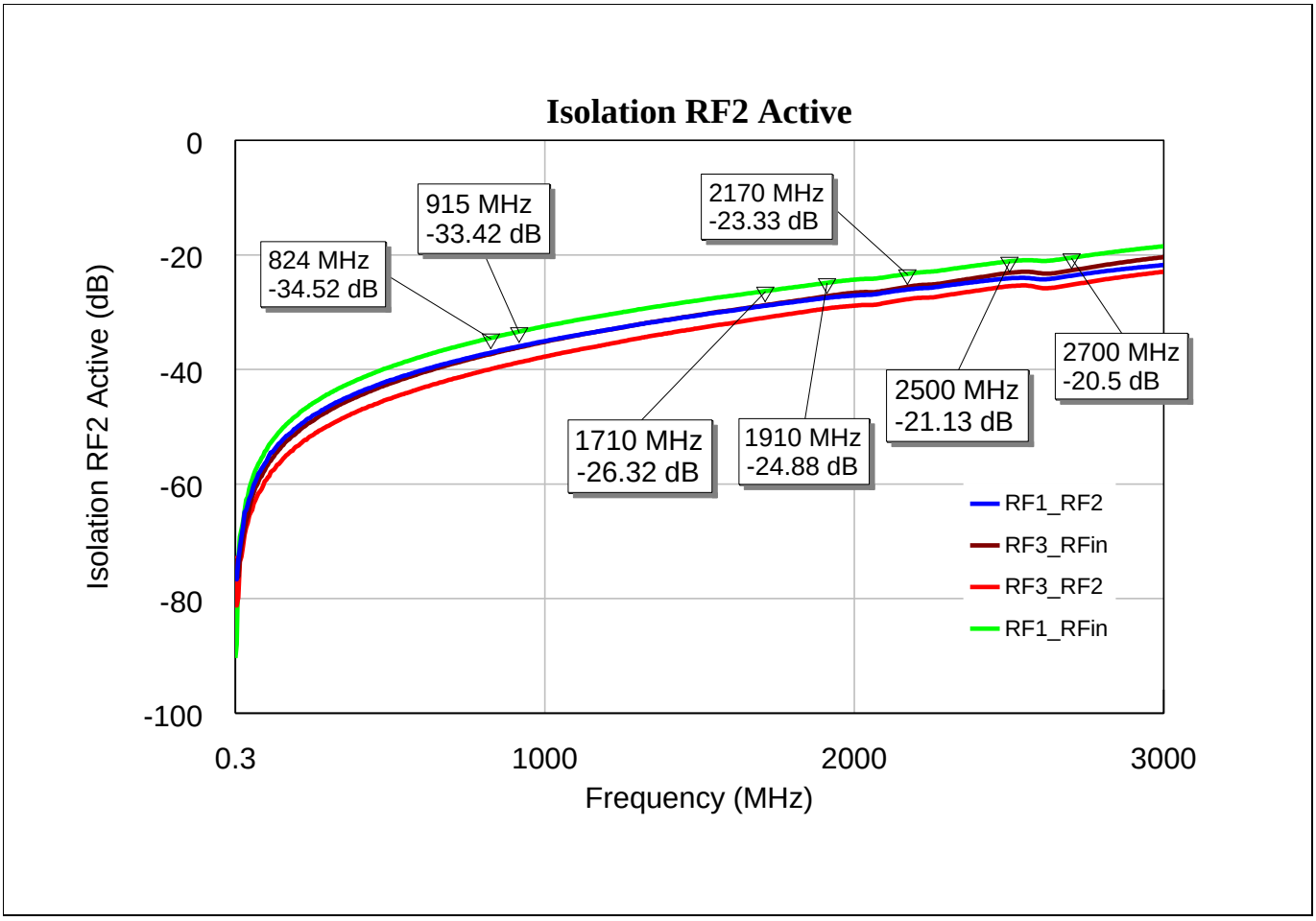


Figure 10 Isolation Port to Port with RF2 active in dB

Table 9 Isolation Port to Port with RF2 active in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF1_RF2	37.07	35.98	28.90	27.51	26.05	24.08	23.65
RF3_RFin	37.33	36.18	28.80	27.22	25.58	23.13	22.72
RF3_RF2	39.96	38.77	30.97	29.36	27.75	25.45	25.23
RF1_RFin	34.53	33.42	26.33	24.88	23.33	21.13	20.50

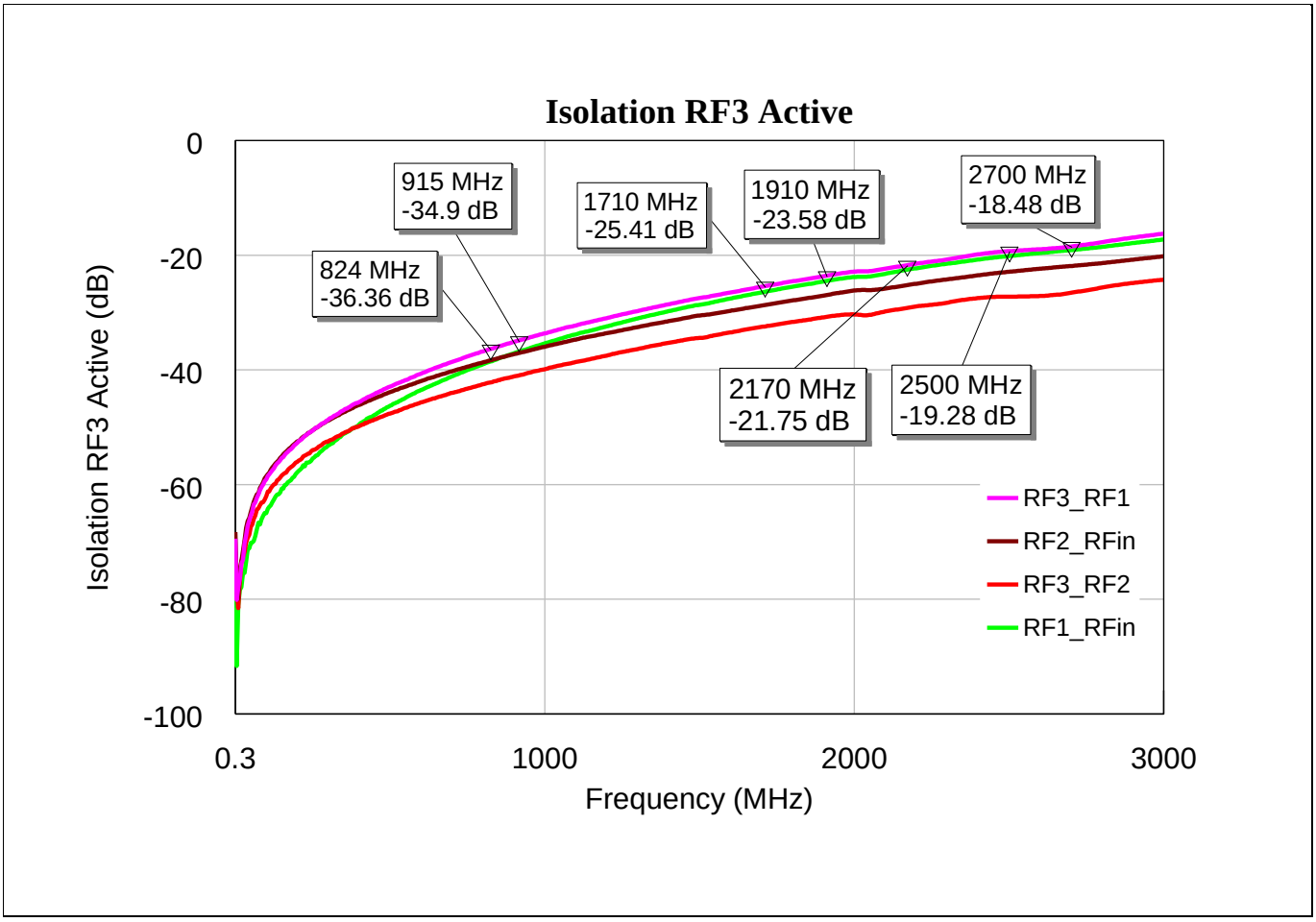


Figure 11 Isolation Port to Port with RF3 active in dB

Table 10 Isolation Port to Port with RF3 active in dB

Frequency (MHz)	824	915	1710	1910	2170	2500	2700
RF3_RF1	36.36	34.90	25.41	23.58	21.75	19.29	18.48
RF2_RFin	38.35	37.08	28.69	26.94	25.21	22.89	21.88
RF3_RF2	42.18	40.98	32.42	30.74	29.20	27.24	26.56
RF1_RFin	38.55	36.85	26.39	24.49	22.54	20.15	19.11

4 Switching time

4.1 Measurement Specifications

Switching On Time: 50% Trigger signal to 90 % RF Signal

Switching Off Time: 50% Trigger signal to 10% RF Signal

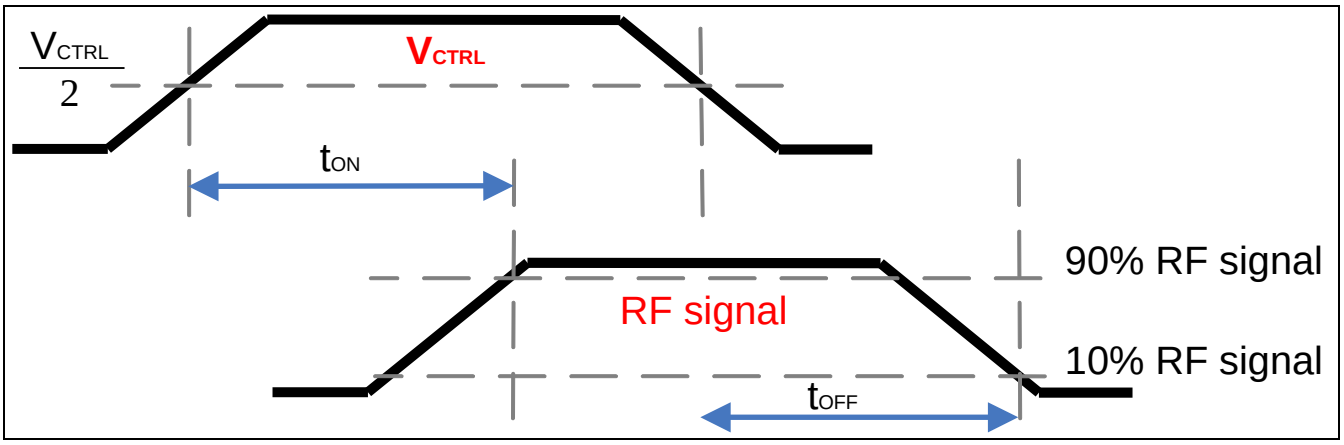


Figure 12 Switching Time

Rise time: 10% to 90% RF Signal

Fall time: 90% to 10% RF Signal

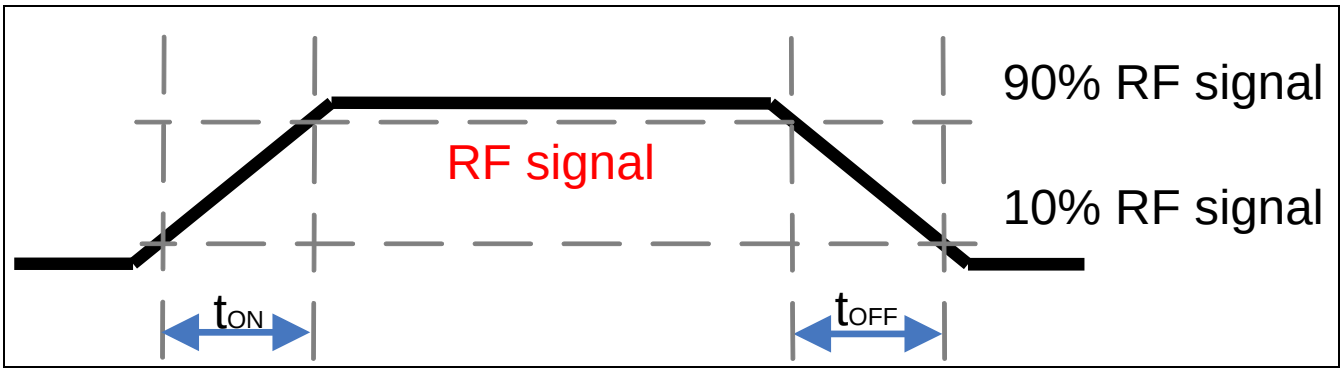


Figure 13 Rise/Fall Time

4.2 Measurement Setup

The setup on below is representing switching time measurement setup. In the Measurement setup the setup is configured for a SPDT switch, where the trigger signal is a one kHz signal with the amplitude of device Vdd/Vctrl. The setup properties (RFin and trigger signal pulse) could be changed for measuring other devices like amplifier.

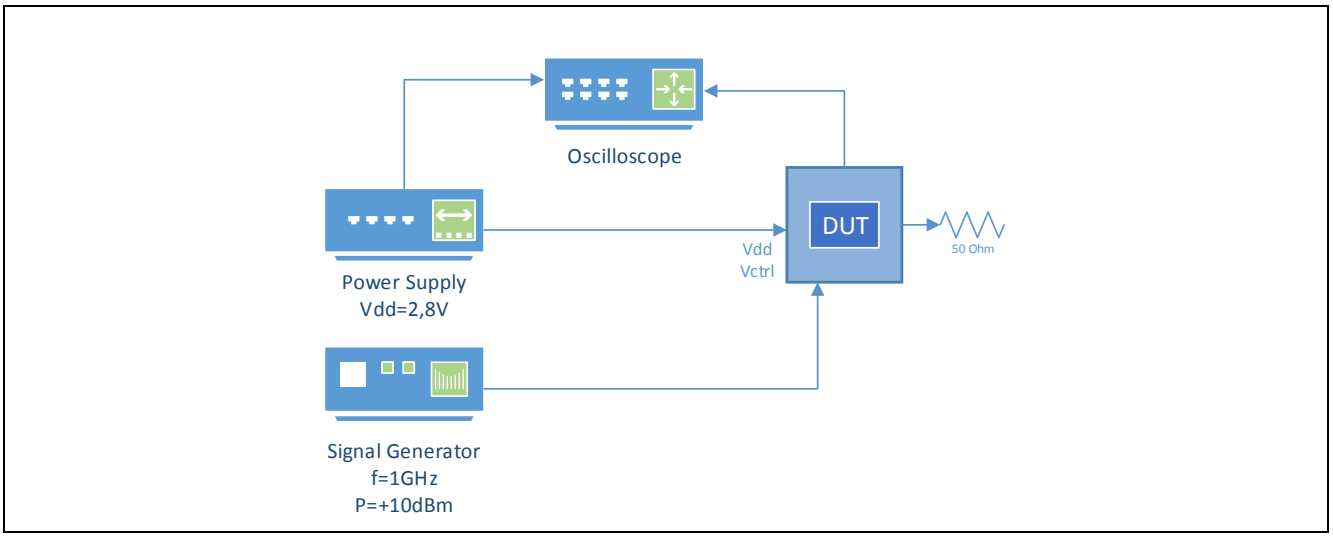


Figure 14 Measurement setup

4.3 Measurement results

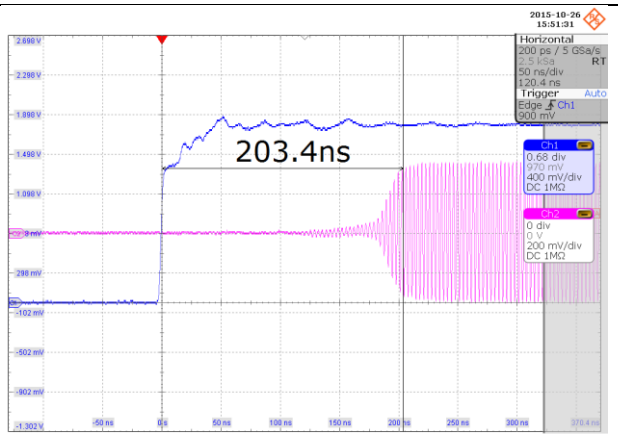
The switching Time measurement setup consist of one pulse generator which generates a sqare wave with 50% duty cycle and an amplitude of 1.8 Volts, an oscilloscope which can detect the 1 GHz signal and the 1 kHz signal and one Signal generator which is set to an output signal of 1GHz with a power level 10 dBm.

If the oscilloscope can not detect the 1 GHz signal of the RF path, due to small bandwith, it is possible tu use a cristal oscillator in front of the oscilloscope (such a device detects any RF signal present at input and commutate that one) that the RF signal can be detected.

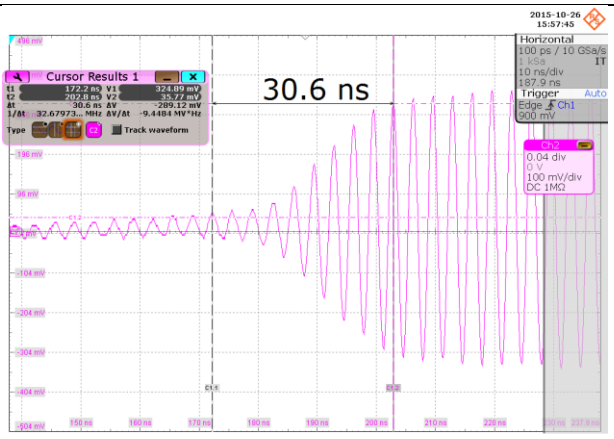
VDD= 2.7V
Vctrl= 0/1.8V Pulsed with 600Hz 50%duty cicle
RFIn= 300MHz @ 0dBm

	Vctrl to RF	RF rise Time
Spec	300ns	150ns
RF1	203.4ns	30.6ns
RF2	238.4ns	23.4ns
RF3	204ns	27ns

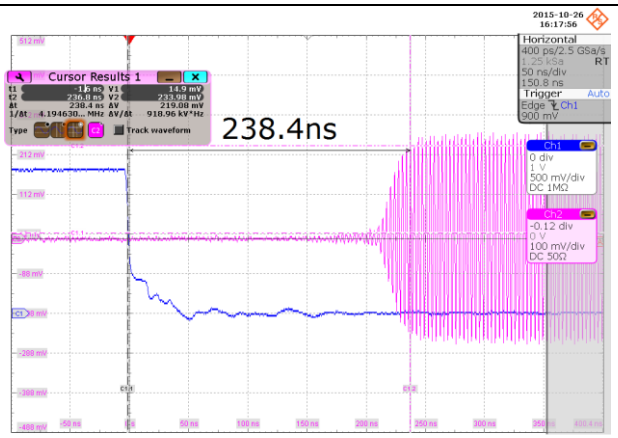
Switching time



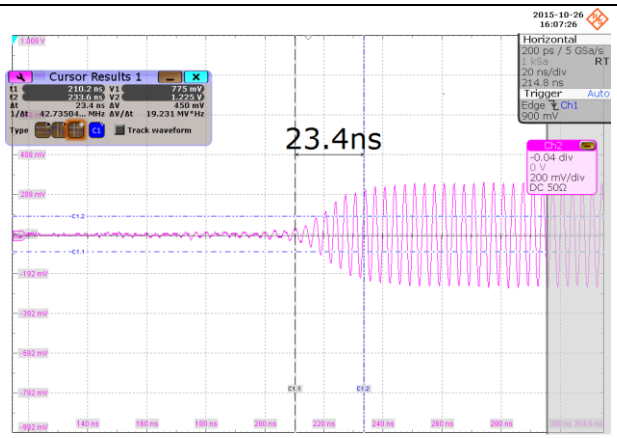
RF1



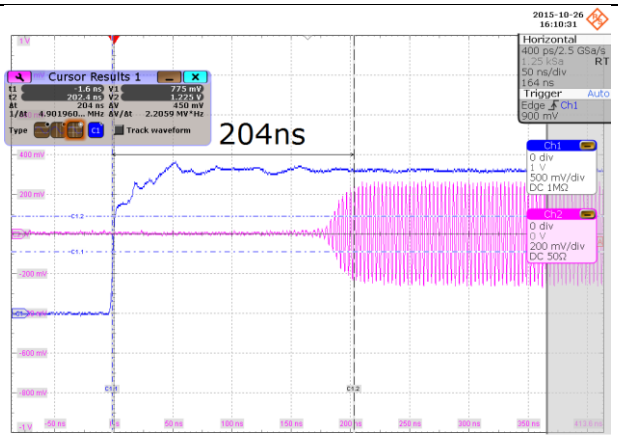
RF1



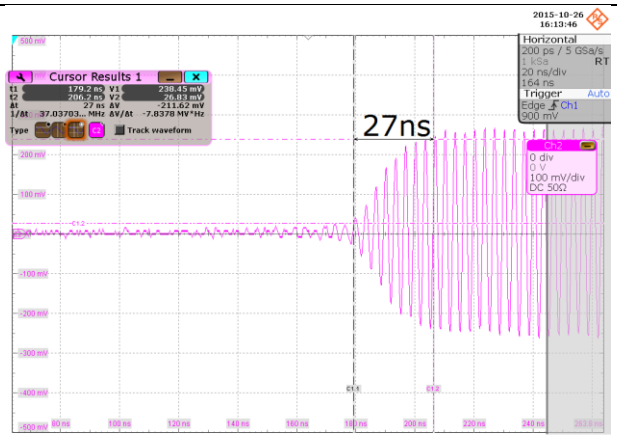
RF2



RF2



RF3



RF3

Switching On Time: 50% Trigger signal to 90 % RF Signal

Rise time: 10% to 90% RF Signal

Figure 15 Screenshots of switching times

5 Intermodulation

Intermodulation distortion is characterized by the appearance in the output of frequencies equal to the sums and differences of integral multiples of the two or more component frequencies present in the input waveform. Defined by the following expressions:

Table 11 IMD Mathematical definitions

Second Order IMD	$f_{IMD2low} = f_{Rx} - f_{Tx}$		$f_{IMD2high} = f_{Rx} + f_{Tx}$
Third Order IMD	$f_{IMD3l} = 2f_{Tx} - f_{Rx}$	$f_{IMD3m} = 2f_{Rx} + f_{Tx}$	$f_{IMD3h} = f_{Rx} + 2f_{Tx}$

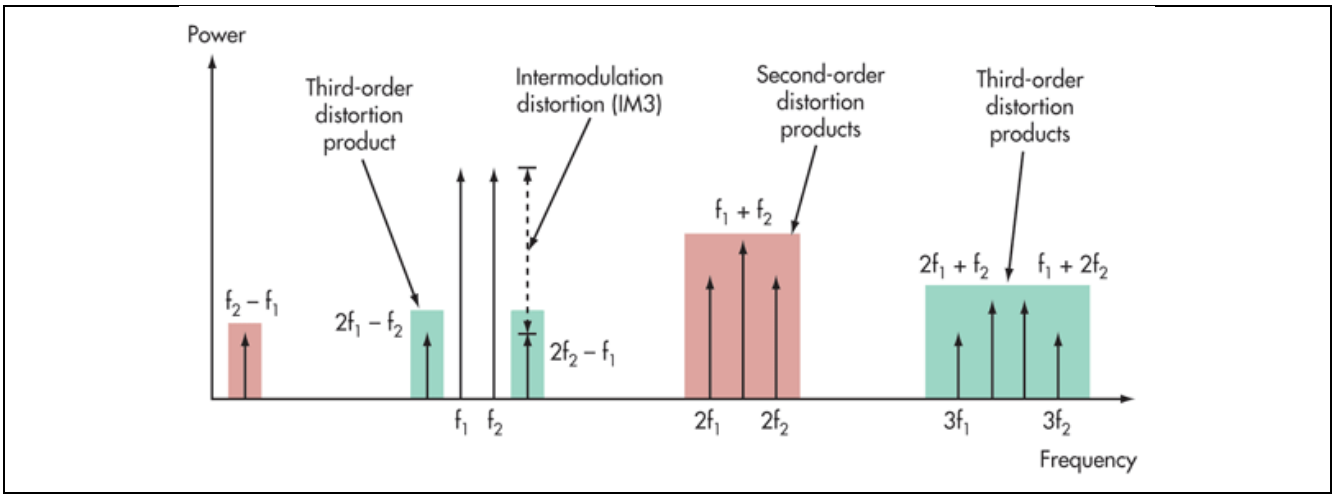


Figure 16 Representation of IMD products

5.1 Test conditions

Developing the same mathematical expressions we can see that external signals matching IMD frequencies can interfere overf_{Rx}. All IMD measurements are made at room temperature with a continuous wave (CW) RF carrier signal for Tx and blocker (jammer) signal.

Table 12 IMD Mathematical definitions extended

Second Order IMD	$f_{IMD2low} = f_{Rx} - f_{Tx} \rightarrow f_{Rx} = f_{IMD2low} + f_{Tx}$		$f_{IMD2high} = f_{Rx} + f_{Tx} \rightarrow f_{Rx} = f_{IMD2high} - f_{Tx}$
Third Order IMD	$f_{IMD3l} = 2f_{Tx} - f_{Rx} \rightarrow f_{Rx} = 2f_{Tx} - f_{IMD3l}$	$f_{IMD3m} = 2f_{Rx} + f_{Tx} \rightarrow f_{Rx} = (f_{Tx} - f_{IMD3m})/2$	$f_{IMD3h} = f_{Rx} + 2f_{Tx} \rightarrow f_{Rx} = f_{IMD3h} - 2f_{Tx}$

One of the possible intermodulation scenarios is shown in Block diagram of RF Switch intermodulation. The transmission (Tx) signal from the main antenna is coupled into the diversity antenna with high power. This signal (21 dBm or 10 dBm depending the case) and a received Jammer signal (-15 dBm) are entering the switch. Thanks to the specified application for the BGS13S2N9 in between the filters and the Transceiver, the Tx signal from the main antenna loose until arriving at the switch input mostly 5 to 10 or more dB, depending of the filter and PCB structure of the RF frontend. The IMD products are measured with a Tx of 21dBm or 10dBm, which is corresponding to the IMD spec of a main antenna diversity switch like Infineon BGS13S2N9. Therefore, the measured IMD products will be extremely better in the specified application circuit within the filters and transceiver as showed in the measurement results below.

