BGM1143N9

BGM1143N9 FEM for GNSS with LTE Band-13 (777-787 MHz) suppression, 0201 components

Application Note AN335

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RF and Protection Devices

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Previous Revision: None	
Page	**Subjects (major changes since last revision)**

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1 Introduction of Global Navigation Satellite Systems (GNSS)

The BGM1143N9 is a Front End Module (FEM) for Global Navigation Satellite Systems (GNSS) application. It is based on Infineon Technologies' B7HF Silicon-Germanium (SiGe) technology, enabling a cost-effective solution in a TSNP-9-1 leadless package with ultra low noise figure, high linearity, low current consumption and high gain, over a wide range of supply voltages from 1.5 V up to 3.3 V. All these features make BGM1143N9 an excellent choice for GNSS FEM as it improves sensitivity, provide better immunity against out-of-band jammer signals, reduces filtering requirement and hence the overall cost of the GNSS receiver.

The GNSS satellites are at an orbit altitude of more than 20,000 km away from earth's surface and transmit power in the range of +47 dBm. After taking losses (atmospheric, antenna etc.) into account, the received signal strength at the GNSS device input is very low in the range of -130 dBm. The ability of the GNSS device to receive such low signal strength and provide meaningful information to the end-user depends strongly on the noise figure of the GNSS receives chain. This ability which is called receiver sensitivity can be improved by using a FEM with low noise figure and high gain at the input of the receiver chain. The improved sensitivity results in a shorter Time-To-First-Fix (TTFF), which is the time required for a GNSS receiver to acquire satellite signals and navigation data, and calculate a position.
Noise figure of the FEM defines the overall noise figure of the GNSS receiver system. This is where BGM1143N9 excels by providing noise figure as low as 1.5 dB and high gain of 15.8 dB, thereby improving the receiver sensitivity significantly. A simple overview of the GNSS RF system in a mobile phone or other handheld devices is shown in Figure 1.