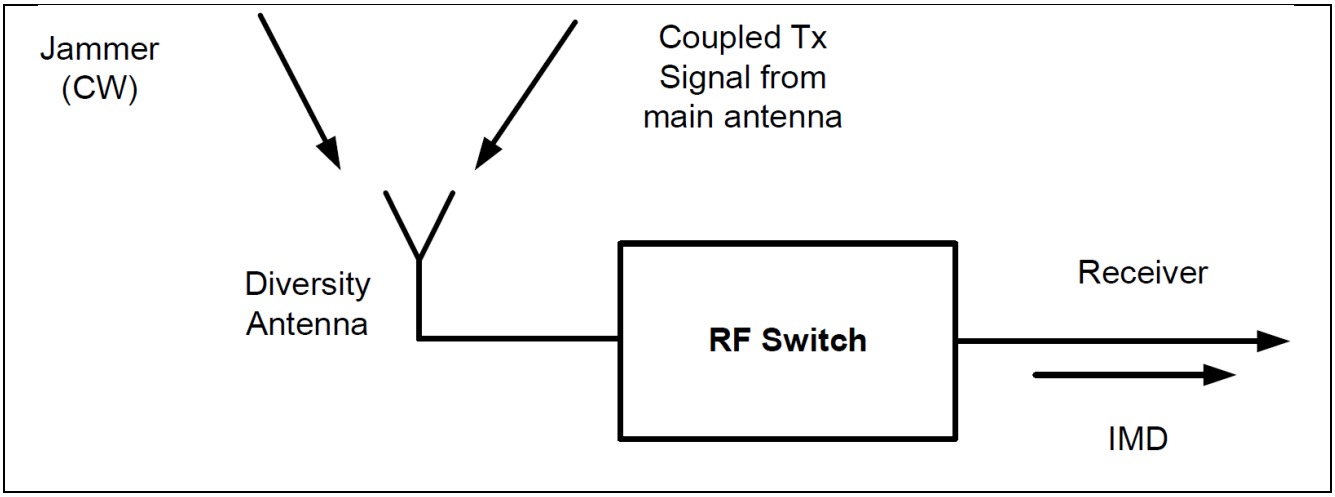


Figure 17 Block diagram of RF Switch intermodulation

Special combinations of TX and Jammer signal are producing intermodulation products 2nd and 3rd order, which fall in the RX band and disturb the wanted RX signal.

5.2 Measurement Setup

The test setup for the IMD measurements has to provide a very high isolation between RX and TX signals. As an example the test setup and the results for the high band are shown (Block diagram of RF Switch intermodulation and Table 11).
For the RX / TX separation a professional duplexer with 80 dB isolation is used.

For each distortion scenario there is a min and a max value given. This variation is caused by a phase shifter connected between switch and duplexer. In the test setup the phase shifter represents a no ideal matching of the switch to a 50 Ohm load.

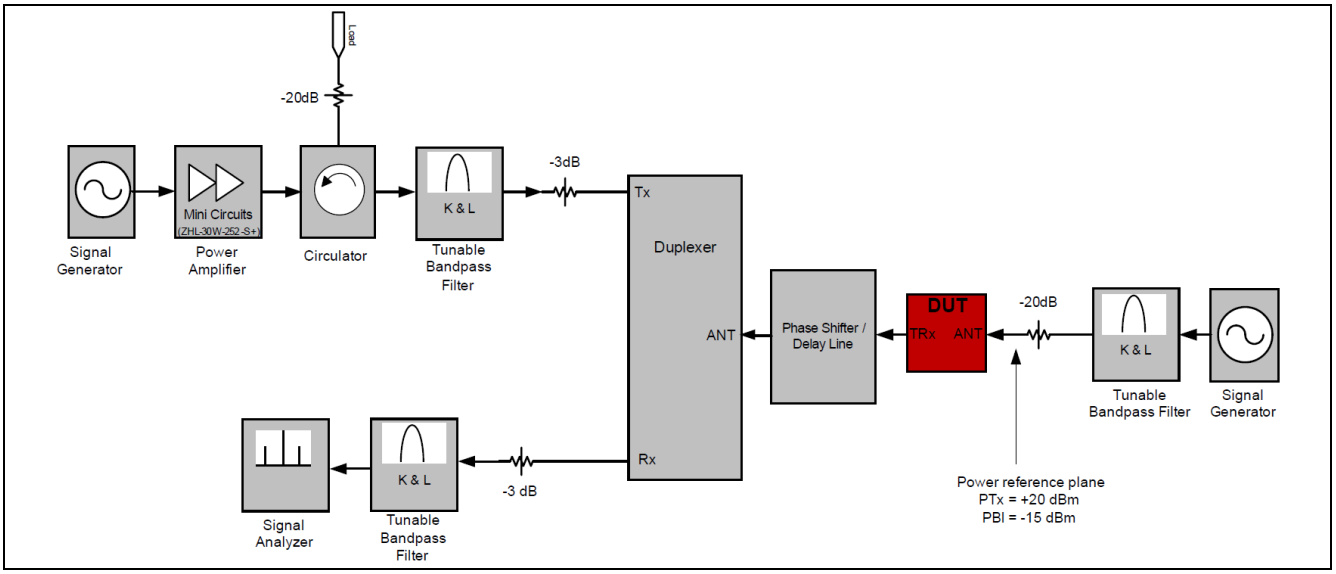


Figure 18 Block diagram of RF Switch intermodulation

5.3 Measurement Results

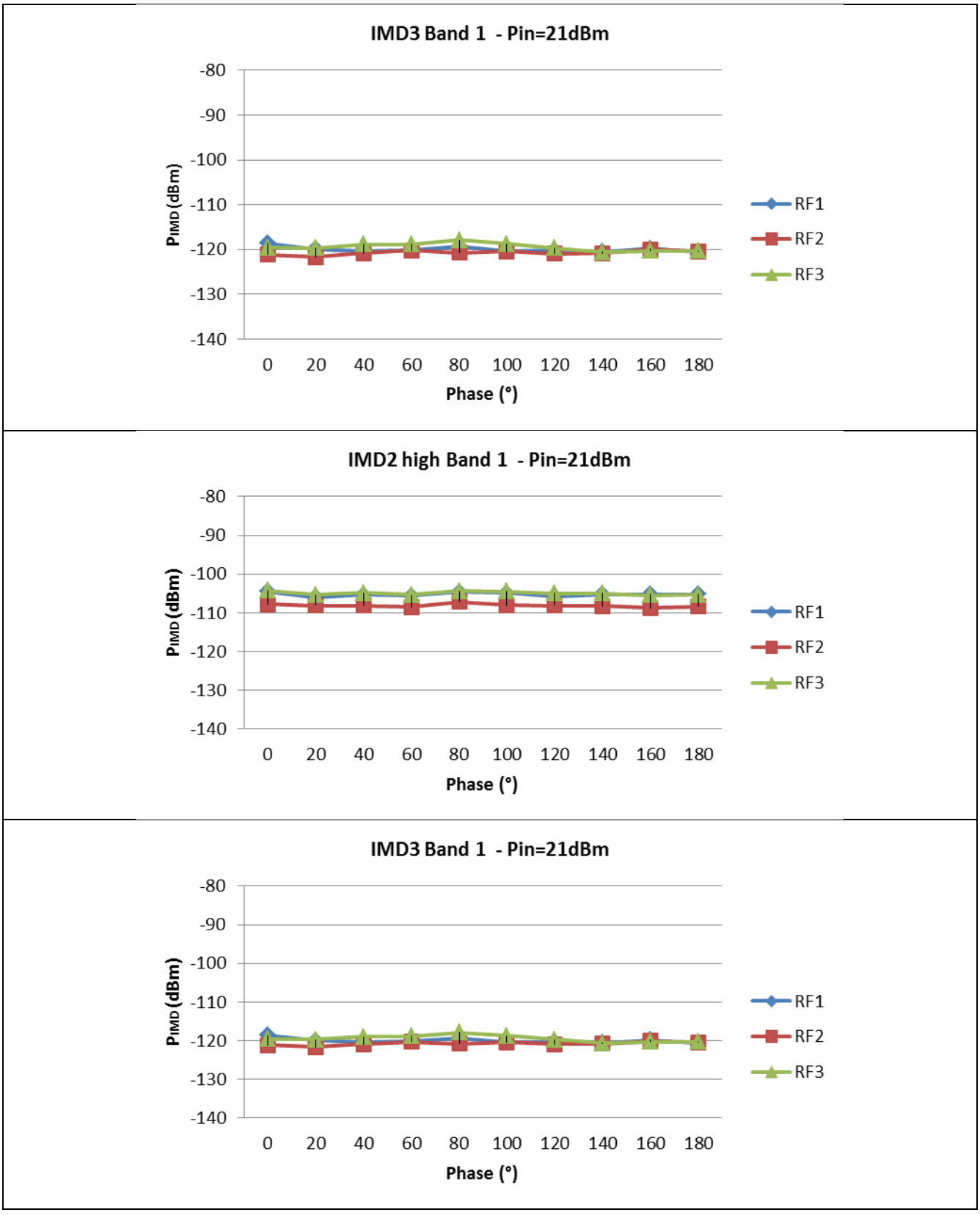


Figure 19 IMD products of Band 1 LTE and Pin=21dBm

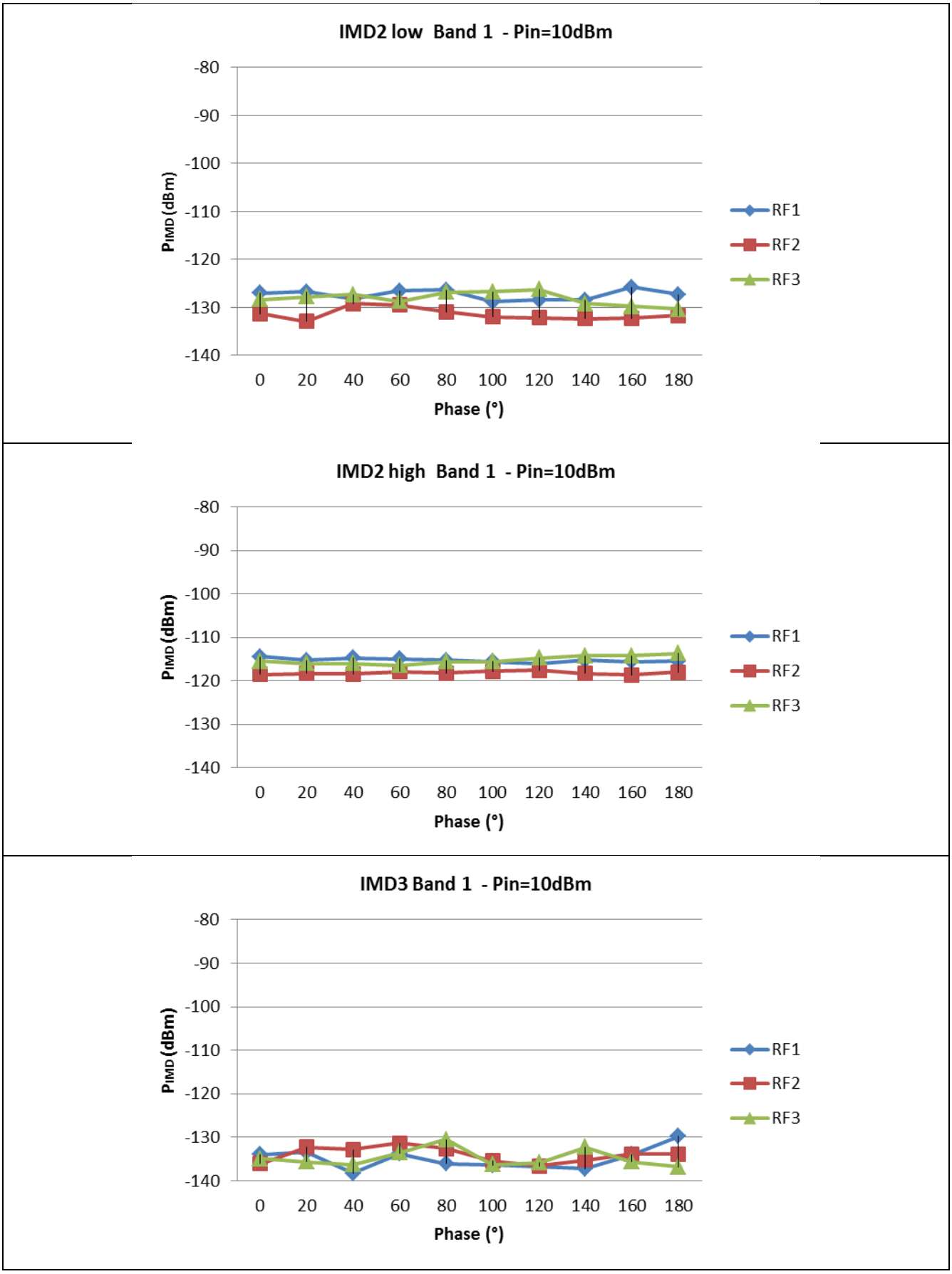


Figure 20 IMD products of Band 1 LTE and Pin=10dBm

Table 13 IMD products of Band 1 LTE

IMD Band I P_{Tx}=21dBm	RF (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=190MHz)	-118.79	-117.21	-120.58	-117.95	-120.03	-118.64
IMD2High ($f_{blocker}$=4090MHz)	-105.98	-104.48	-108.78	-107.15	-105.42	-104.22
IMD3 ($f_{blocker}$=1760MHz)	-120.58	-118.6	-121.66	-120.01	-120.6	-117.88

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=190MHz)	-128.81	-125.77	-132.89	-129.22	-130.34	-126.27
IMD2High ($f_{blocker}$=4090MHz)	-116.06	-114.41	-118.66	-117.53	-116.4	-113.68
IMD3 ($f_{blocker}$=1760MHz)	-138.28	-129.76	-136.56	-131.38	-136.82	-130.55

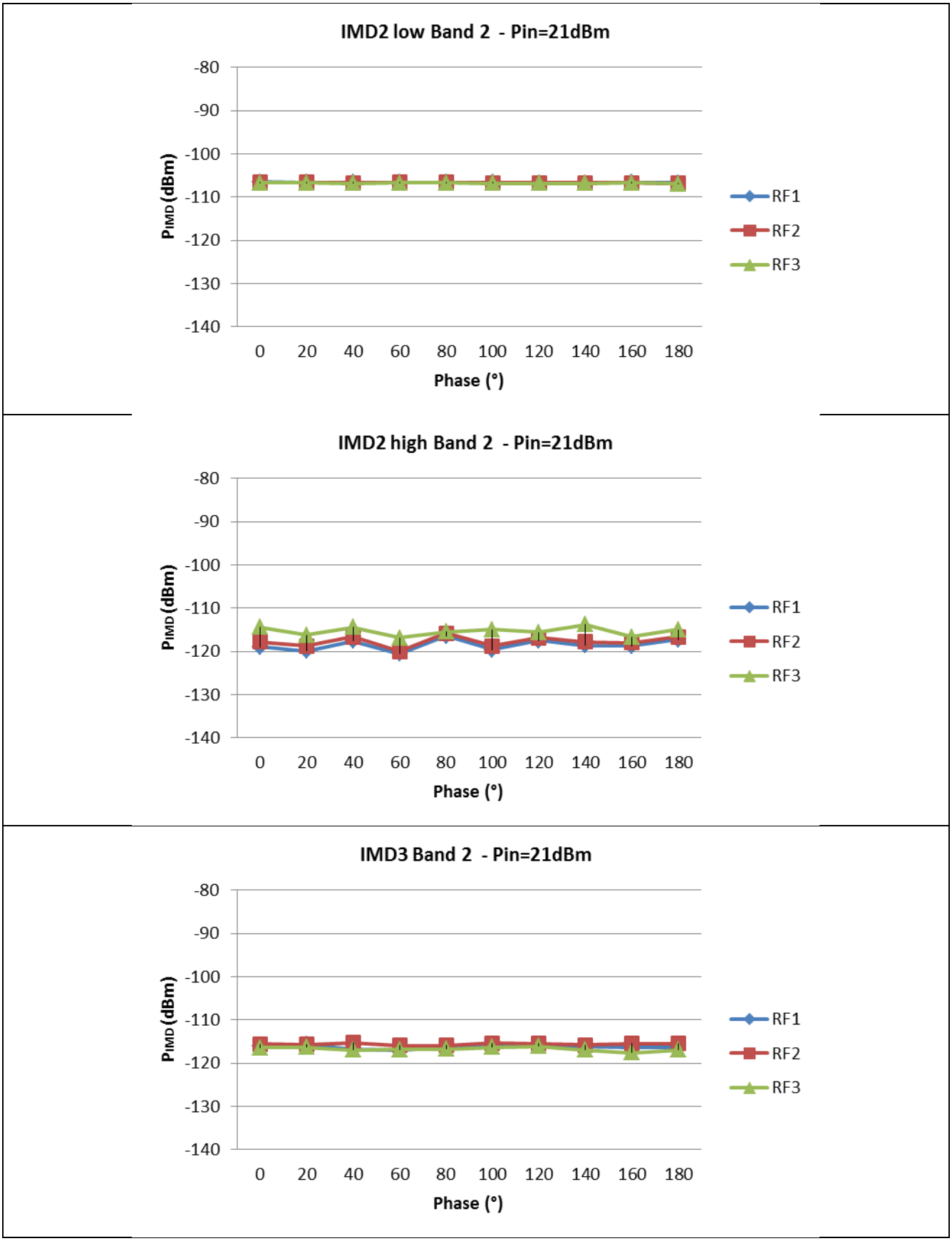


Figure 21 IMD products of Band 2 LTE and Pin=21dBm

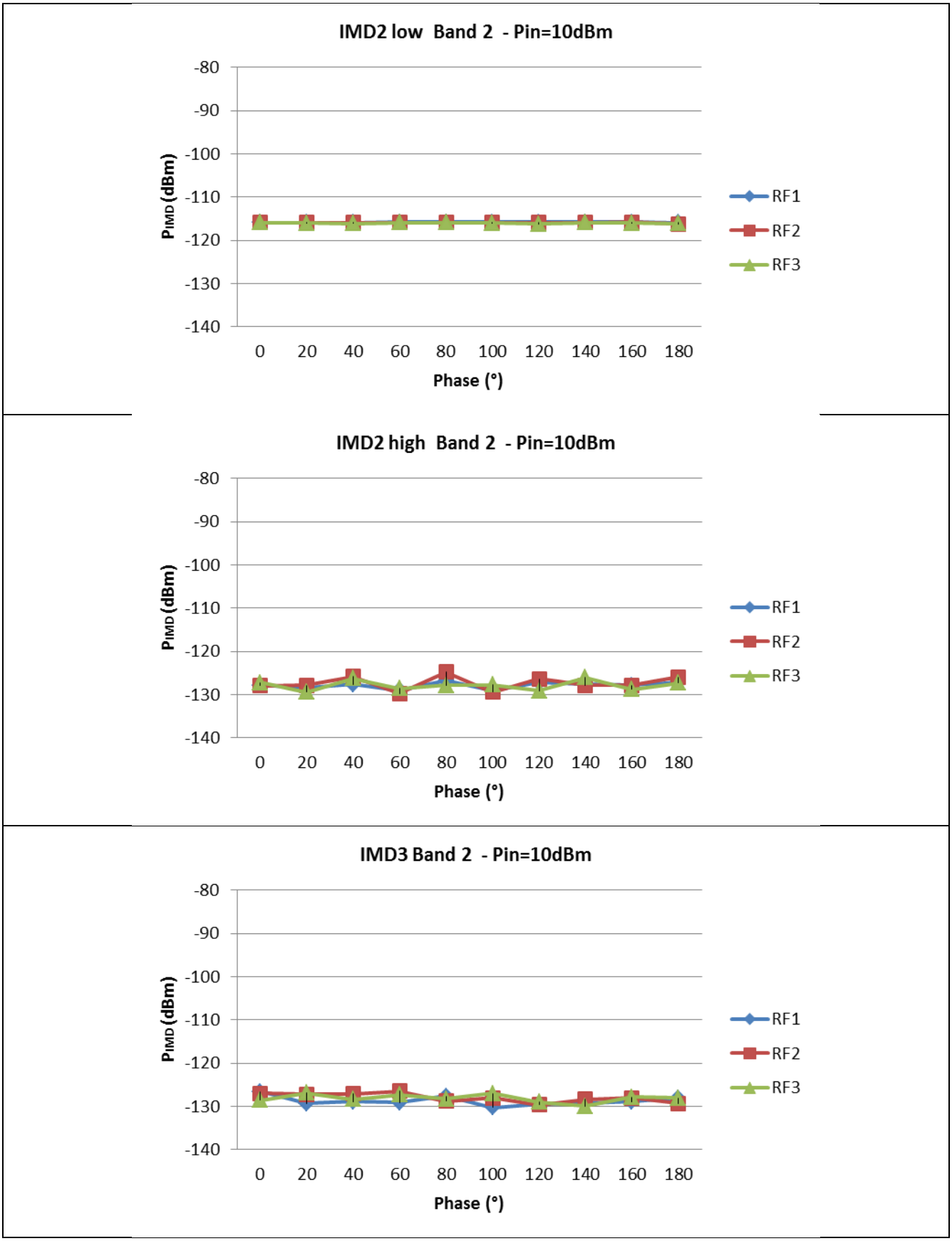


Figure 22 IMD products of Band 2 LTE and Pin=10dBm

Intermodulation

Table 14 IMD products of Band 2 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=80MHz)	-106.73	-106.56	-106.79	-106.62	-106.89	-106.73
IMD2High ($f_{blocker}$=3840MHz)	-120.62	-116.42	-120	-115.84	-116.87	-113.79
IMD3 ($f_{blocker}$=1800MHz)	-116.95	-115.75	-115.91	-115.32	-117.56	-116.14

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=80MHz)	-115.96	-115.77	-116.19	-115.78	-116.2	-115.9
IMD2High ($f_{blocker}$=3840MHz)	-129.06	-126.81	-129.76	-124.82	-129.45	-126.06
IMD3 ($f_{blocker}$=1800MHz)	-130.35	-126.63	-129.64	-126.47	-129.93	-126.93

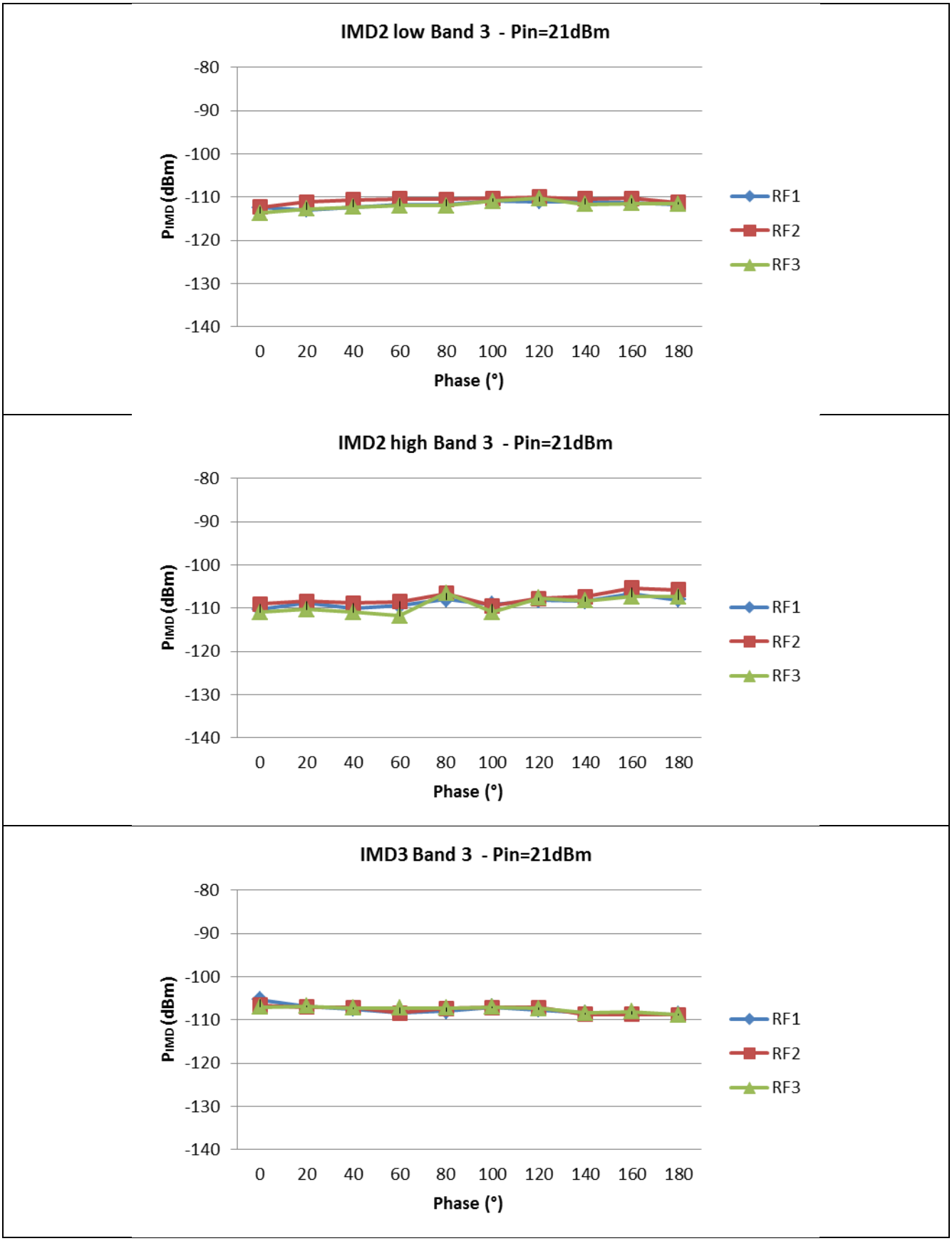


Figure 23 IMD products of Band 3 LTE and Pin=21dBm

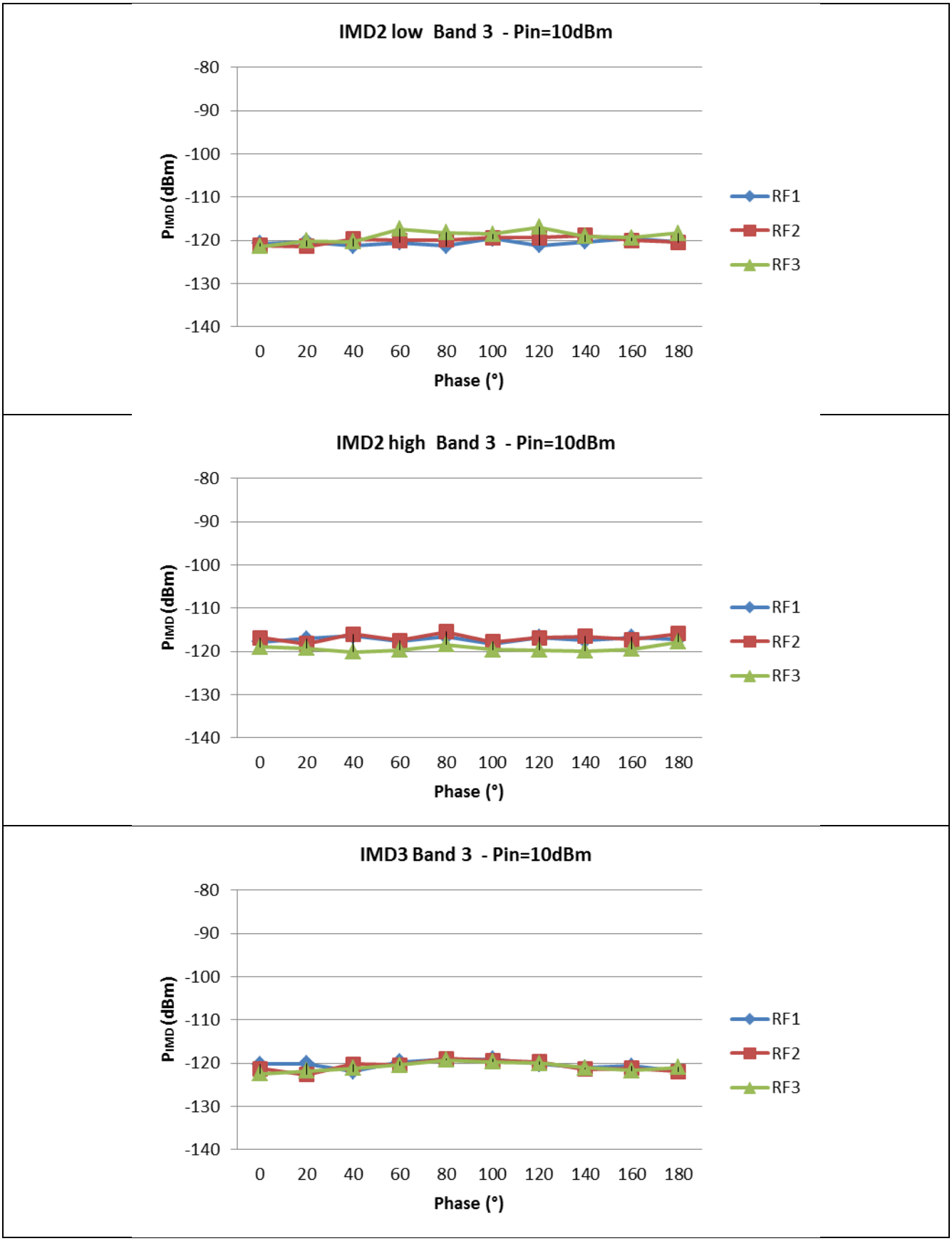


Figure 24 IMD products of Band 3 LTE and Pin=10dBm

Intermodulation

Table 15 IMD products of Band 3 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=400MHz)	-112.54	-110.51	-112.28	-110	-113.65	-110.37
IMD2High ($f_{blocker}$=3856MHz)	-110.37	-106.61	-109.42	-105.37	-111.8	-106.54
IMD3 ($f_{blocker}$=1332.5MHz)	-108.7	-105.34	-108.81	-106.62	-108.82	-106.83

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=400MHz)	-121.34	-119.62	-121.43	-118.93	-121.37	-116.94
IMD2High ($f_{blocker}$=3856MHz)	-118.26	-116.43	-118.29	-115.55	-120.12	-117.85
IMD3 ($f_{blocker}$=1332.5MHz)	-121.95	-119.45	-122.70	-118.95	-122.45	-119.26

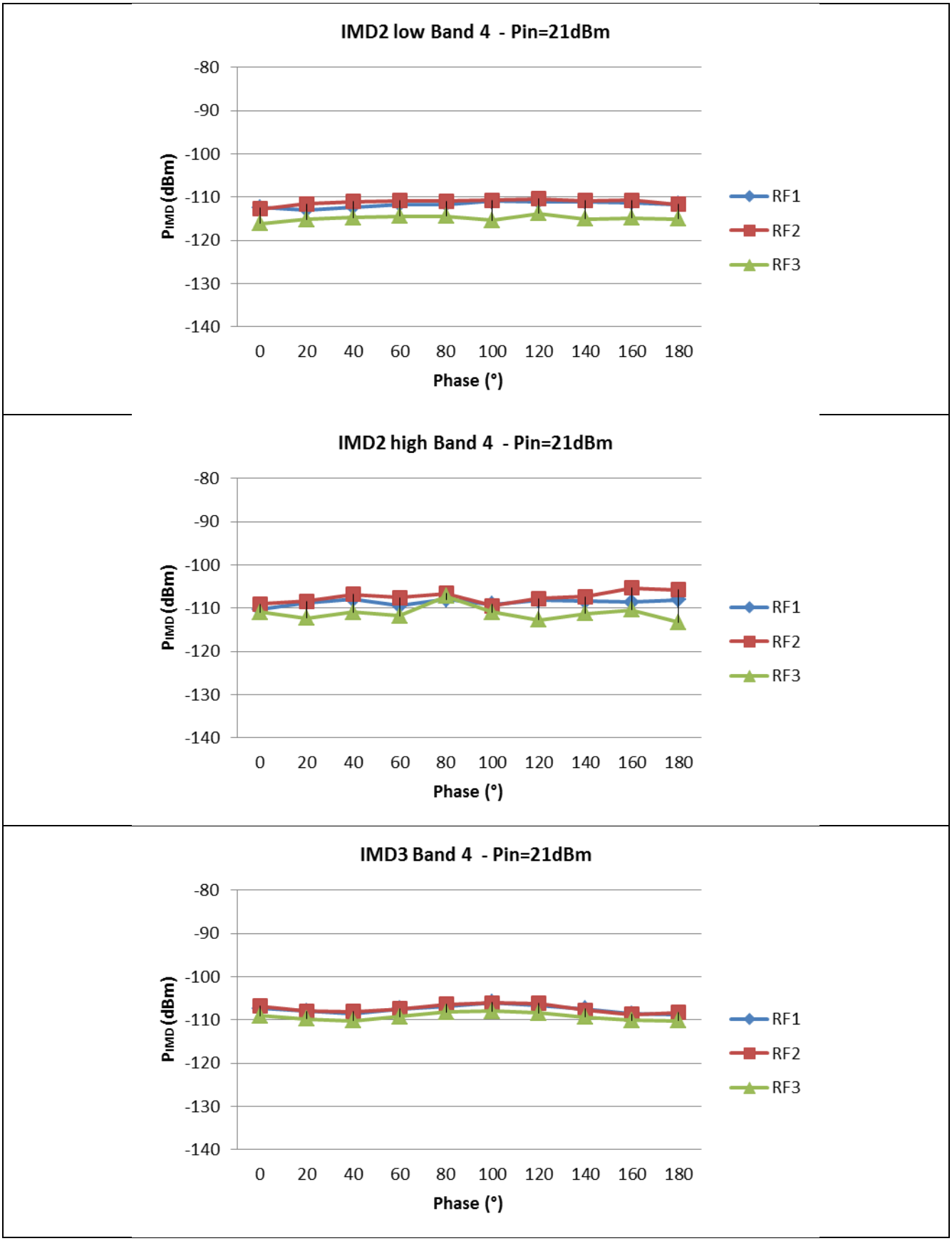


Figure 25 IMD products of Band 4 LTE and Pin=21dBm

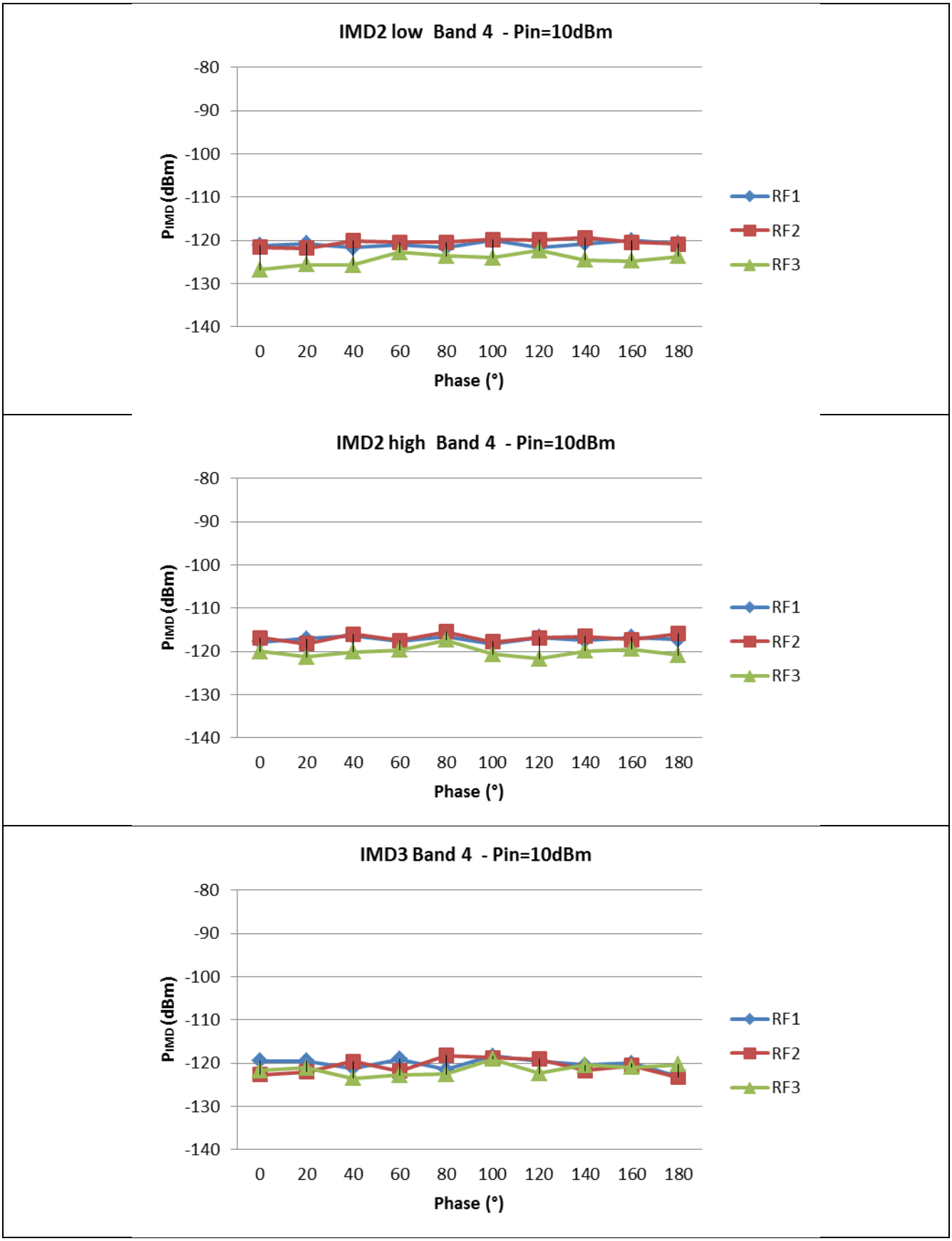


Figure 26 IMD products of Band 4 LTE and Pin=10dBm

Table 16 IMD products of Band 4 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=400MHz)	-112.97	-110.94	-112.71	-110.43	-116.08	-113.8
IMD2High ($f_{blocker}$=3856MHz)	-110.37	-107.95	-109.42	-105.37	-113.31	-107.22
IMD3 ($f_{blocker}$=1332.5MHz)	-108.7	-106.03	-108.78	-106.14	-110.22	-108.04

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=400MHz)	-121.77	-120.05	-121.86	-119.36	-126.8	-122.37
IMD2High ($f_{blocker}$=3856MHz)	-118.26	-116.43	-118.29	-115.55	-121.7	-117.43
IMD3 ($f_{blocker}$=1332.5MHz)	-123.22	-118.37	-123.27	-118.28	-123.52	-119.09

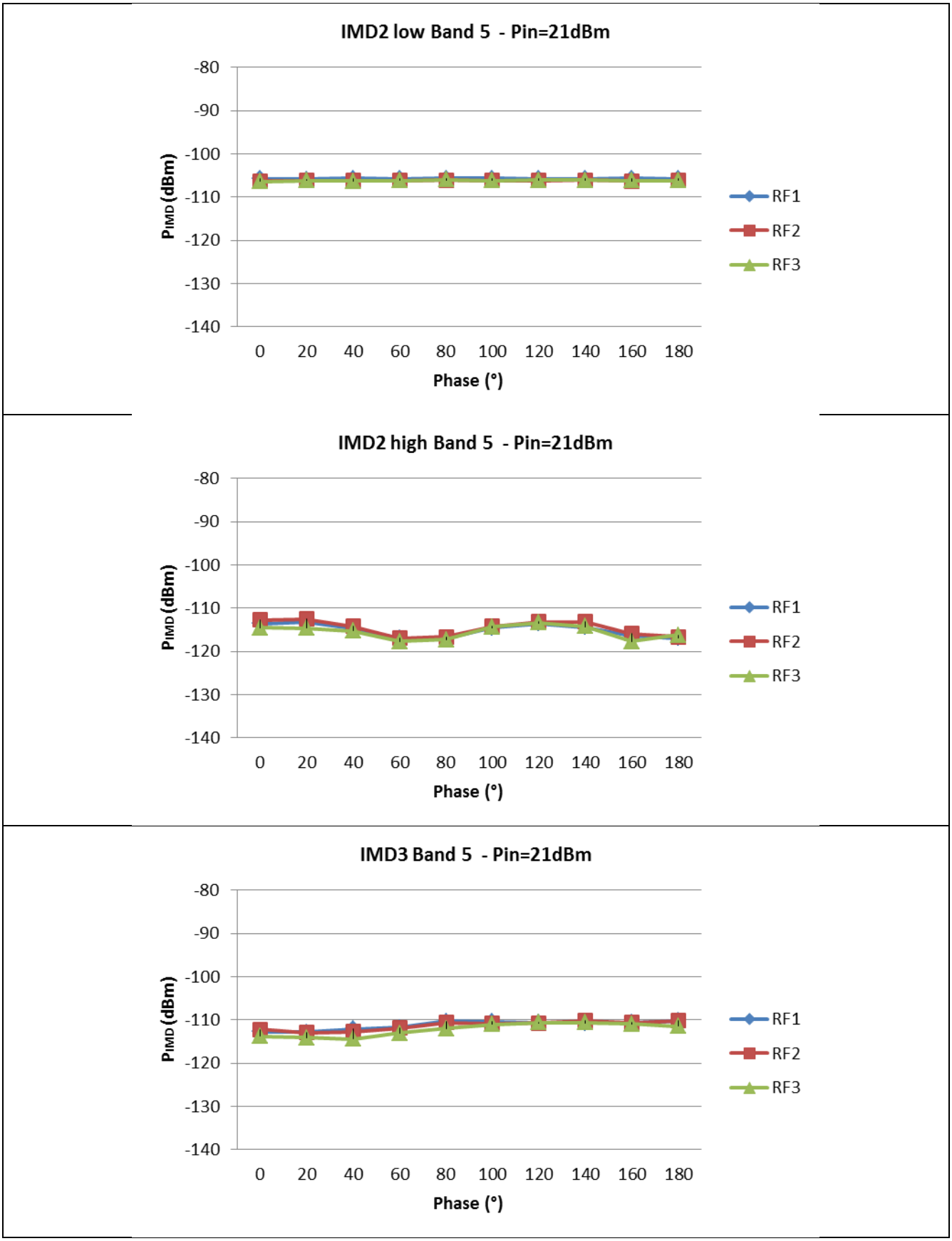


Figure 29 IMD products of Band 5 LTE and Pin=21dBm

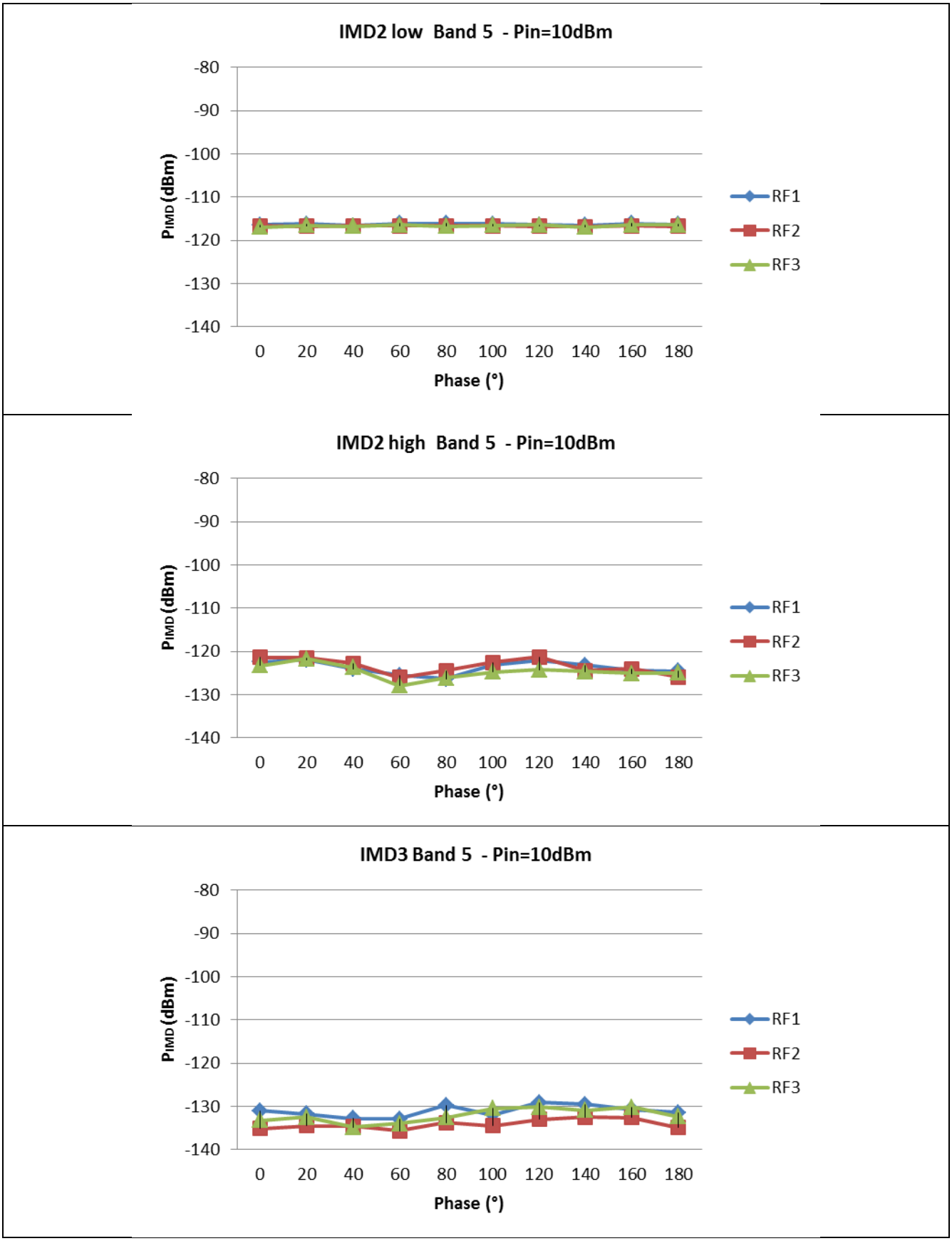


Figure 30 IMD products of Band 5 LTE and Pin=10dBm

Intermodulation

Table 17 IMD products of Band 5 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=45MHz)	-105.87	-105.63	-106.31	-106.1	-106.38	-106.03
IMD2High ($f_{blocker}$=1718MHz)	-117	-113.22	-116.94	-112.57	-117.69	-113.34
IMD3 ($f_{blocker}$=791.5MHz)	-112.82	-110.22	-112.96	-110.17	-114.42	-110.6

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=45MHz)	-116.65	-116.15	-116.84	-116.65	-117.01	-116.43
IMD2High ($f_{blocker}$=1718MHz)	-126.41	-121.99	-126.02	-121.27	-128.01	-121.77
IMD3 ($f_{blocker}$=791.5MHz)	-132.9	-129.15	-135.68	-132.56	-134.84	-130.15

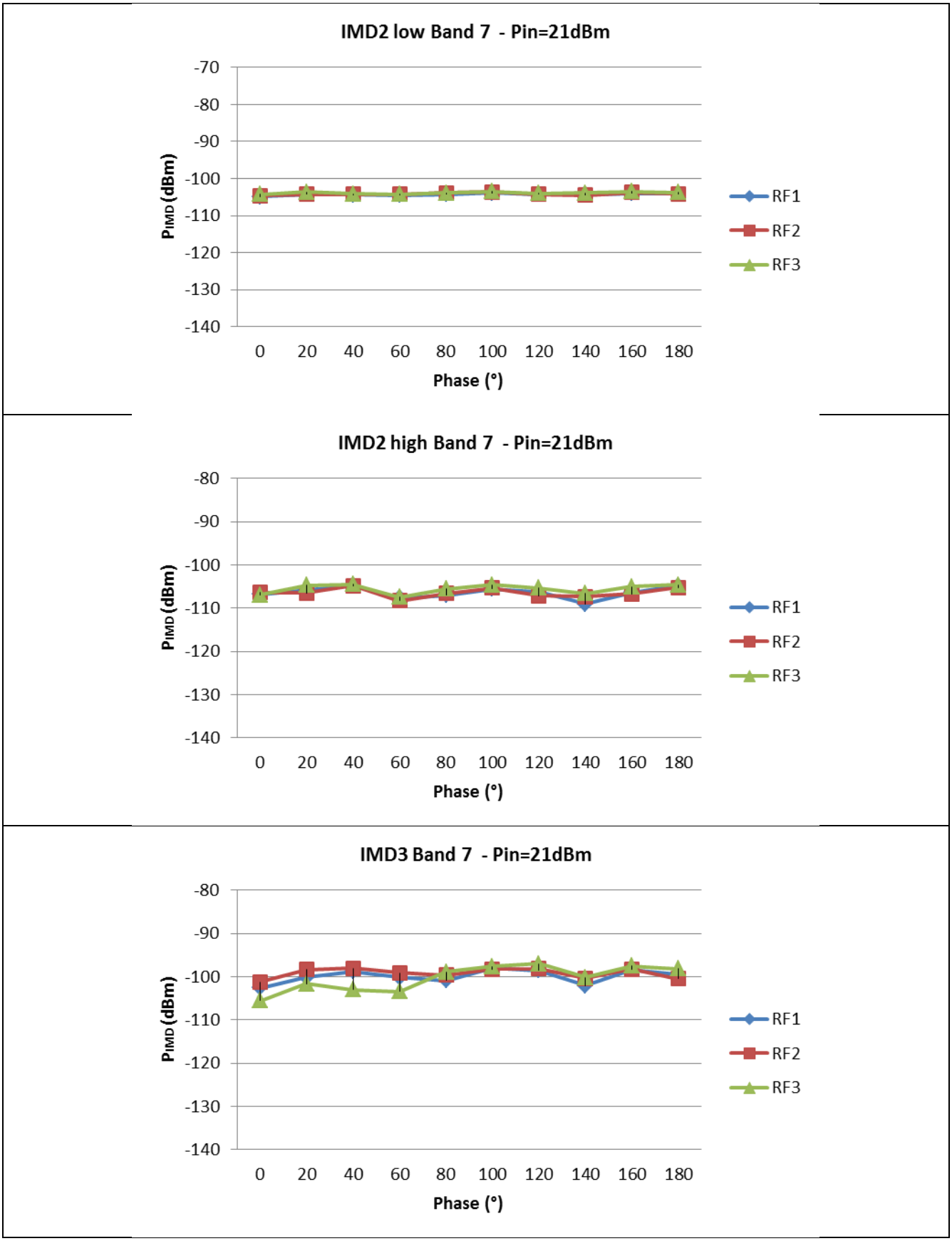


Figure 32 IMD products of Band 7 LTE and Pin=21dBm

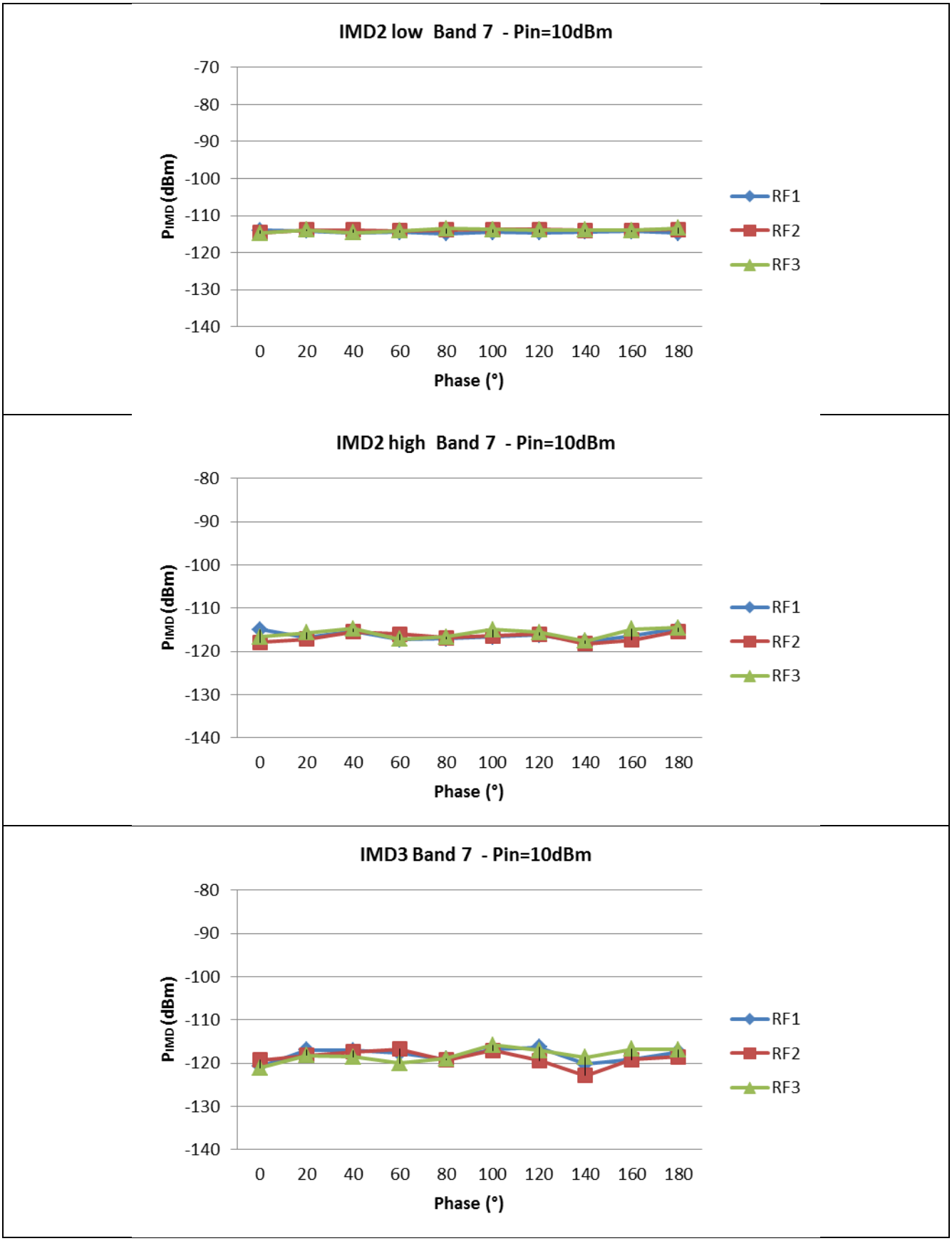


Figure 33 IMD products of Band 7 LTE and Pin=10dBm

Table 18 IMD products of Band 7 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=120MHz)	-104.92	-103.94	-104.63	-103.65	-104.29	-103.48
IMD2High ($f_{blocker}$=5190MHz)	-109.01	-104.75	-108.36	-104.83	-107.46	-104.46
IMD3 ($f_{blocker}$=2415MHz)	-102.59	-98.05	-101.24	-98.02	-105.61	-97.04