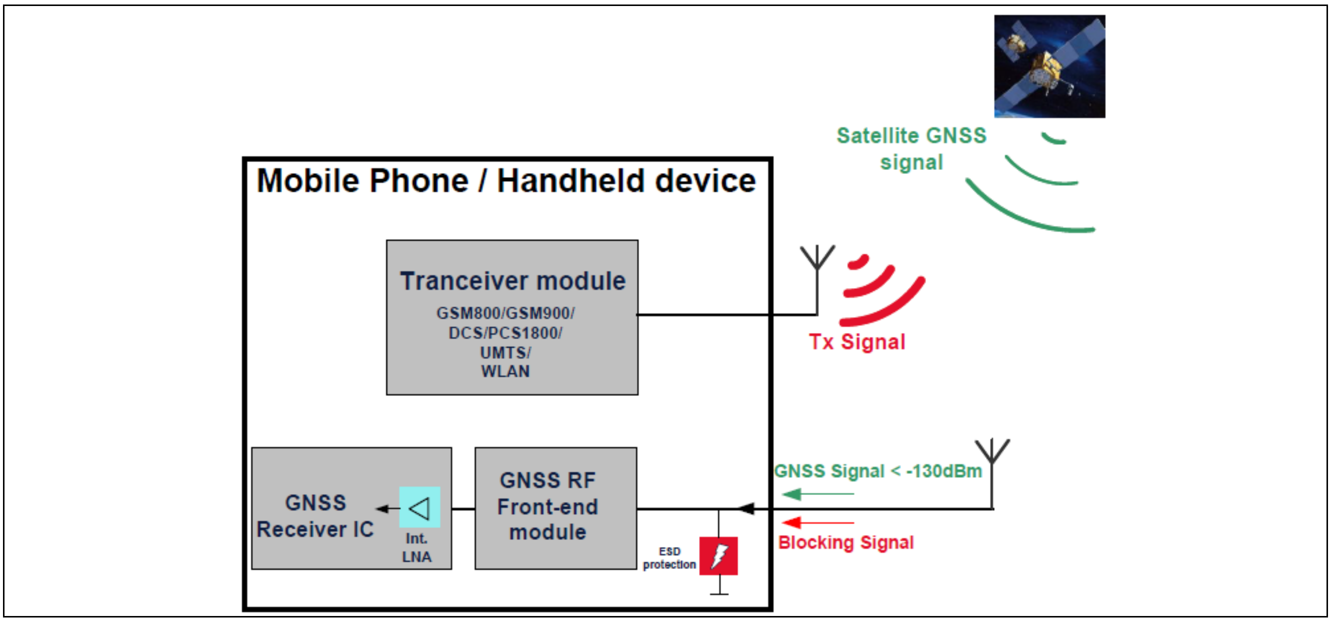

Figure 1 RF System Ovrview: Mobile Phone

The ever growing demand to integrate more and more functionality into one device leads to many challenges when transmitter/receiver has to work simultaneously without degrading the performance of each other. In today's smart-phones a GNSS receiver simultaneously co-exists with transceivers in the GSM/EDGE/UMTS/LTE bands. These 3G/4G transceivers transmit high power in the range of +24 dBm which due to insufficient isolation couple to the GNSS receiver. The cellular signals can mix to produce Intermodulation products exactly in the GNSS receiver frequency band. For example, GSM 1712.7 MHz mixes with UMTS 1850 MHz to produce third-order-product exactly at GPS band. To quantify the effect, BGM1143N9 shows out-of-band input IP3 at GPS band of +60 dBm, as a result of frequency mixing between GSM 1712.7 MHz and UMTS 1850 MHz with power levels of +10 dBm. Due to this high out-of-band input 3rd order intercept point (IIP3); BGM1143N9 is especially suitable for the GPS function in mobile phones.

As the industry inclines toward assembly miniaturization and also surface mount technology matures, there is a desire to have smaller and thinner components. This is especially the case with portable electronics where higher circuit density allows device design flexibility and also optimum use of the limited space available. BGM1143N9 has a small package with dimensions of 1.5mm x 1.1mm x 0.73mm and it requires only two external components, two inductors for providing the input matching. All the device/phone manufacturers implement very good power supply filtering on their boards so that the RF bypass capacitor mentioned

in this application circuit may not be needed in the end. The minimal number of external SMD components reduces the application bill of materials, assembly complexity and the PCB area thus making it an ideal solution for compact and cost-effective GNSS LNA. The output of the BGM1143N9 is internally matched to 50 Ω, and a DC blocking capacitor is integrated on-chip, thus no external component is required at the output.