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=120MHz)	-114.82	-114.04	-114.59	-113.76	-114.7	-113.42
IMD2High ($f_{blocker}$=5190MHz)	-117.78	-114.72	-118.25	-115.41	-117.62	-114.56
IMD3 ($f_{blocker}$=2415MHz)	-120.79	-116.38	-122.85	-116.72	-121.05	-115.83

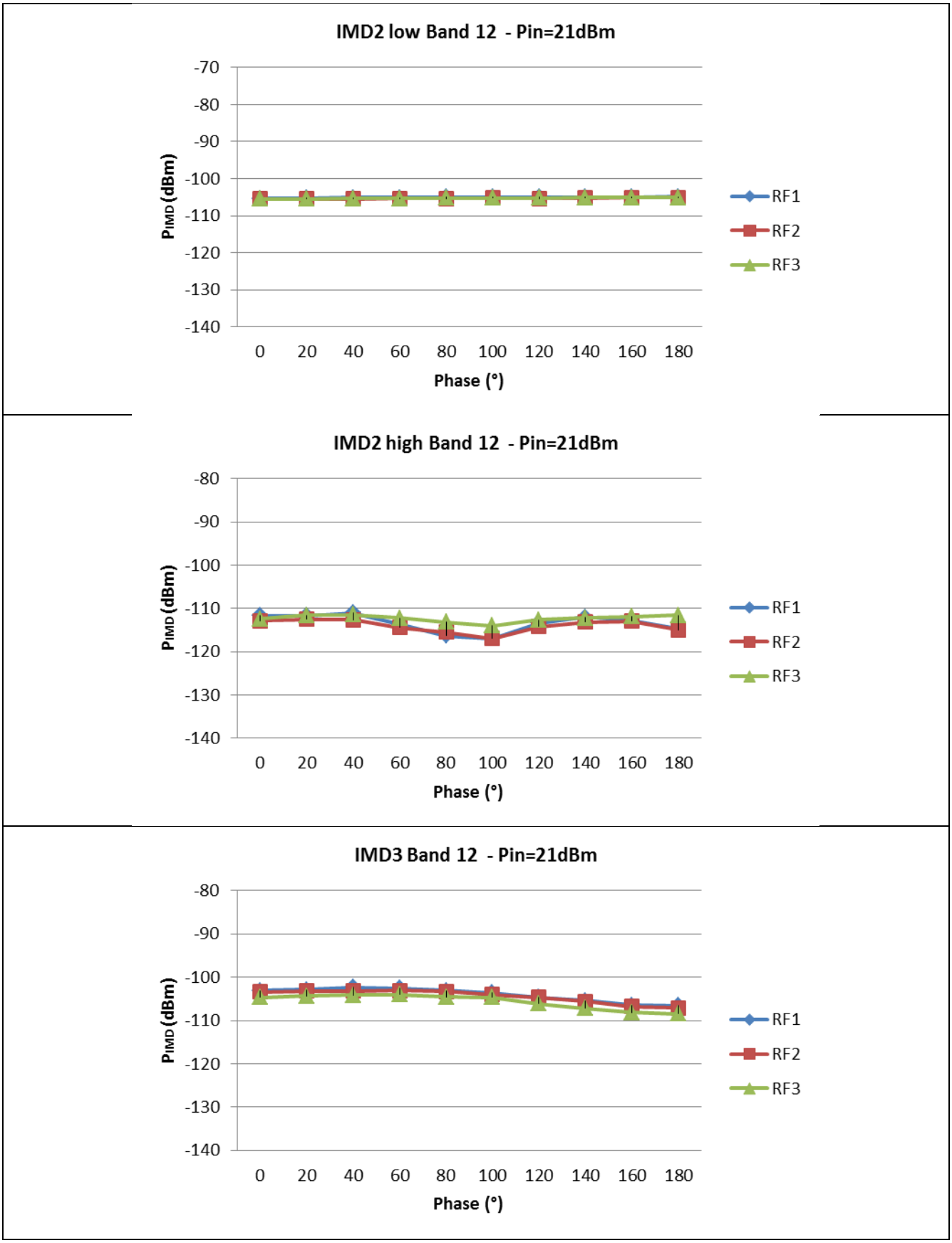


Figure 35 IMD products of Band 12 LTE and Pin=21dBm

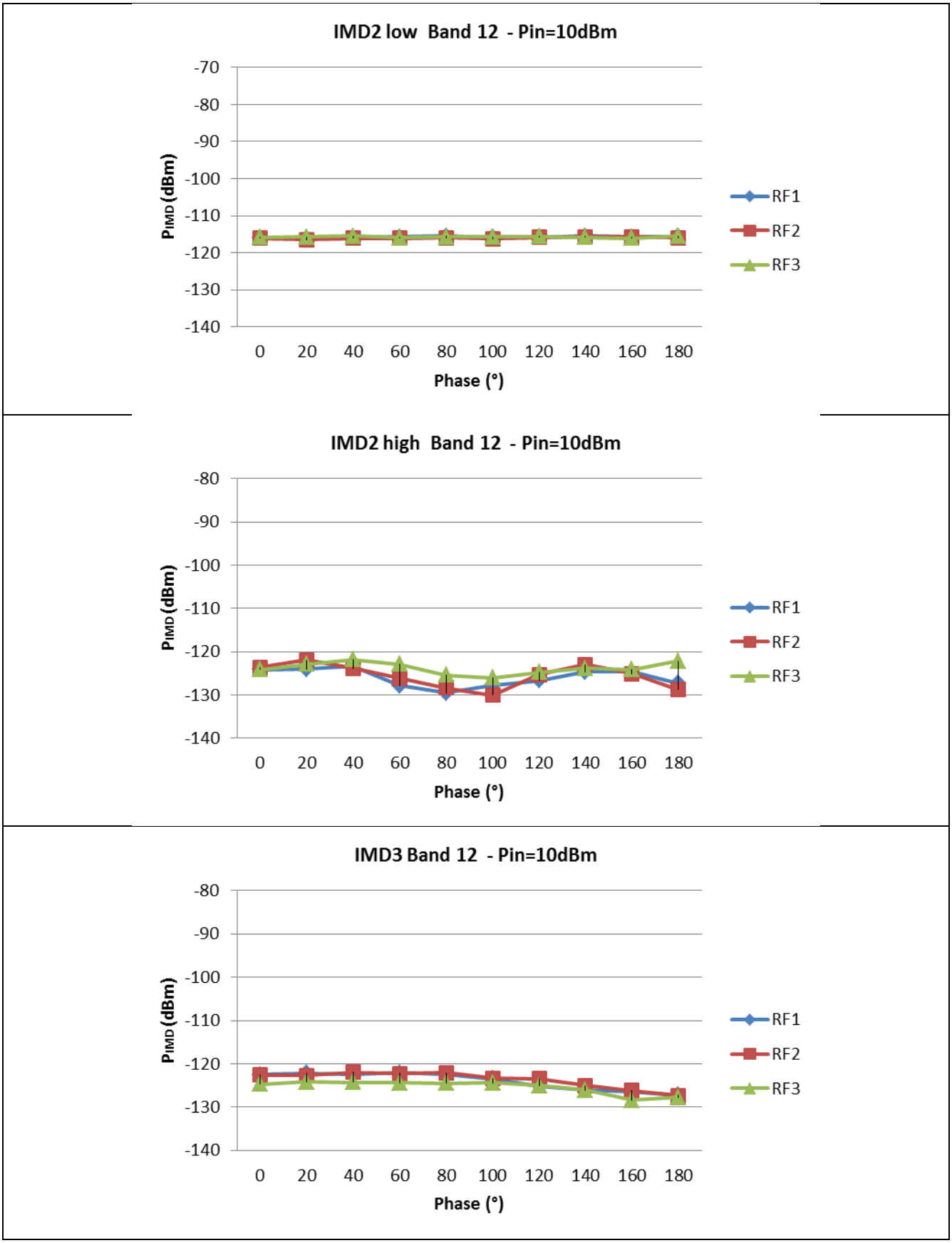


Figure 36 IMD products of Band 12 LTE and Pin=10dBm

Intermodulation

Table 19 IMD products of Band 12 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=30MHz)	-105.42	-104.89	-105.55	-105.17	-105.48	-105.13
IMD2High ($f_{blocker}$=1462MHz)	-117.01	-111.02	-117.02	-112.58	-114.04	-111.43
IMD3 ($f_{blocker}$=686MHz)	-106.56	-102.37	-107.1	-103.12	-108.46	-104.03

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=30MHz)	-116.01	-115.49	-116.51	-115.72	-116.11	-115.45
IMD2High ($f_{blocker}$=1462MHz)	-129.55	-123.48	-130.09	-121.99	-126.02	-121.79
IMD3 ($f_{blocker}$=686MHz)	-127.23	-122.08	-127.31	-121.95	-128.44	-124.16

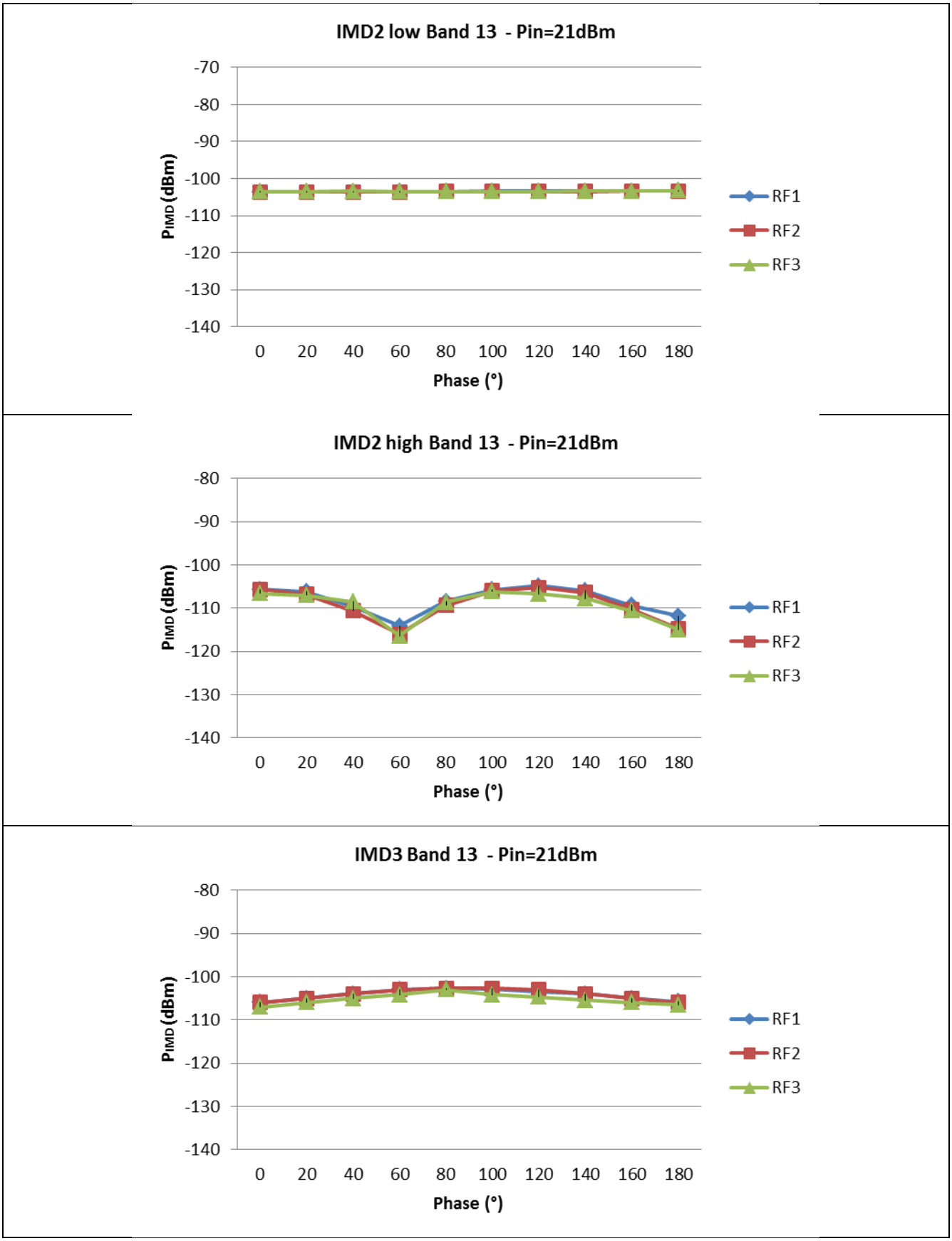


Figure 38 IMD products of Band 13 LTE and Pin=21dBm

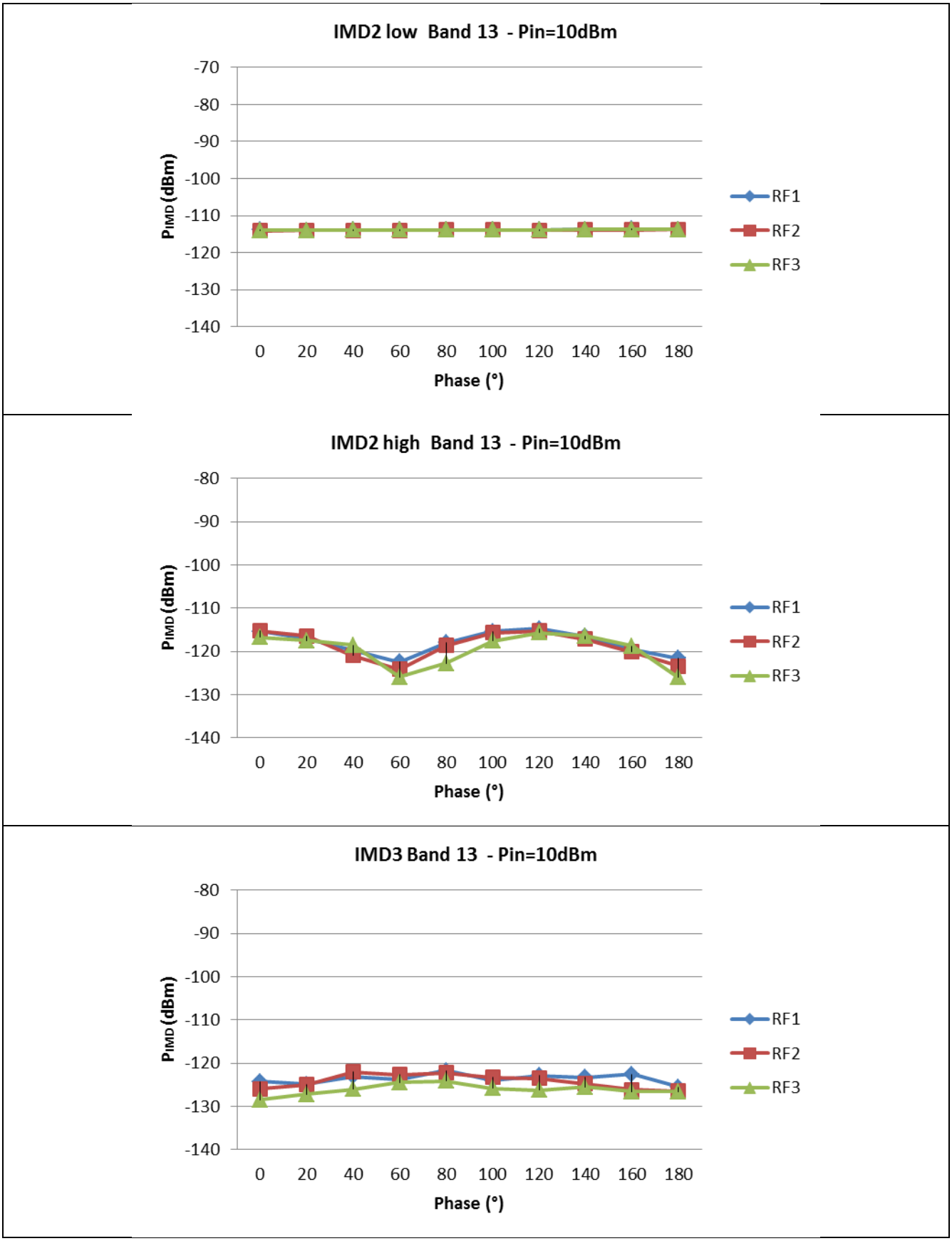


Figure 39 IMD products of Band 13 LTE and Pin=10dBm

Table 20 IMD products of Band 13 TE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=31MHz)	-103.68	-103.32	-103.69	-103.43	-103.58	-103.32
IMD2High ($f_{blocker}$=1533MHz)	-114.12	-104.78	-115.99	-105.25	-116.47	-106.24
IMD3 ($f_{blocker}$=813MHz)	-106	-102.7	-106	-102.7	-107	-103

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=31MHz)	-113.96	-113.69	-114.1	-113.8	-114.03	-113.71
IMD2High ($f_{blocker}$=1533MHz)	-122.49	-114.77	-124.13	-115.27	-126.06	-115.76
IMD3 ($f_{blocker}$=813MHz)	-125.57	-121.71	-126.5	-122	-128.55	-124.2

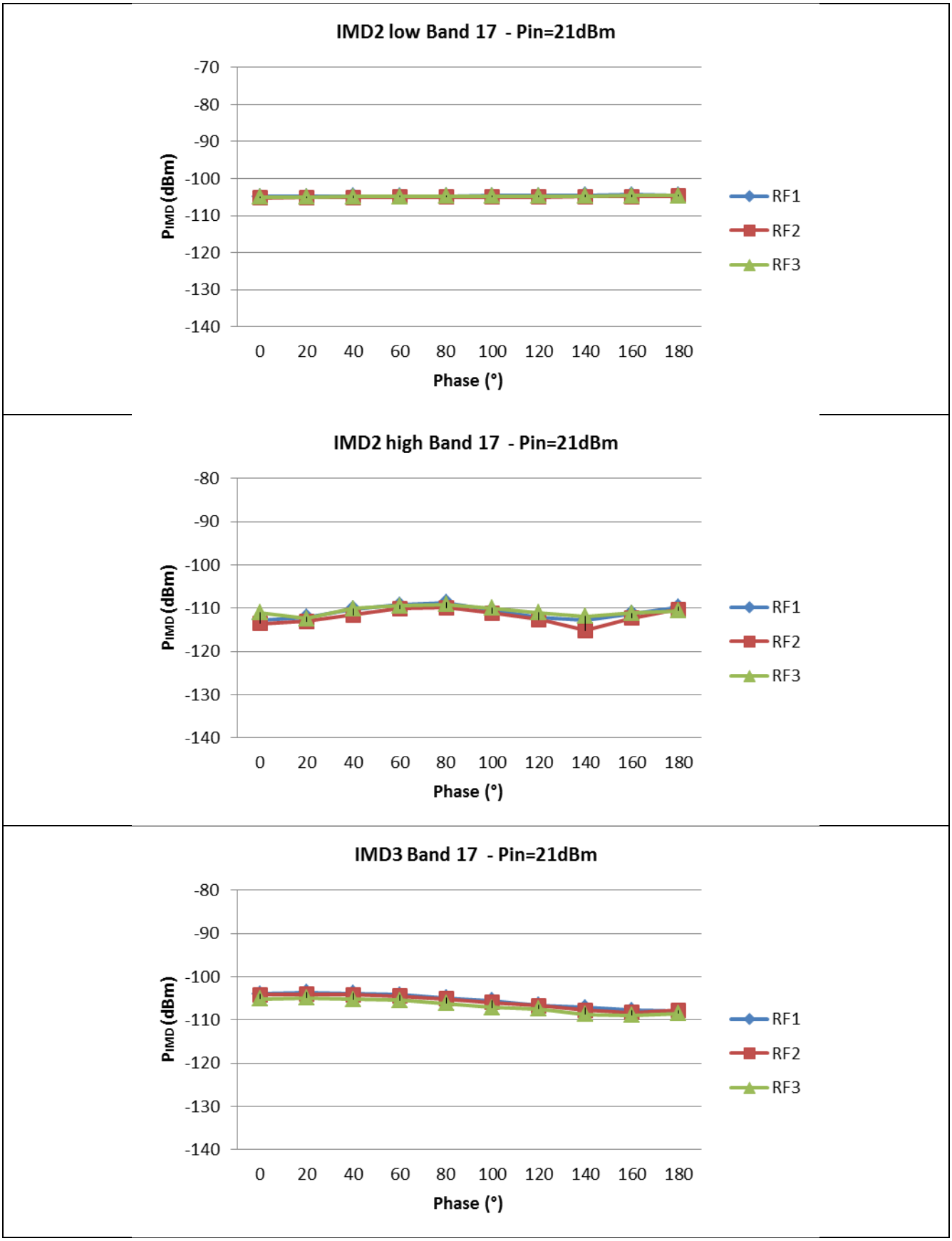


Figure 41 IMD products of Band 17 LTE and Pin=21dBm

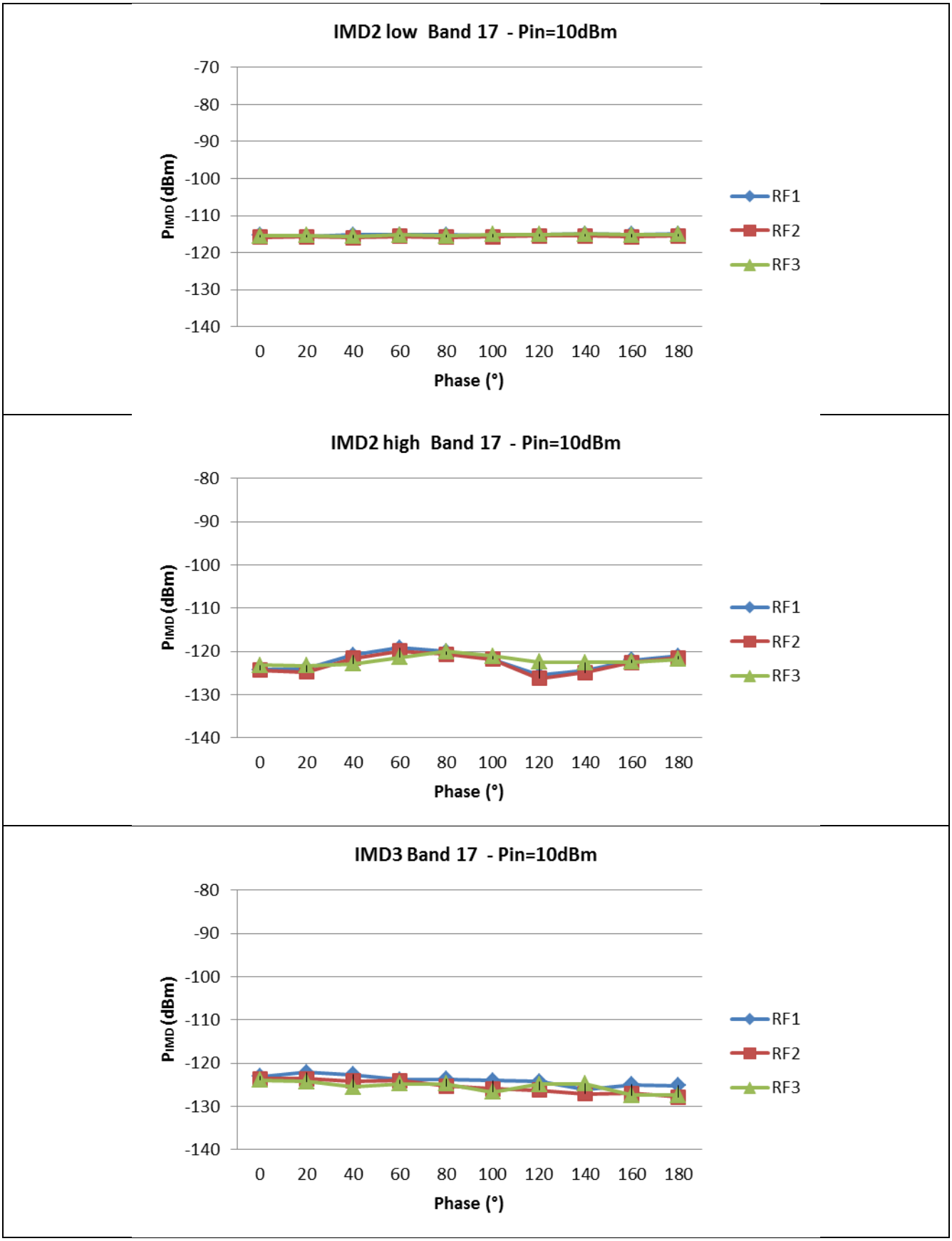


Figure 42 IMD products of Band 17 LTE and Pin=10dBm

Intermodulation

Table 21 IMD products of Band 17 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=30MHz)	-104.85	-104.41	-105.21	-104.75	-104.96	-104.65
IMD2High ($f_{blocker}$=1450MHz)	-112.76	-108.74	-115.21	-109.87	-112.41	-109.15
IMD3 ($f_{blocker}$=680MHz)	-108	-103.61	-108.34	-104.12	-108.98	-104.95