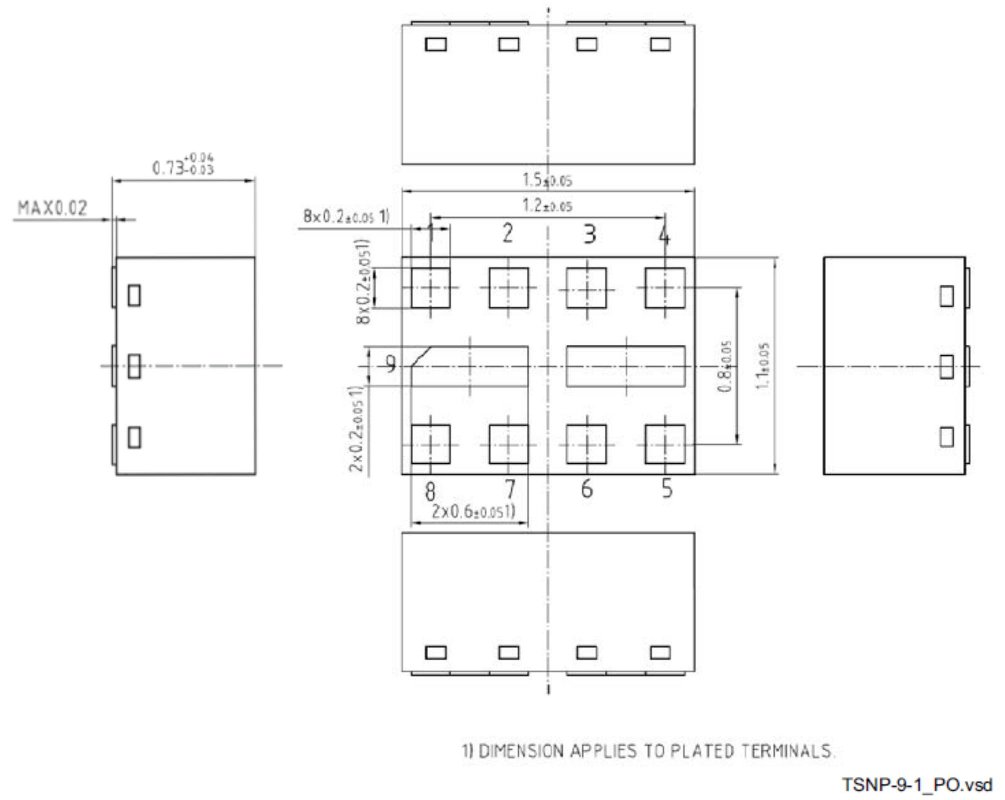

Figure 2 BGM1143N9 TSNP-9-1 leadless Package size

The device also integrates an on-chip ESD protection which can resist until 2 kV (referenced to human body model) in all pins. The integrated power on/off feature provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the low current consumption (3.8 mA) makes the device suitable for portable technology like GNSS receivers and mobiles phones.

The Internal circuit block diagram of the BGM1143N9 is presented in Figure 3. Table 1 shows the pin assignment of BGM1143N9. Table 2 shows the truth table to turn on/off BGM1143N9 by applying different voltage to the PON pin.

2 BGM1143N9 Overview

2.1 Features

- High insertion power gain: 15.8 dB
- Out-of-band input 3rd order intercept point: +60 dBm
- Input 1 dB compression point: -6 dBm
- Low noise figure: 1.5 dB
- Low current consumption: 3.8 mA
- Operating frequencies: 1550 - 1615 MHz
- Supply voltage: 1.5 V to 3.3 V
- Digital on/off switch (1 V logic high level)
- Ultra small TSNP-9-1 leadless package (footprint: 1.5 x 1.1 mm^2)
- RF output internally matched to 50 Ω
- Only 2 external SMD component necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

2.2 Key Applications of BGM1143N9

➢ Ideal for all Global Navigation Satellite Systems (GNSS) like

- GPS (Global Positioning System) working in the L1 band at 1575.42 MHz
- GLONASS (Russian GNSS) working in the L1 band from 1598.06 MHz to 1605.38 MHz
- Galileo (European GNSS) working in the E2-L1-E1 band from 1559 MHz to 1592 MHz
- COMPASS (Chinese Beidou Navigation System) working in E2 band at 1561.10 MHz and E1 band at 1589.74 MHz

2.3 Description

The BGM1143N9 is a combination of a low-insertion-loss pre-filter with Infineon's high performance low noiseamplifier (LNA) for Global Navigation Satellite Systems (GNSS) from applications from 1550 MHz to 1615 MHz like GPS, GLONASS, Beidou, Galileo and others. All frequency bands can be used at the same time. Through the low insertion loss of the filter, the BGM1143N9 provides 15.8 dB gain, 1.5 dB noise figure and high linearity performance. In addition BGM1143N9 provides very high out-of-band attenuation in conjunction with a high input compression point. Its current consumption is as low as 3.8 mA. It operates over the 1.5 V to 3.6 V supply voltage range.