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=30MHz)	-115.6	-115.01	-115.98	-115.44	-115.65	-115.03
IMD2High ($f_{blocker}$=1450MHz)	-125.53	-119.19	-126.26	-119.96	-123.28	-120.07
IMD3 ($f_{blocker}$=680MHz)	-126.22	-122.21	-127.89	-123.61	-127.45	-123.91

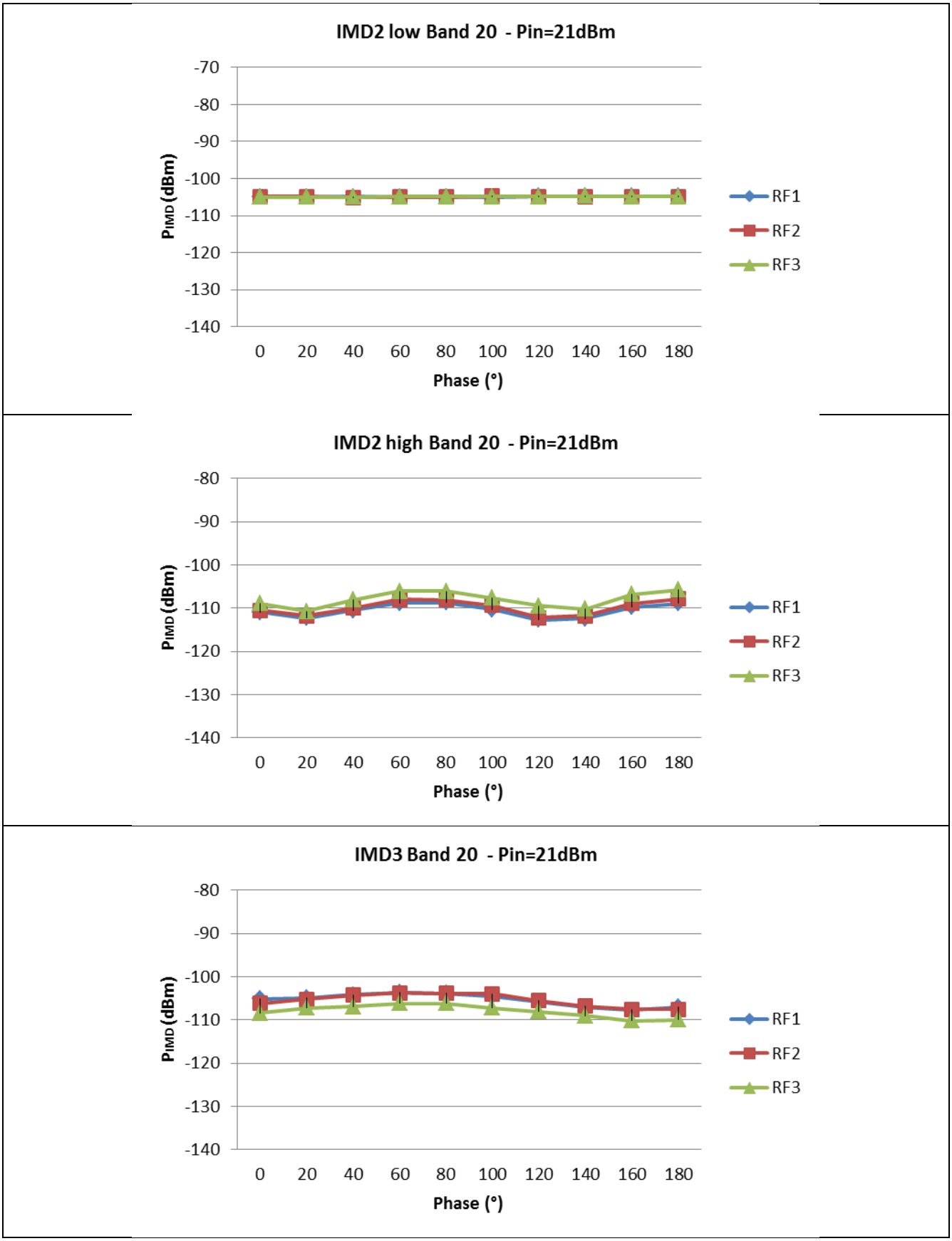


Figure 44 IMD products of Band 20 LTE and Pin=21dBm

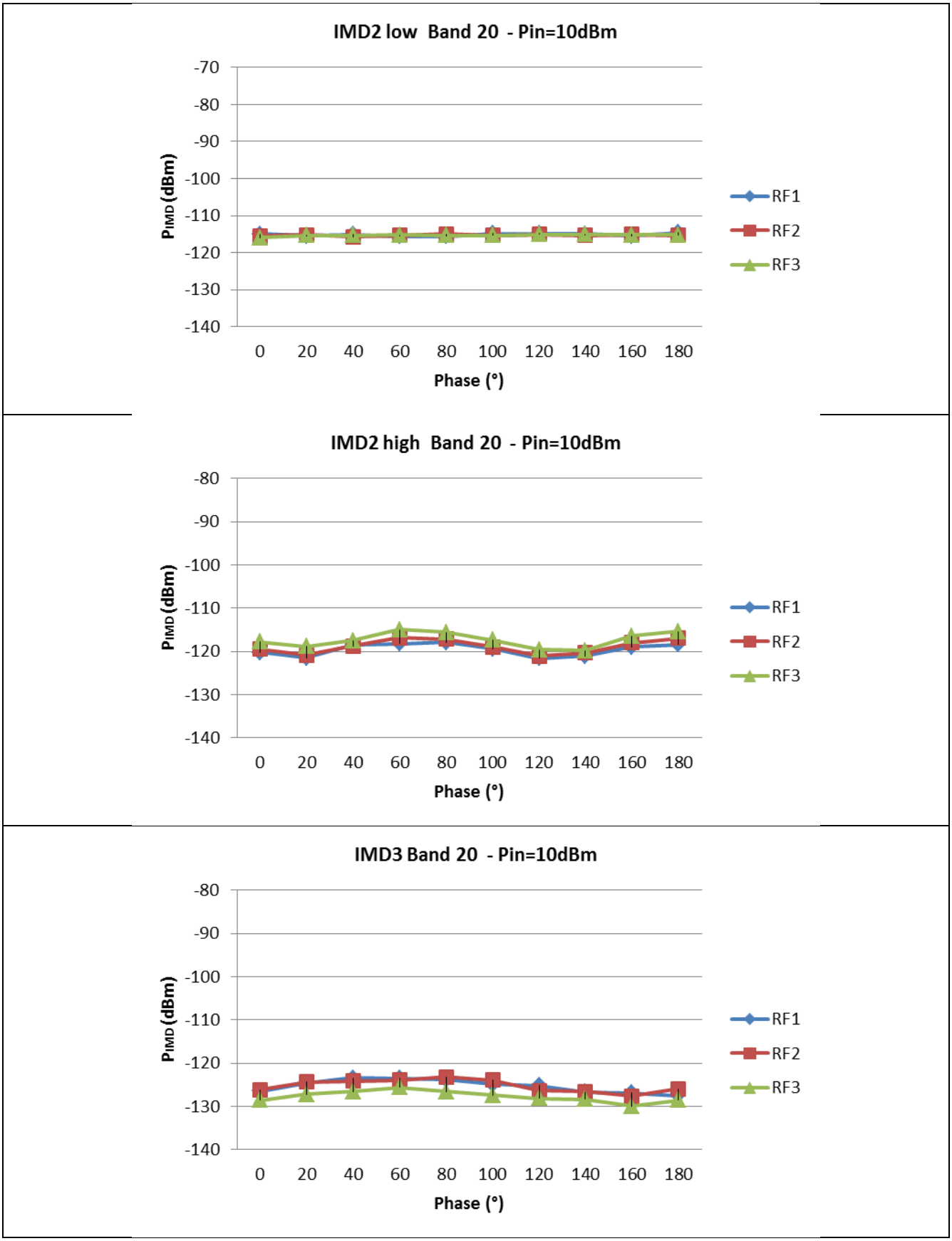


Figure 45 IMD products of Band 20 LTE and Pin=10dBm

Table 22 IMD products of Band 20 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=41MHz)	-104.95	-104.75	-105.07	-104.8	-105.02	-104.79
IMD2High ($f_{blocker}$=1653MHz)	-112.71	-108.68	-112.27	-107.86	-110.79	-105.81
IMD3 ($f_{blocker}$=888MHz)	-107.81	-103.71	-107.61	-103.79	-110.22	-106.17

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=41MHz)	-115.59	-114.67	-115.7	-114.96	-115.93	-115.08
IMD2High ($f_{blocker}$=1653MHz)	-121.66	-117.88	-121.05	-116.87	-119.82	-114.98
IMD3 ($f_{blocker}$=888MHz)	-127.6	-123.47	-127.66	-123.26	-129.94	-125.7

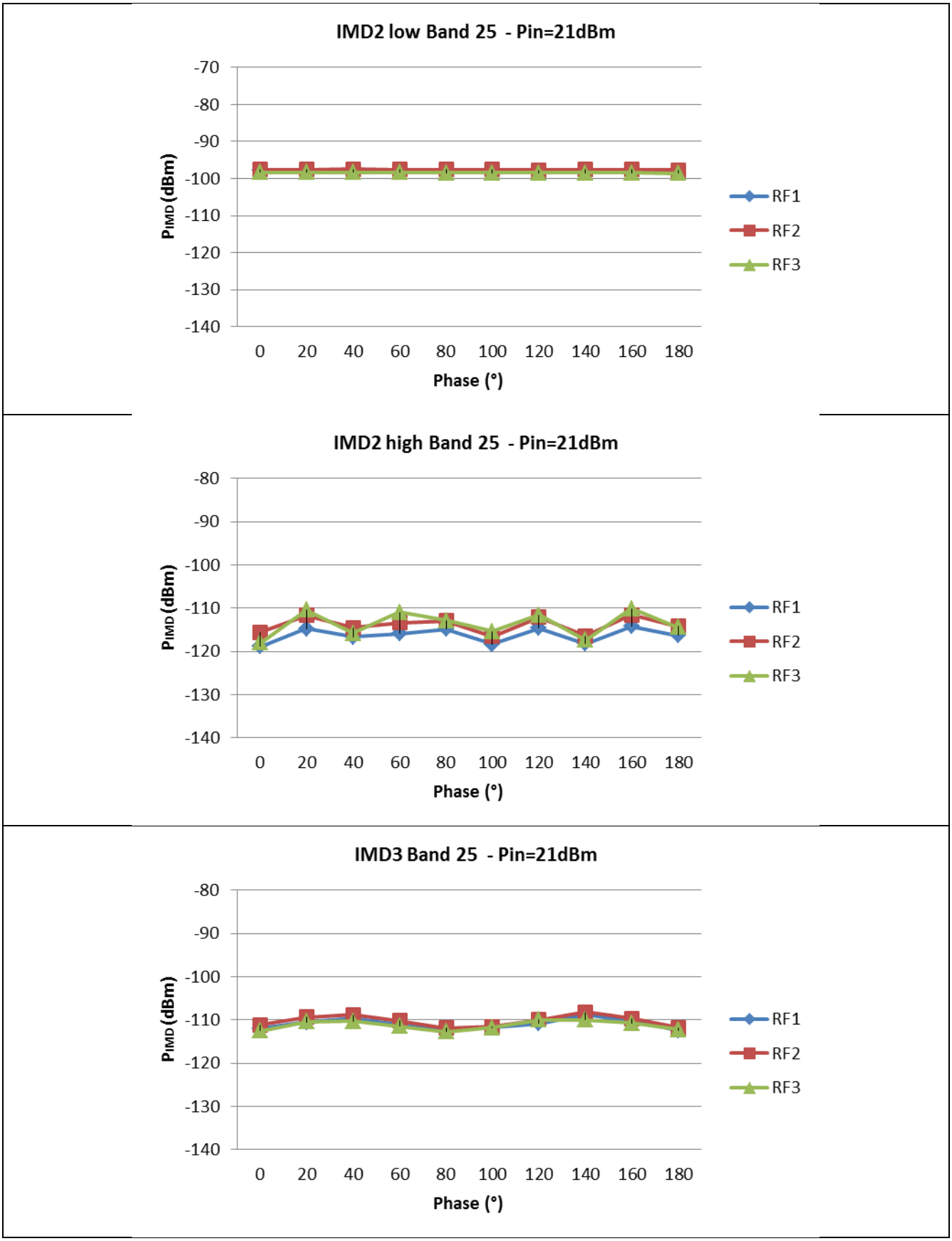


Figure 47 IMD products of Band 25 LTE and Pin=21dBm

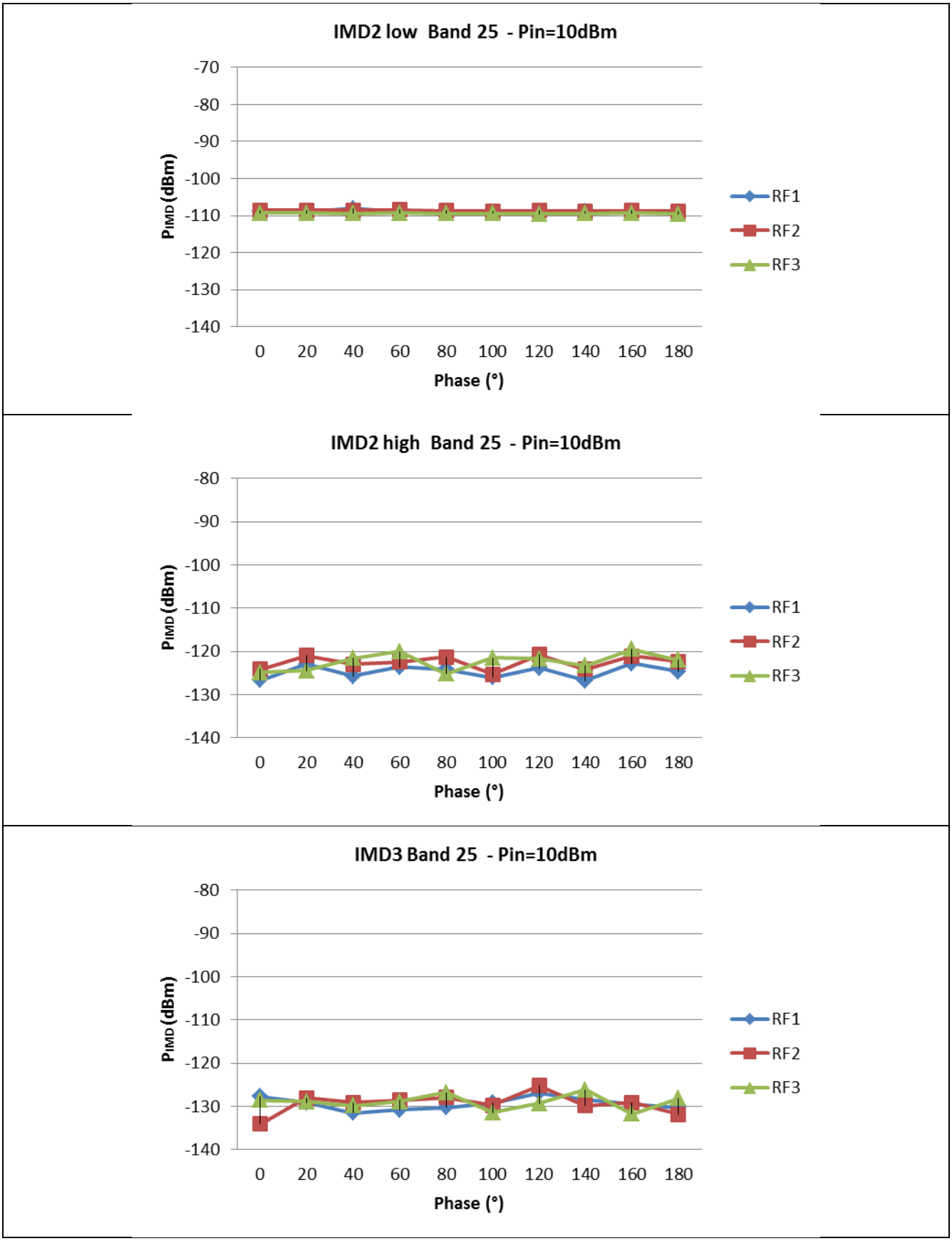


Figure 48 IMD products of Band 25 LTE and Pin=10dBm

Intermodulation

Table 23 IMD products of Band 25 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=95MHz)	-98.06	-97.86	-97.7	-97.52	-98.63	-98.31
IMD2High ($f_{blocker}$=3860MHz)	-118.88	-114.26	-116.6	-111.56	-118.03	-110.09
IMD3 ($f_{blocker}$=1787.5MHz)	-112.43	-108.85	-111.89	-108.2	-112.72	-110

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=95MHz)	-109.21	-108.05	-108.84	-108.44	-109.54	-109.29
IMD2High ($f_{blocker}$=3860MHz)	-126.81	-122.78	-125.33	-120.75	-125.21	-119.55
IMD3 ($f_{blocker}$=1787.5MHz)	-131.6	-126.92	-134.08	-125.21	-131.81	-126.17

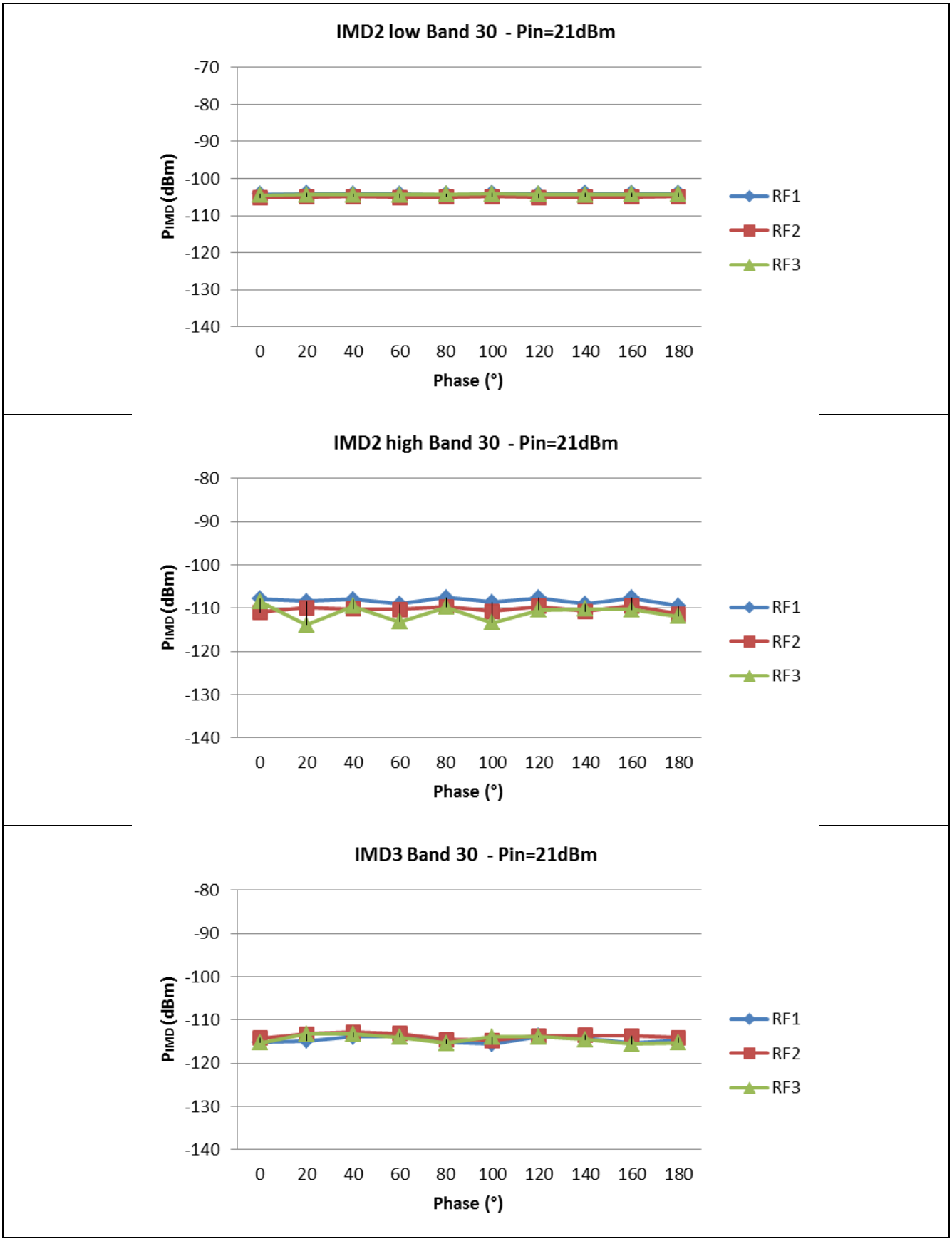


Figure 50 IMD products of Band 30 LTE and Pin=21dBm

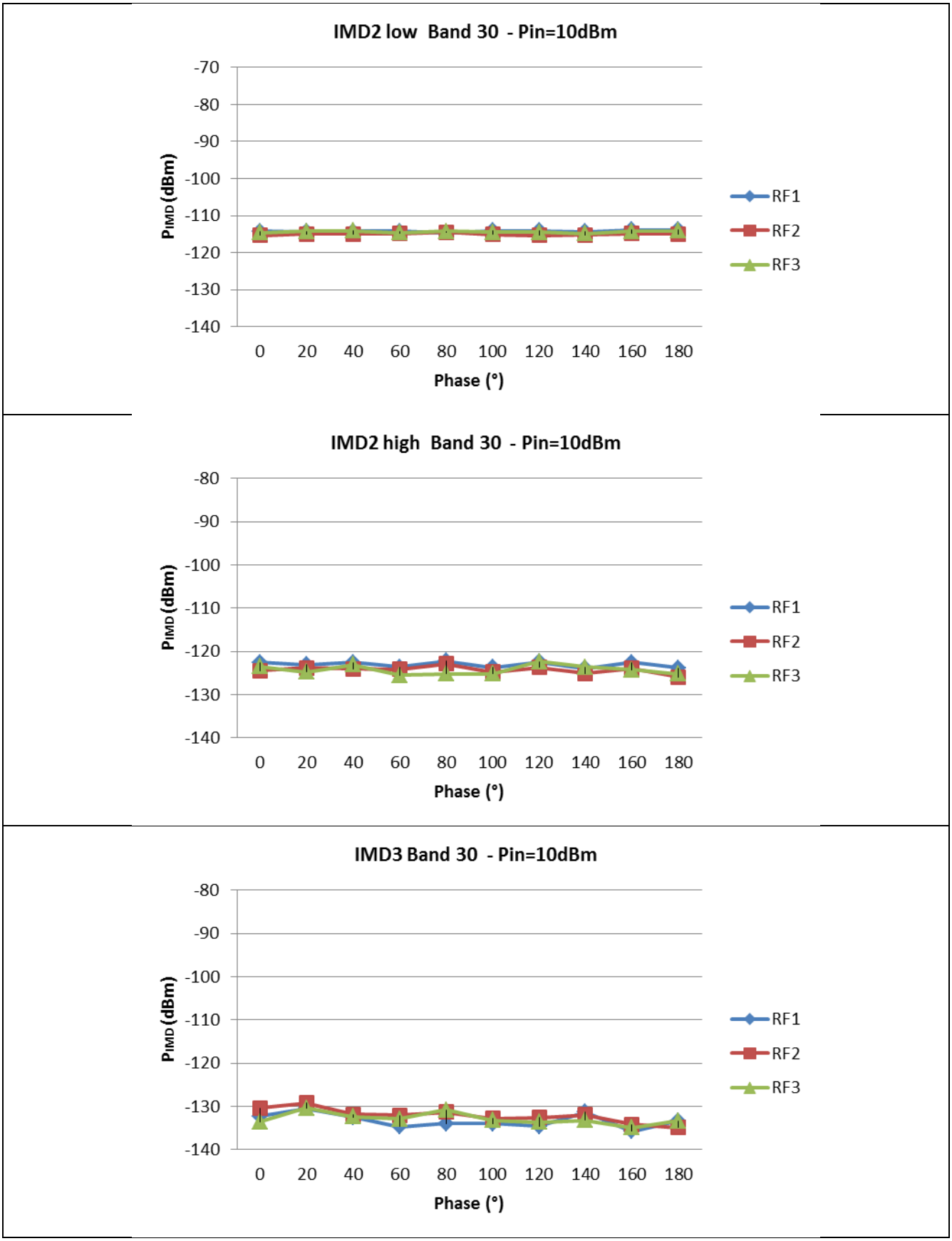


Figure 51 IMD products of Band 30 LTE and Pin=10dBm

Table 24 IMD products of Band 30 LTE

IMD Band I P_{Tx}=21dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=45MHz)	-104.25	-103.97	-105.11	-104.86	-104.45	-104.15
IMD2High ($f_{blocker}$=4665MHz)	-109.47	-107.53	-111.42	-109.42	-113.87	-108.54
IMD3 ($f_{blocker}$=2265MHz)	-115.57	-113.82	-114.71	-112.87	-115.61	-113.26

IMD Band I P_{Tx}=10dBm	RF1 (dBm)		RF2 (dBm)		RF3 (dBm)	
	Min	Max	Min	Max	Min	Max
IMD2Low[2] ($f_{blocker}$=45MHz)	-114.6	-113.82	-115.39	-114.54	-114.85	-114.08
IMD2High ($f_{blocker}$=4665MHz)	-123.94	-122.26	-125.95	-122.89	-125.58	-122.32
IMD3 ($f_{blocker}$=2265MHz)	-135.77	-130.51	-134.91	-129.29	-134.98	-130.4

2) The results of IMD2low can be improved by using an external shunt inductor of 27nH from RFin to GND.

6 Harmonic Generation

Harmonic generation is another important parameter for the characterization of a RF switch. RF switches have in such a Differential Band select Switching application to deal with high RF levels, up to 24 dBm. With this high RF power at the input of the switch harmonics are generated. This harmonics (2nd and 3rd) can disturb the other reception bands or cause distortion in other RF applications (GPS, WLan) within the mobile phone.

6.1 Measurement Setup

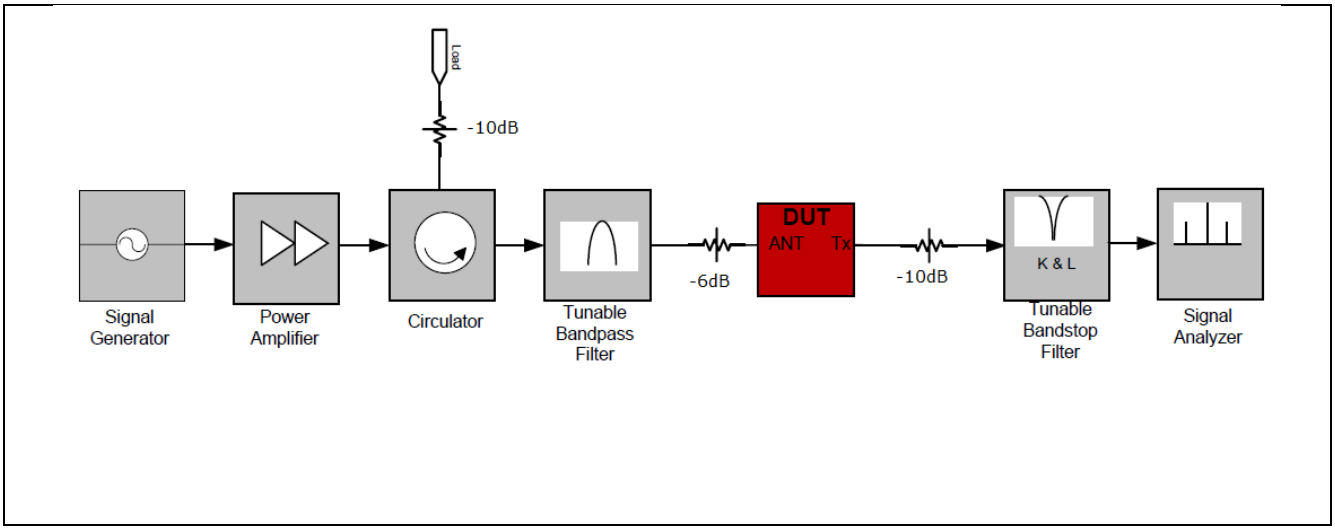


Figure 53 Setup for harmonics measurement

The results for the 2nd and 3rd order harmonic generation at different Bands are shown from for all RF ports on the following points. All measurements are done at room temperature with a CW Tx carrier signal.
The x-axis shows the input power and the yaxis show the generated harmonics in dBm.

6.2 Measurement results

6.2.1 Harmonics for Band 1

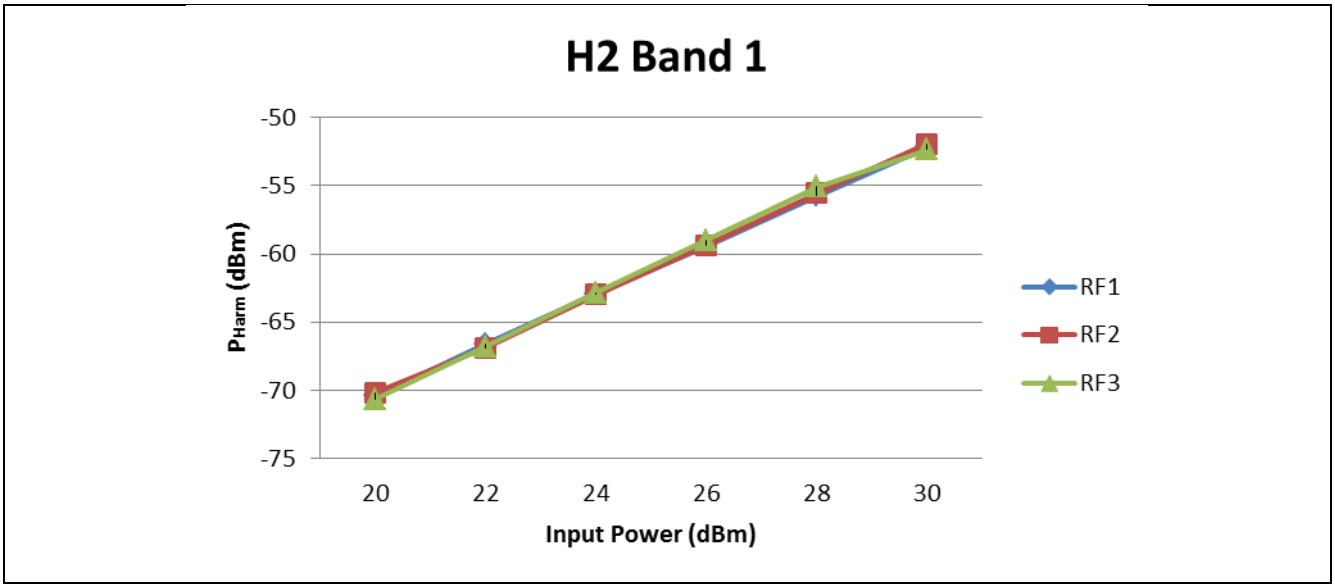


Figure 54 2nd harmonics at fc=1950MHz

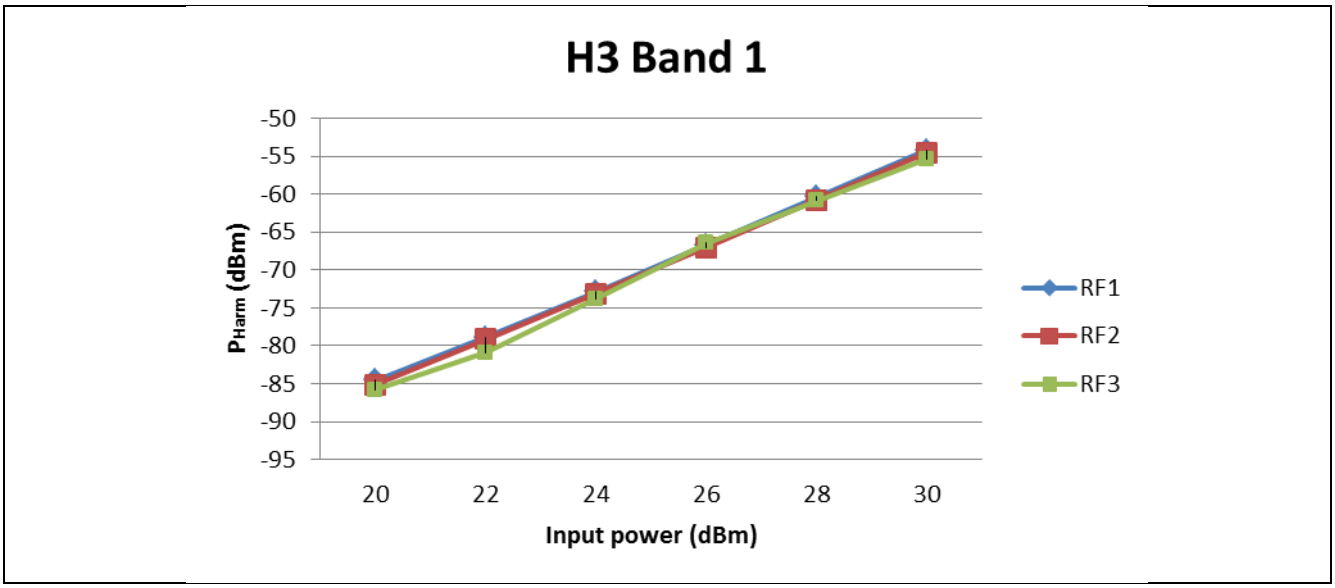


Figure 55 3rd harmonics at fc=1950MHz

fc=1950MHz		Band 1					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-70.42	-70.15	-70.66	-84.5	-85.15	-85.8
	22	-66.62	-66.86	-66.78	-78.82	-79.11	-80.9
	24	-62.95	-63	-62.85	-72.82	-73.1	-73.75
	26	-59.41	-59.35	-58.98	-66.7	-66.98	-66.45
	28	-55.75	-55.55	-55.1	-60.36	-60.78	-60.85
	30	-52.15	-51.92	-52.36	-54.15	-54.53	-55.38

6.2.2 Harmonics for Band 2

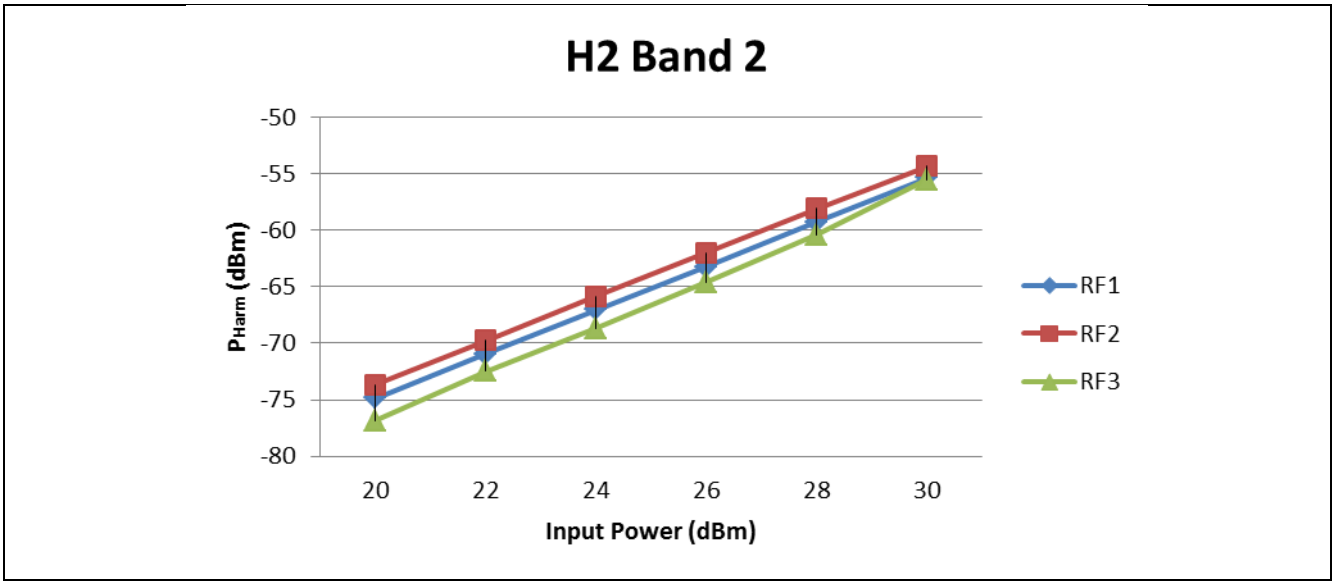


Figure 56 2nd harmonics at fc=1880MHz

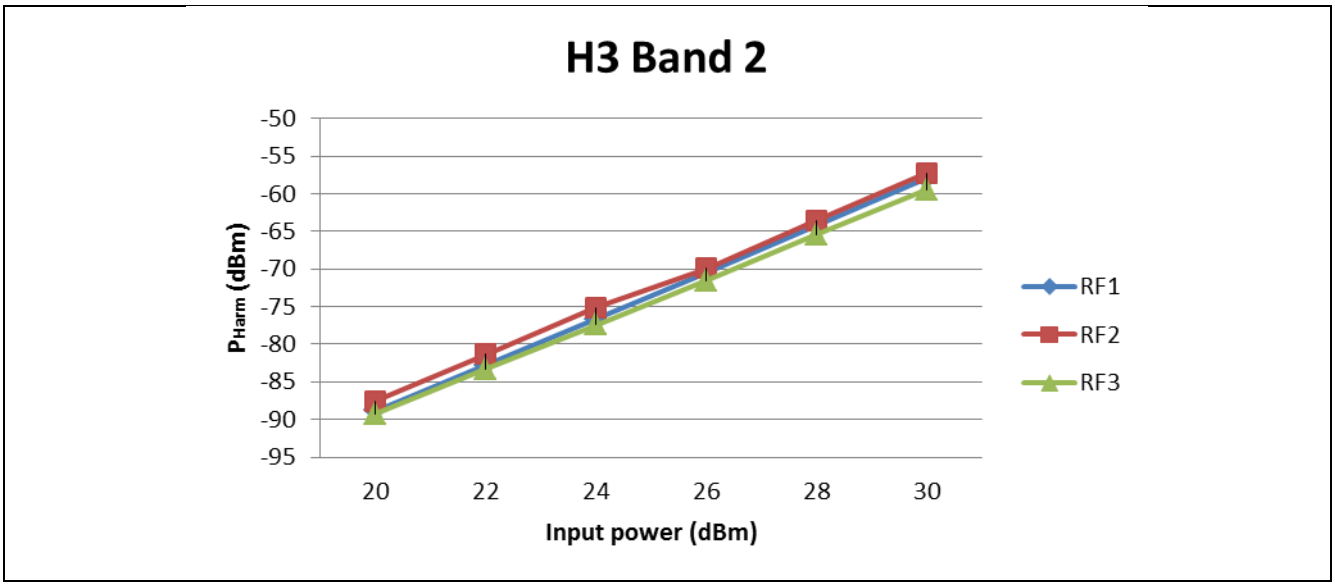


Figure 57 3rd harmonics at fc=1880MHz

fc=1880MHz		Band 2					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-74.87	-73.65	-76.82	-88.8	-87.5	-89.25
	22	-70.95	-69.75	-72.5	-82.75	-81.33	-83.25
	24	-67.05	-65.85	-68.65	-76.65	-75.15	-77.45
	26	-63.22	-62	-64.6	-70.55	-69.92	-71.52
	28	-59.25	-58.05	-60.41	-64.15	-63.52	-65.39
	30	-55.32	-54.33	-55.5	-57.9	-57.25	-59.42

6.2.3 Harmonics for Band 3

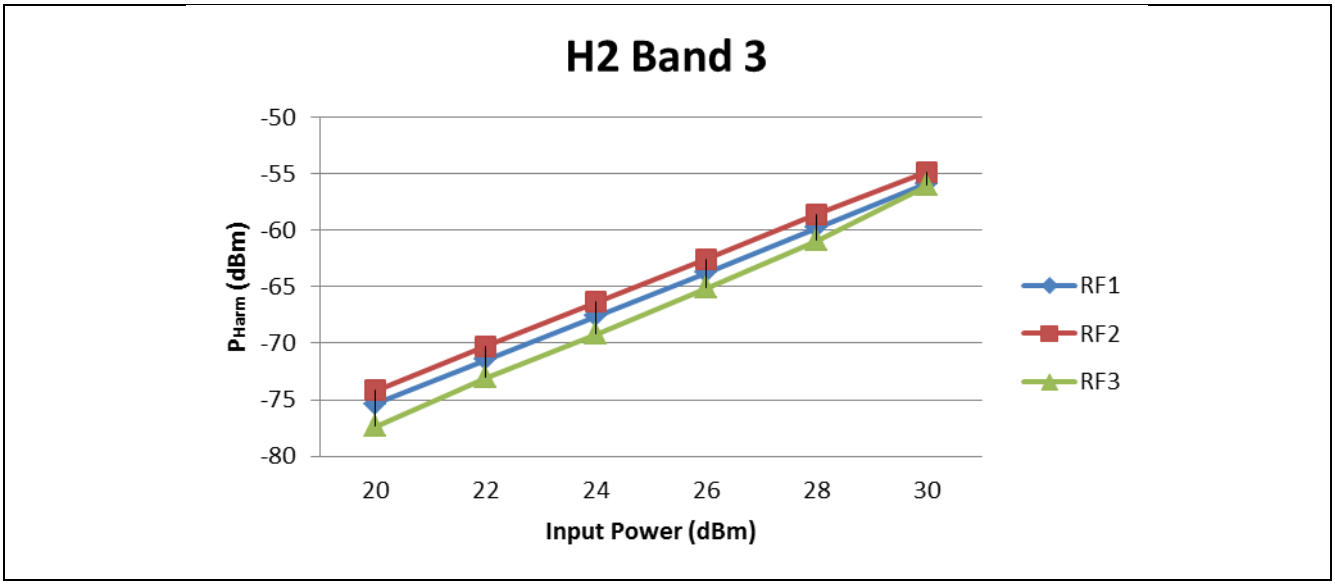


Figure 58 2nd harmonics at fc=1732,5MHz

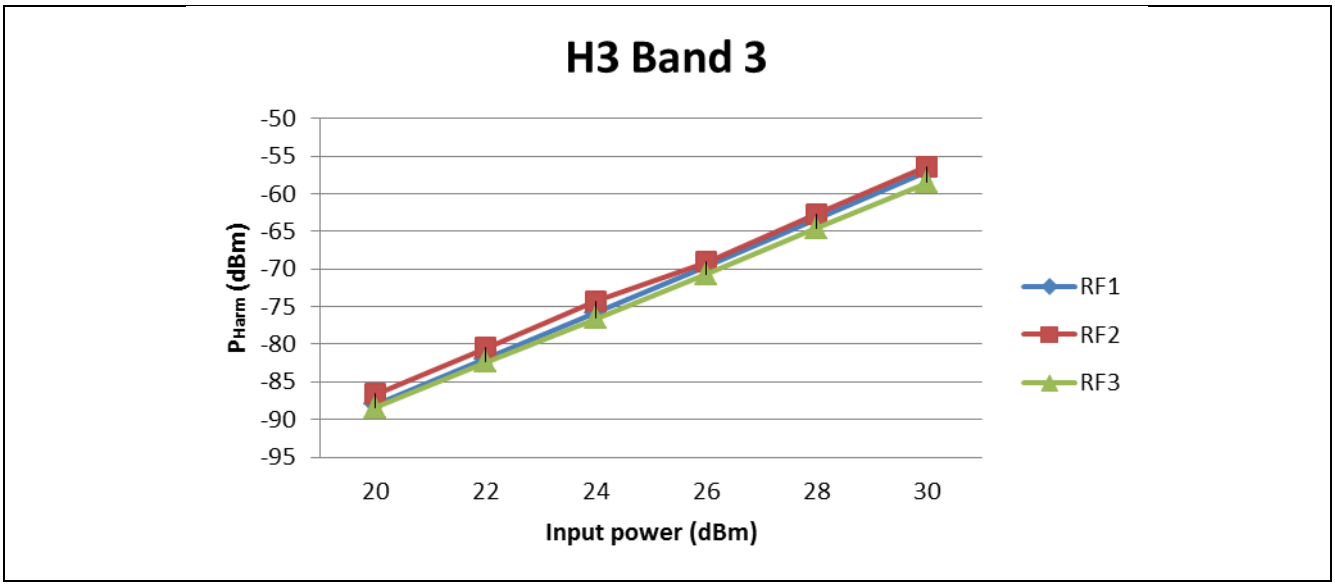


Figure 59 3rd harmonics at fc=1732,5MHz

fc=1747.5MHz		Band 3					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-75.39	-74.17	-77.34	-87.94	-86.64	-88.39
	22	-71.47	-70.27	-73.02	-81.89	-80.47	-82.39
	24	-67.57	-66.37	-69.17	-75.79	-74.29	-76.59
	26	-63.74	-62.52	-65.12	-69.69	-69.06	-70.66
	28	-59.77	-58.57	-60.93	-63.29	-62.66	-64.53
	30	-55.84	-54.85	-56.02	-57.04	-56.39	-58.56

6.2.4 Harmonics for Band 4

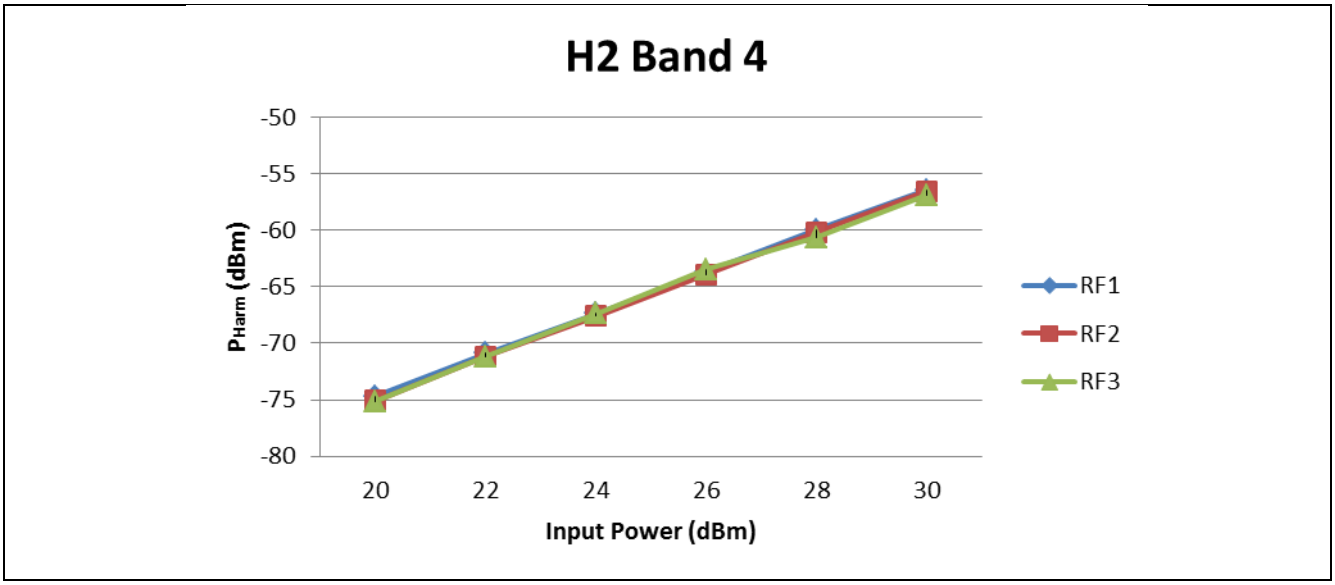


Figure 60 2nd harmonics at fc=1732,5MHz

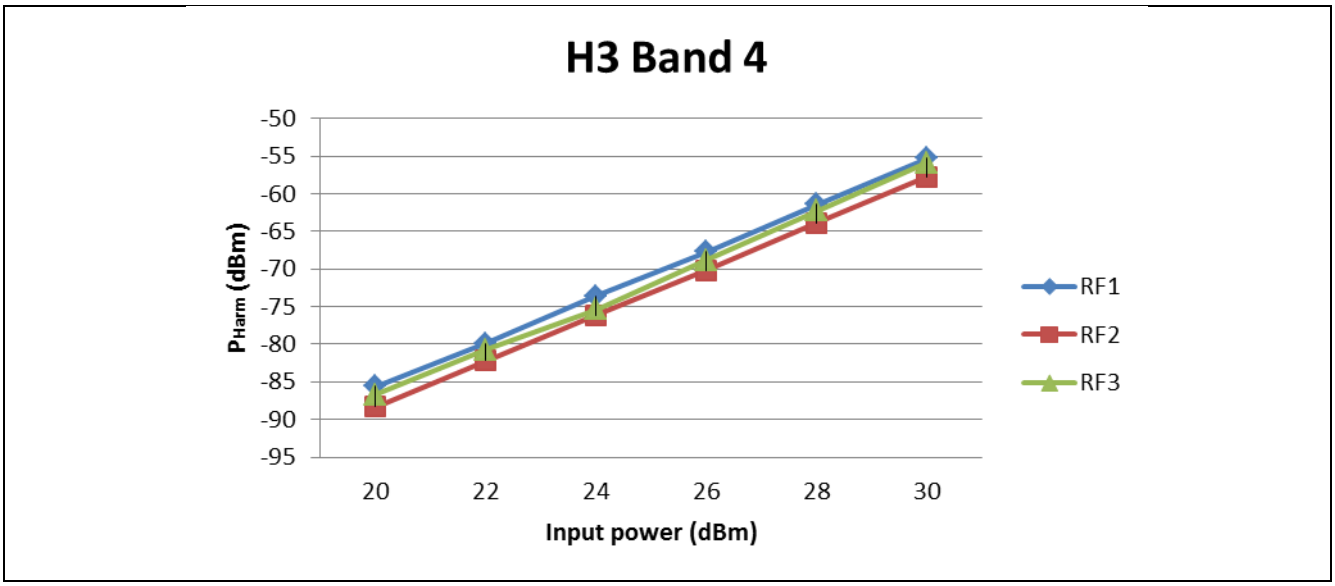


Figure 61 3rd harmonics at fc=1732,5MHz

fc=1732.5MHz		Band 4					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-74.7	-75.07	-75.14	-85.57	-88.35	-86.66
	22	-70.89	-71.15	-71.15	-79.9	-82.15	-80.77
	24	-67.35	-67.61	-67.35	-73.55	-76.15	-75.38
	26	-63.7	-63.9	-63.45	-67.75	-70.22	-68.82
	28	-59.95	-60.18	-60.61	-61.43	-63.87	-62.25
	30	-56.4	-56.55	-56.88	-55.25	-57.78	-55.88

6.2.5 Harmonics for Band 5

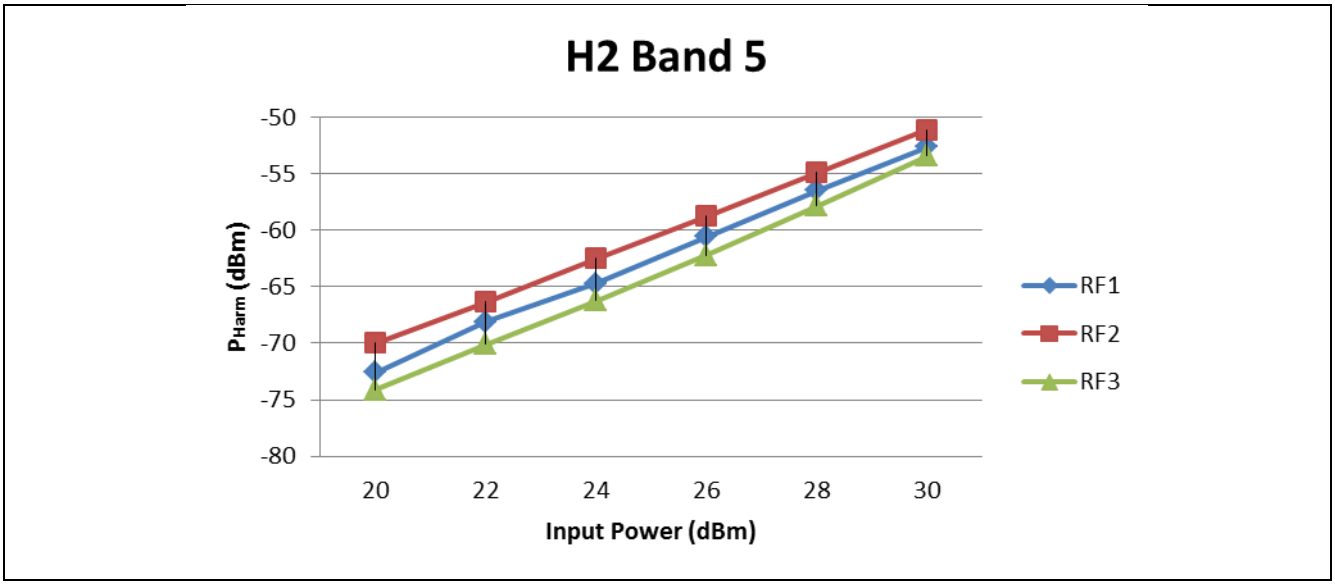


Figure 62 2nd harmonics at fc=2535MHz

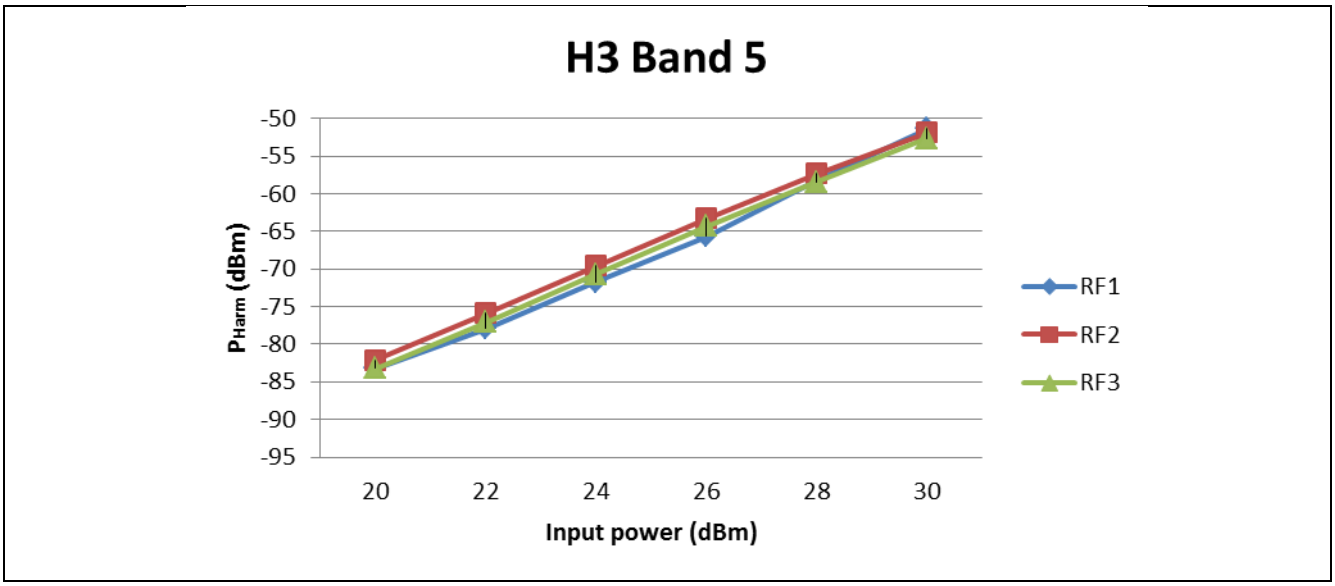


Figure 63 3rd harmonics at fc=2535MHz

fc=836.5MHz		Band 5					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-72.6	-70	-74.1	-83.2	-82.1	-83.2
	22	-68.1	-66.35	-70.1	-77.9	-75.9	-77.1
	24	-64.69	-62.5	-66.26	-71.7	-69.6	-70.7
	26	-60.57	-58.76	-62.19	-65.7	-63.25	-64.33
	28	-56.48	-54.9	-57.82	-58.2	-57.34	-58.4
	30	-52.64	-51.11	-53.4	-51.35	-51.85	-52.65

6.2.6 Harmonics for Band 7

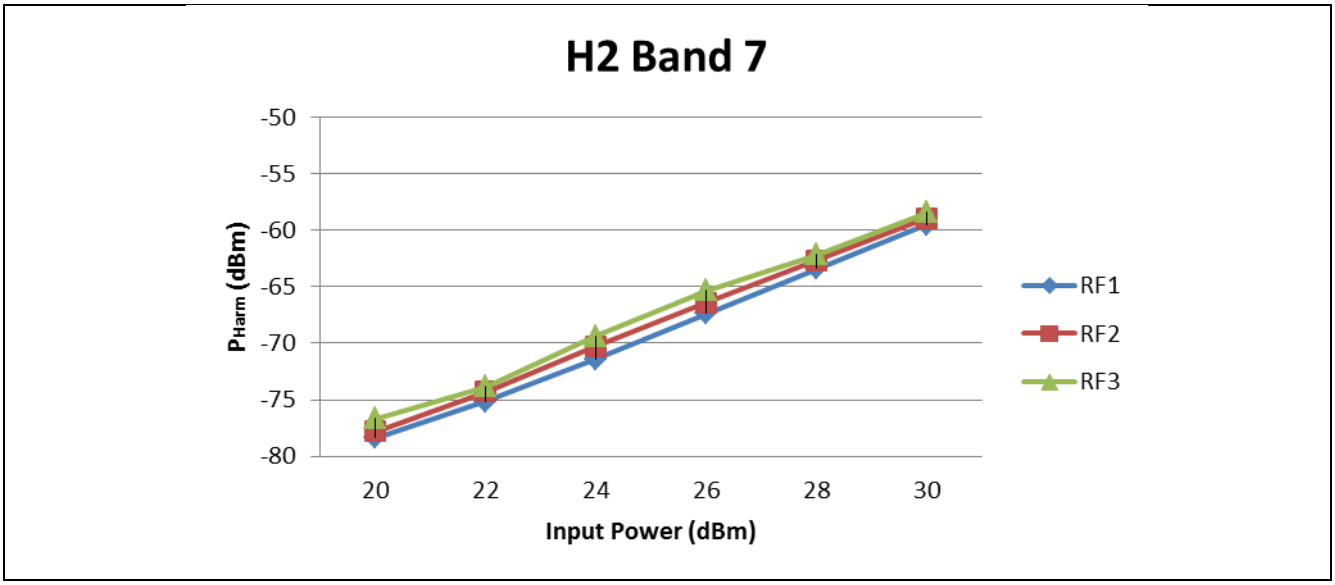


Figure 64 2nd harmonics at fc=2535MHz

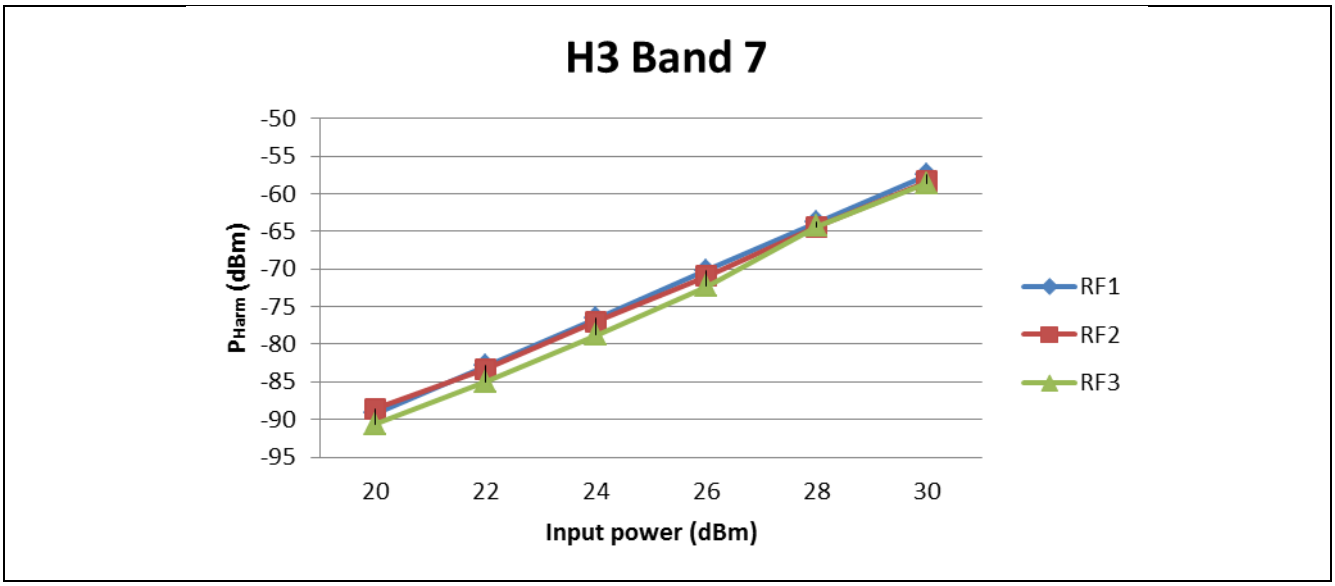


Figure 65 3rd harmonics at fc=2535MHz

fc=2535MHz		Band 7					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-78.4	-77.78	-76.69	-89.12	-88.58	-90.64
	22	-75.17	-74.29	-73.86	-82.87	-83.3	-84.96
	24	-71.38	-70.28	-69.33	-76.57	-76.98	-78.8
	26	-67.39	-66.38	-65.3	-70.2	-70.99	-72.34
	28	-63.41	-62.64	-62.15	-63.76	-64.38	-64.35
	30	-59.51	-58.94	-58.42	-57.5	-58.36	-58.61

6.2.7 Harmonics for Band 12

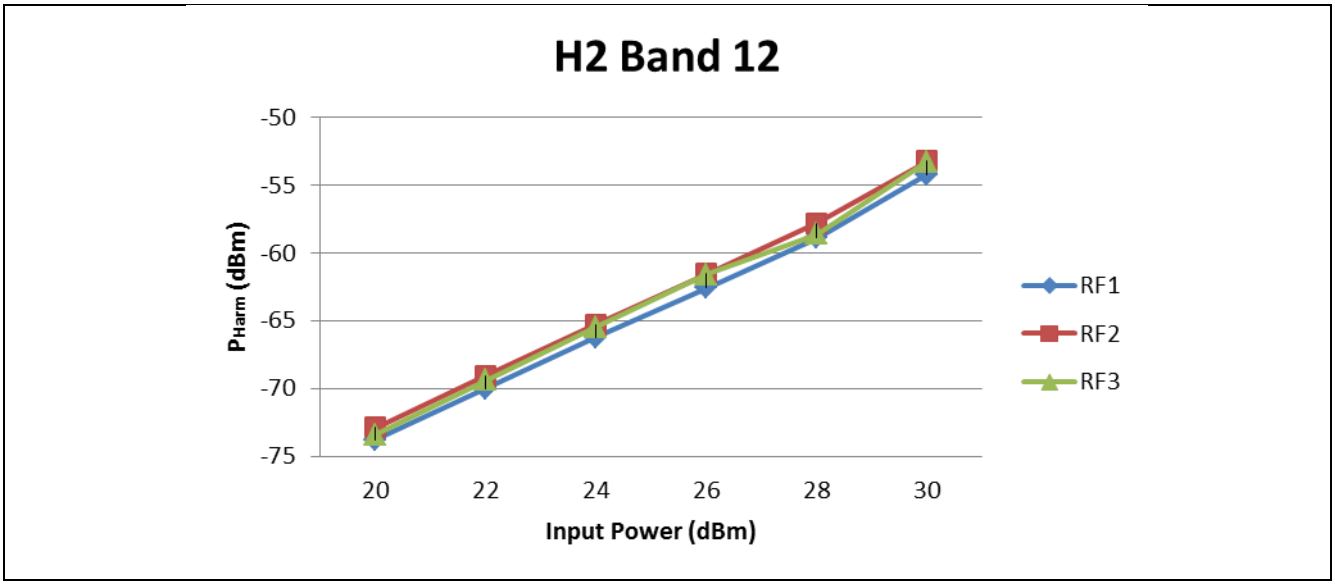


Figure 66 2nd harmonics at fc=716MHz

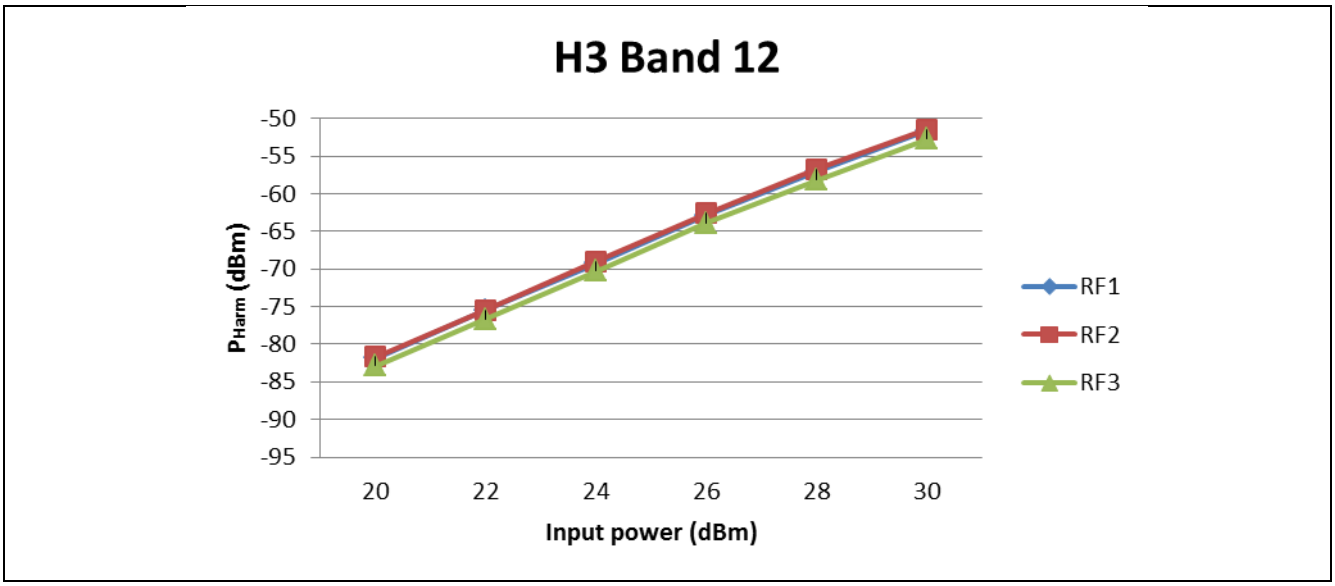


Figure 67 3rd harmonics at fc=716MHz

fc=716MHz		Band 12					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-73.8	-72.89	-73.4	-81.8	-81.65	-82.9
	22	-70	-69.08	-69.39	-75.5	-75.44	-76.62
	24	-66.22	-65.28	-65.46	-69.23	-69.02	-70.25
	26	-62.6	-61.54	-61.6	-62.87	-62.59	-63.9
	28	-58.9	-57.82	-58.59	-57.07	-56.78	-58.15
	30	-54.2	-53.21	-53.28	-51.6	-51.42	-52.74

6.2.8 Harmonics for Band 13

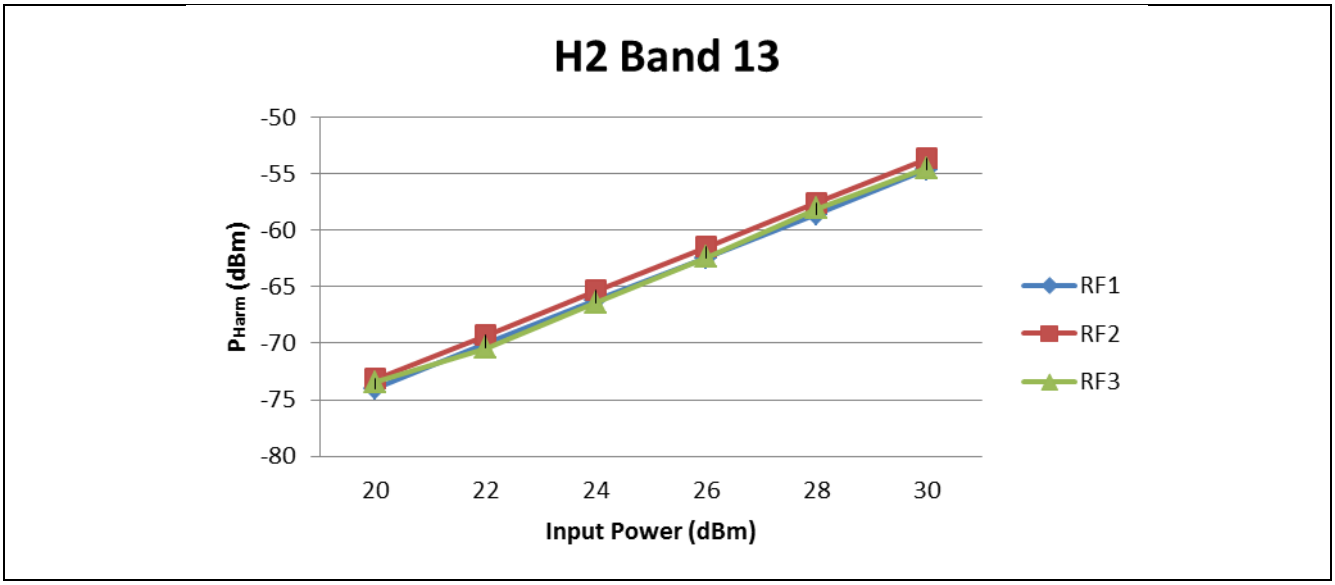


Figure 68 2nd harmonics at fc=782MHz

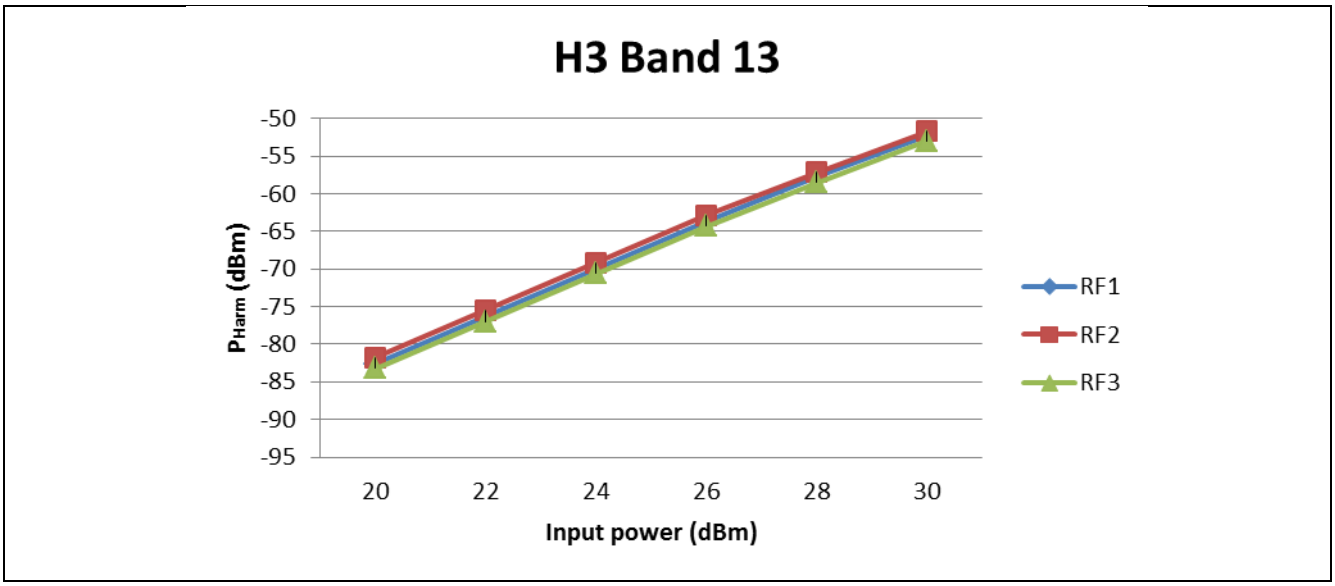


Figure 69 3rd harmonics at fc=782MHz

fc=782MHz		Band 13					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-73.98	-73.18	-73.44	-82.6	-81.77	-83.2
	22	-70.02	-69.3	-70.43	-76.33	-75.45	-77
	24	-66.2	-65.35	-66.43	-69.95	-69.18	-70.62
	26	-62.45	-61.48	-62.38	-63.65	-62.86	-64.28
	28	-58.55	-57.53	-58.08	-57.8	-57.15	-58.55
	30	-54.59	-53.63	-54.5	-52.3	-51.75	-53

6.2.9 Harmonics for Band 17

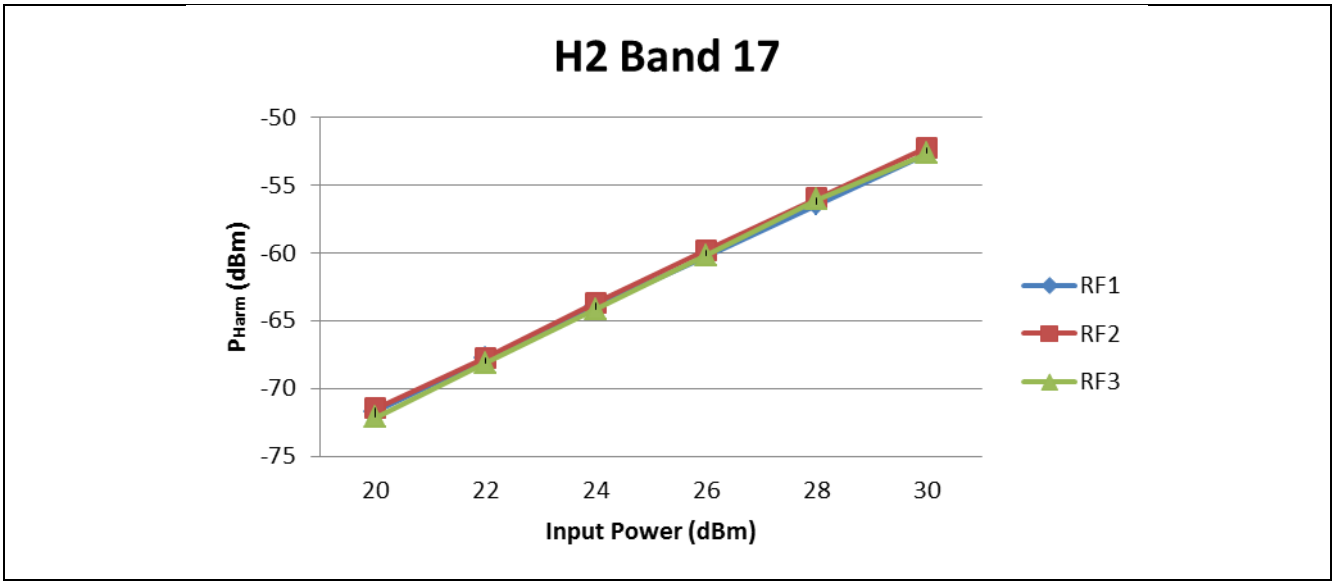


Figure 70 2nd harmonics at fc=710MHz

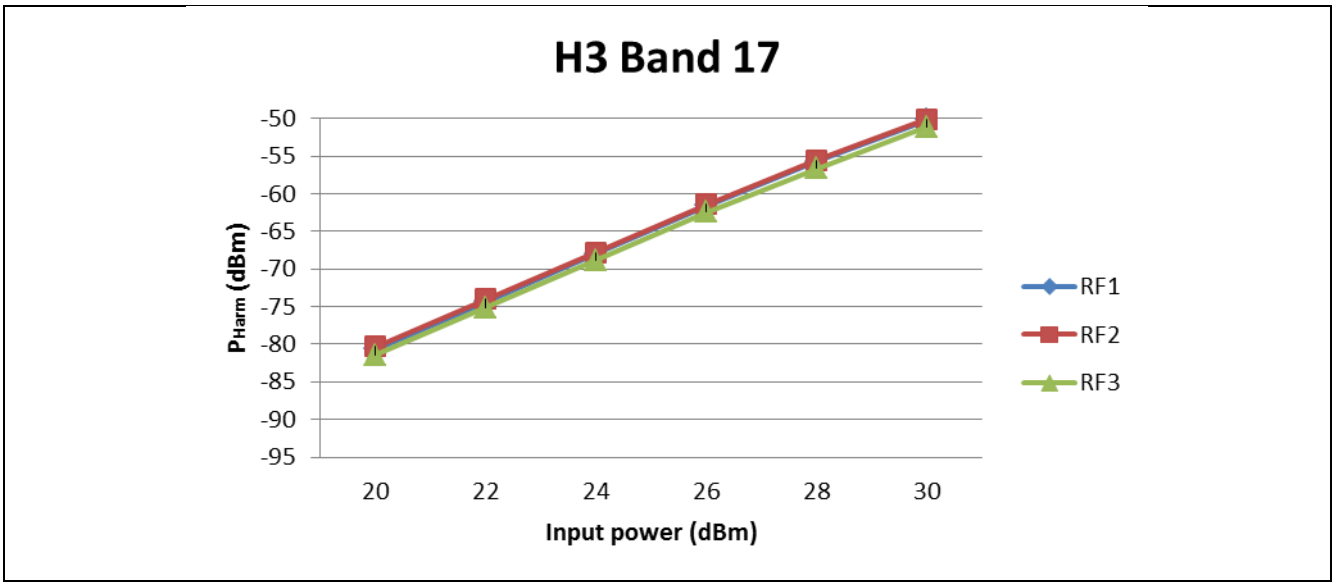


Figure 71 3rd harmonics at fc=710MHz

fc=710MHz		Band 17					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-71.7	-71.48	-72.11	-80.65	-80.35	-81.4
	22	-67.8	-67.75	-68.11	-74.35	-74.05	-75.16
	24	-63.97	-63.65	-64.15	-67.95	-67.8	-68.85
	26	-60.22	-59.8	-60.19	-61.57	-61.4	-62.48
	28	-56.44	-55.95	-56.05	-55.7	-55.54	-56.64
	30	-52.65	-52.22	-52.66	-50.15	-50.11	-51.13

6.2.10 Harmonics for Band 20

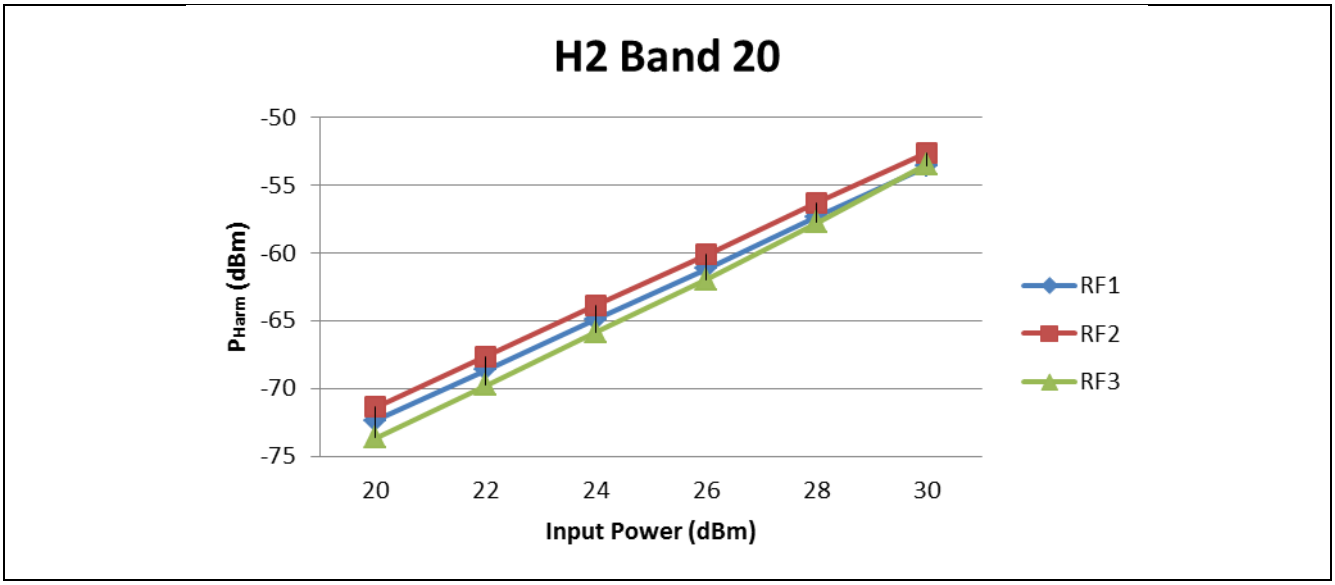


Figure 72 2nd harmonics at fc=847MHz

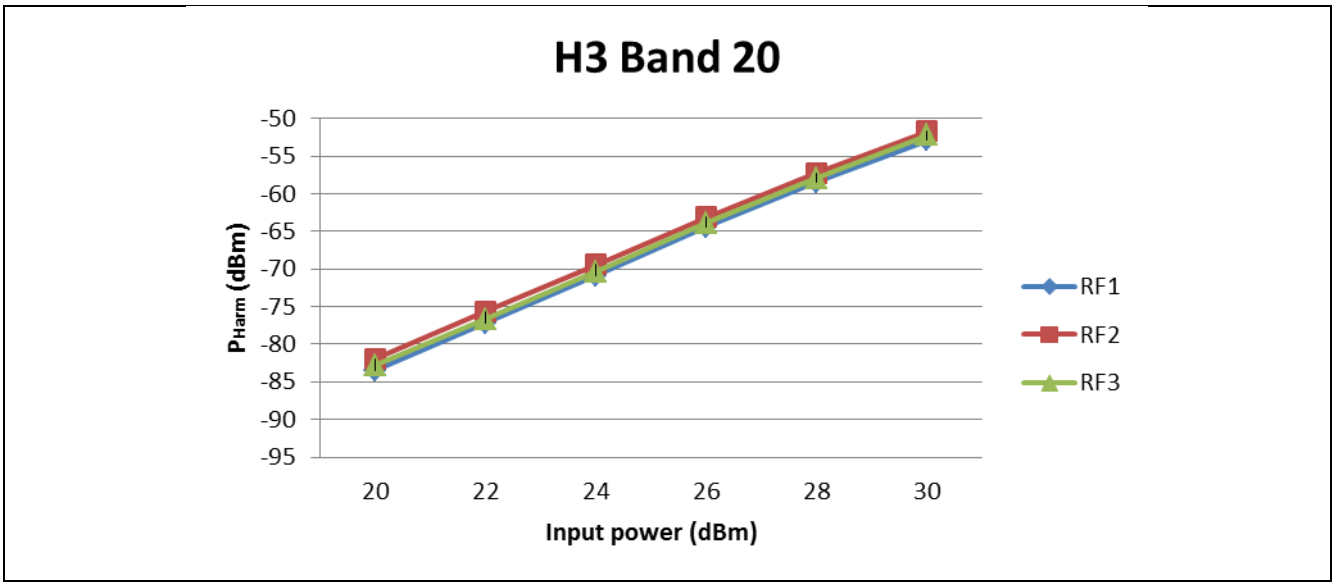


Figure 73 3rd harmonics at fc=847MHz

fc=847MHz		Band 20					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-72.36	-71.36	-73.65	-83.47	-81.95	-82.75
	22	-68.63	-67.63	-69.75	-77.15	-75.65	-76.65
	24	-64.88	-63.87	-65.85	-70.88	-69.38	-70.35
	26	-61.15	-60.14	-61.95	-64.36	-63.08	-63.86
	28	-57.35	-56.28	-57.78	-58.46	-57.25	-57.9
	30	-53.58	-52.61	-53.45	-52.95	-51.75	-52.25

6.2.11 Harmonics for Band 25

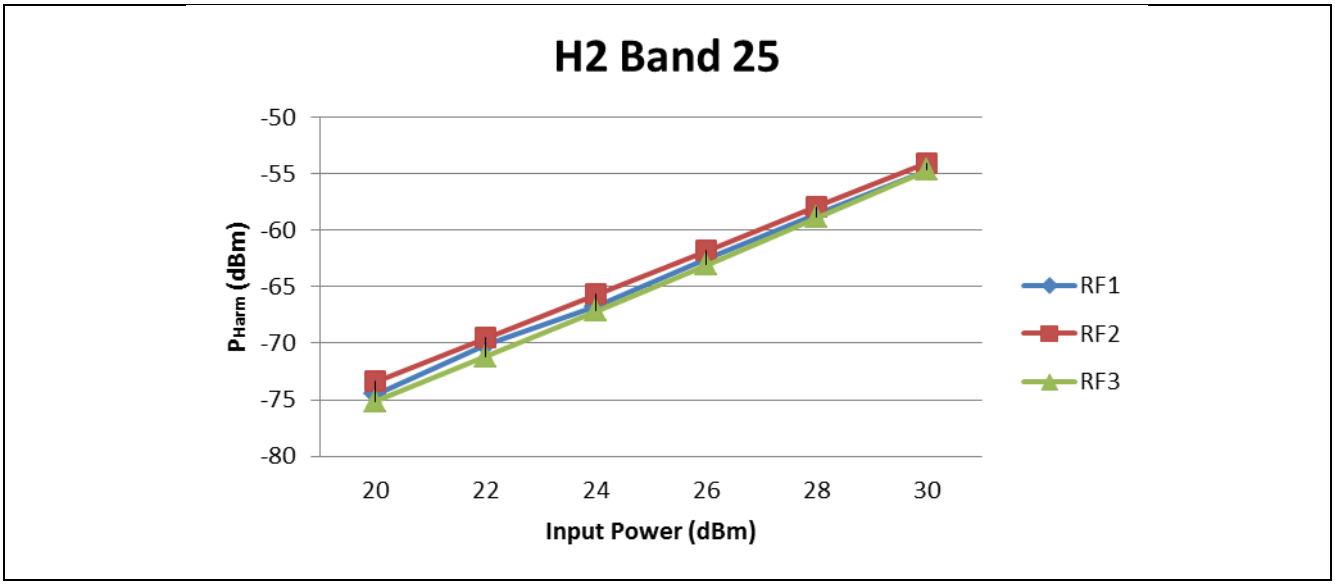


Figure 74 2nd harmonics at fc=1882,5MHz

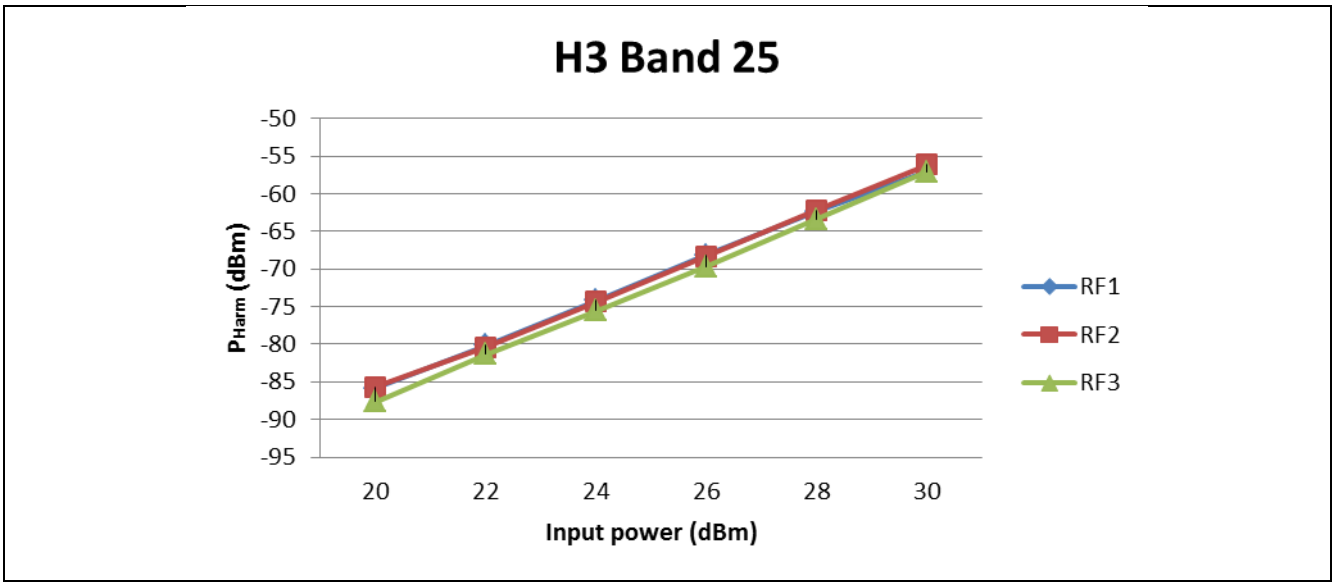


Figure 75 3rd harmonics at fc=1882,5MHz

fc=1882.5MHz		Band 25					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-74.5	-73.4	-75.15	-85.8	-85.7	-87.62
	22	-70.15	-69.5	-71.15	-80.15	-80.43	-81.35
	24	-66.72	-65.64	-67.15	-74.15	-74.35	-75.55
	26	-62.5	-61.83	-63.05	-68.12	-68.3	-69.65
	28	-58.55	-57.88	-58.85	-62.35	-62.15	-63.35
	30	-54.65	-54.05	-54.68	-57.01	-56.15	-57.05

6.2.12 Harmonics for Band 30

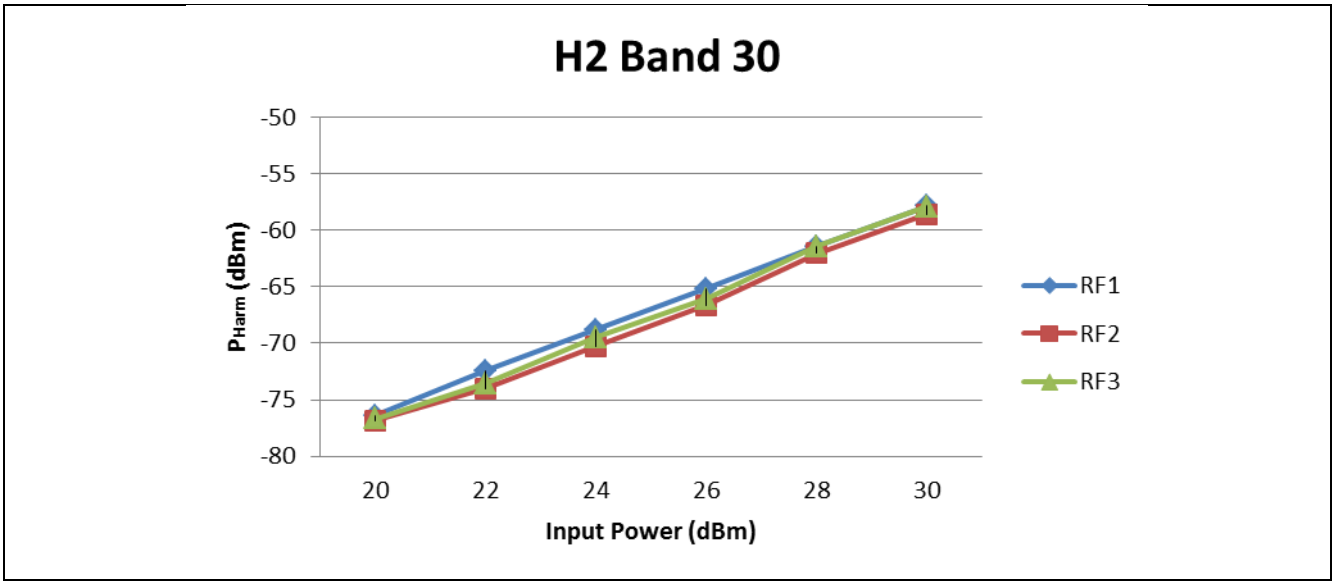


Figure 76 2nd harmonics at fc=2310MHz

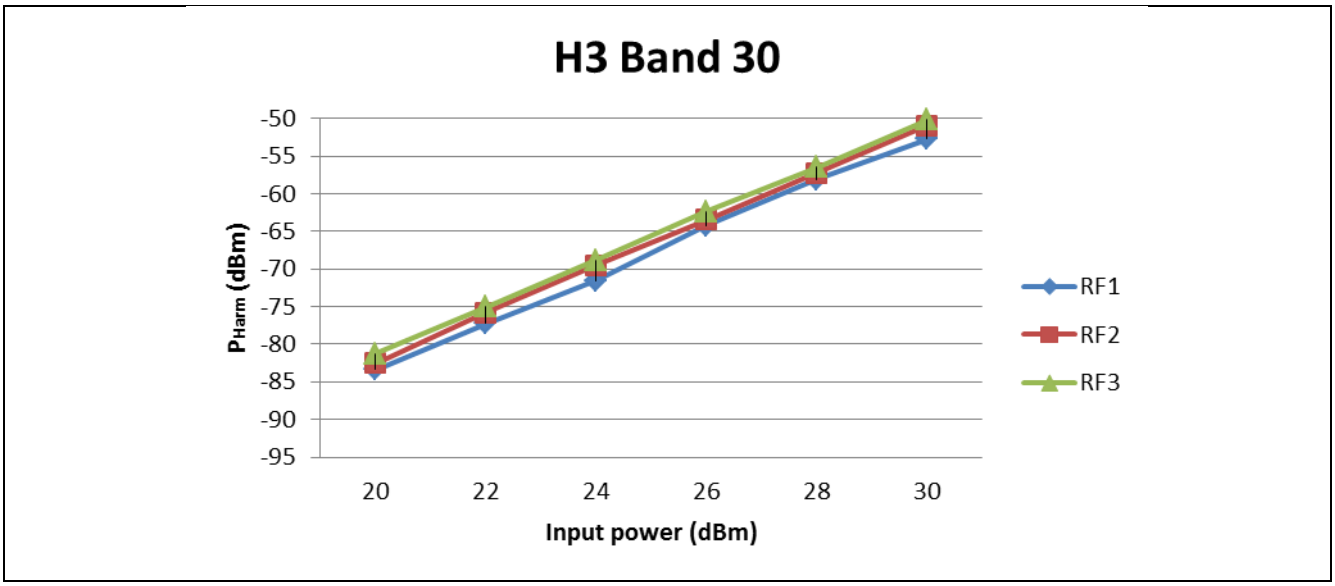


Figure 77 3rd harmonics at fc=2310MHz

fc=2310MHz		Band 30					
		H2			H3		
		RF1 (dBm)	RF2 (dBm)	RF3 (dBm)	RF1 (dBm)	RF2 (dBm)	RF3 (dBm)
RFin (dBm)	20	-76.37	-76.82	-76.66	-83.35	-82.51	-81.21
	22	-72.43	-74	-73.55	-77.27	-75.76	-75.07
	24	-68.76	-70.28	-69.45	-71.51	-69.51	-68.8
	26	-65.16	-66.66	-66.06	-64.23	-63.45	-62.34
	28	-61.4	-62.04	-61.4	-58.13	-57.22	-56.48
	30	-57.84	-58.57	-57.88	-52.75	-50.96	-50.21

7 Evaluation Board and Layout Information

7.1 Evaluation Board

In this application note, the following PCB is used:

PCB Marking: **BGS13xN9**

PCB material: **FR4**

ε_r of PCB material: **4.3**

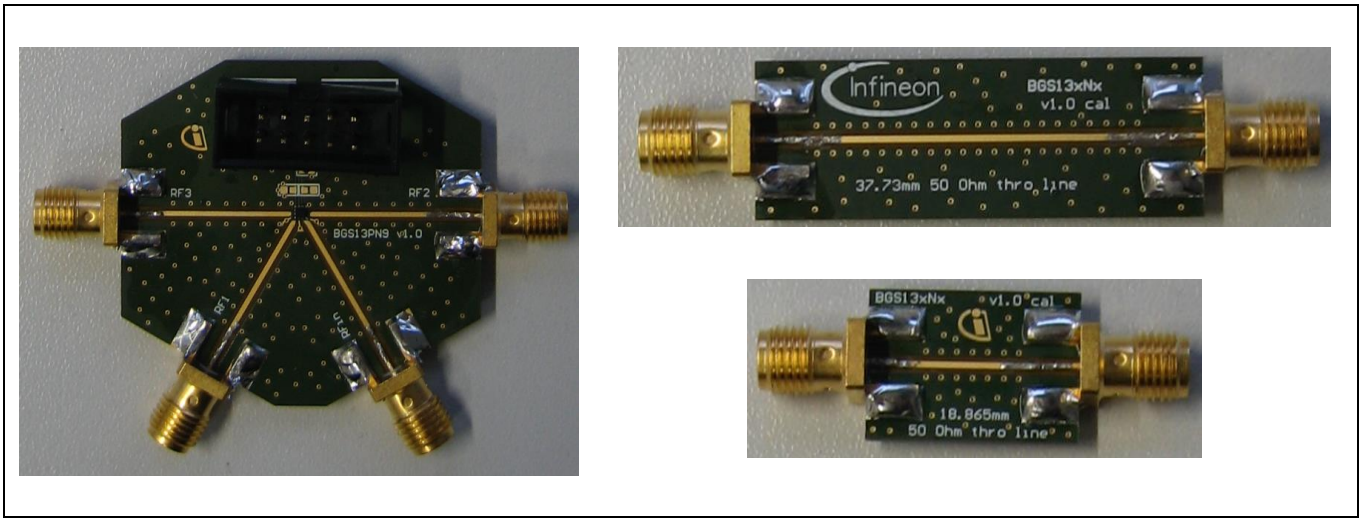


Figure 78 BGS13S2N9 Application Board and deembedding kit

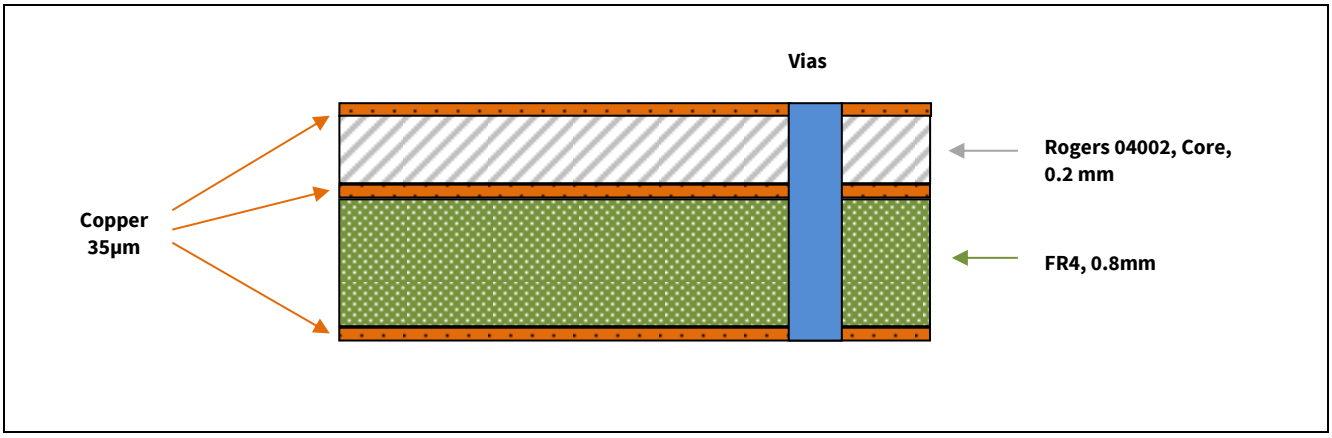


Figure 79 PCB crosssection of the evaluation board for BGS13S2N9

7.2 Measurement description and deembedding

Below is a picture of the evaluation board used for the measurements (SMA connector for deembeding procedure). The board is designed in the way that all connecting 50 Ohm lines have the same length.

To get correct called “device level” measurement values for the insertion loss of the BGS13S2N9 all influences and losses of the evaluation board, lines and connectors have to be eliminated. Therefore a separate deembedding board, representing the line length is necessary.

After full port calibration of the network analyzer (NWA) a deembedding has to be done in several steps:

- Use an SMA connector whose inner conductor has been removed to tune out one of the SMA to PCB transitions using the port extension on one port (Figure 80). Turn port extensions on.
- Measure S21 of the halfthru structure (BGS13S2N9 Application Board and deembedding kit, smallest board) with port extension enabled. The result is the deembedding of S21 including only one SMA connector and the transmission line to the chip. Store this as Sparameter (s2p) file.
- Turn all port extension off.
- Load the stored sparameter file as deembedding on all used NWA ports
- Check insertion loss with the deembedding through board (BGS13S2N9 Application Board and deembedding kit right upper board)

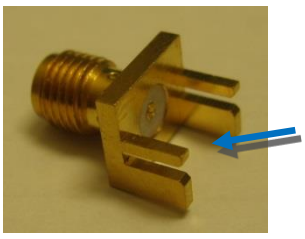


Figure 80 SMA connector for deembeding procedure

If the check of the deembedding shows an insertion loss of the through about + 0.4 dB (depending on the measurement setup accuracy, e.g. NWA) then the Device itself can be measured.

8 Authors

Renat Rius, Application Engineer of Business Unit “RF and Protection Devices”
André Dewai, Senior Application Engineer of the Business Unit “RF and Protection Devices”

Authors

Revision History

Major changes since the last revision

Page or Reference	Description of change

Edition 2016-02-03

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference <AN_2015_02_PL32_001>

IMPORTANT NOTICE

The information contained in this application note is given as a hint for the implementation of the product only and shall in no event be regarded as a description or warranty of a certain functionality, condition or quality of the product. Before implementation of the product, the recipient of this application note must verify any function and other technical information given herein in the real application. Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this application note.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer's technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

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

WARNINGS

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.