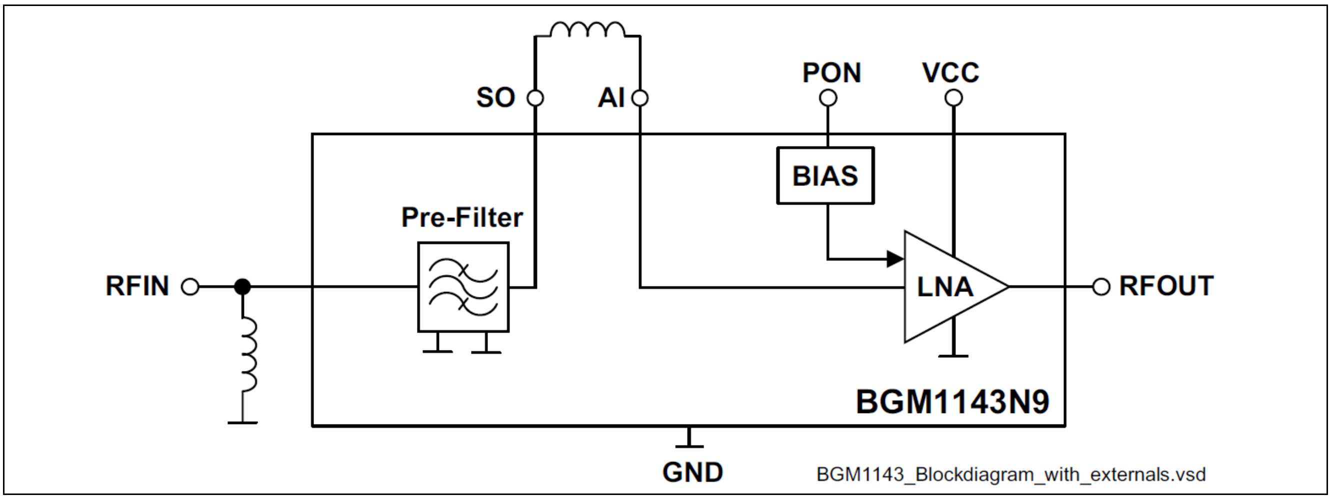

Figure 3 Equivalent Circuit Block diagram of BGM1143N9

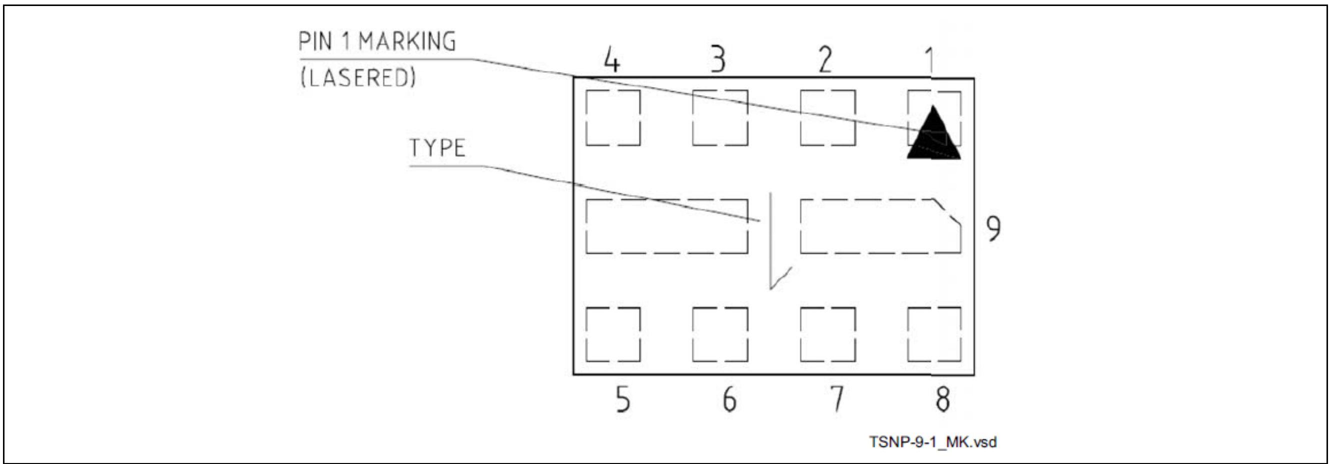

Figure 4 Package and pin connections of BGM1143N9

Table 1 Pin Assignment of BGM1143N9

Pin No.	Symbol	Function
1	VCC	DC supply Ground
2	PON	Power on control
3	GND	Ground
4	RFIN	RF input
5	GND	Ground
6	SO	Pre-filter output
7	AI	LNA input
8	RFOUT	RF Output
9	GND	Ground

Table 2 Pin Assignment of BGM1143N9

LNA Mode	Symbol	ON/OFF Control Voltage at PON pin	
		Min	Max
ON	PON, on	1.0 V	VCC
OFF	PON, off	0 V	0.4 V

3 Application Circuit and Performance Overview

Device: BGM1143N9

Application: BGM1143N9 FEM for GNSS with LTE Band-13 (777-787 MHz) suppression, 0201 components

PCB Marking: BGM1143N9

3.1 Summary of Measurement Results

Table 3 Electrical Characteristics for COMPASS/Galileo at Vcc = Vpon = 1.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			V	
DC Current	Icc	3.9			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	15.2	15.4	14.6	dB	
Noise Figure	NF	2.06	1.74	2.1	dB	PCB and SMA losses 0.1 dB are substracted
Input Return Loss	RLin	10.1	13	11.8	dB	
Output Return Loss	RLout	21.2	15.8	19.3	dB	
Reverse Isolation	IRev	24.4	23.8	24.7	dB	
Input P1dB	IP1dB	-8.3	-7.9	-7.6	dBm	f_{gal} = 1559 MHz f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605 MHz
Output P1dB	OP1dB	5.9	6.5	6	dBm	
Input IP3 In-band	IIP3	-3.7	-3.4	-2.9	dBm	$f_{1\ gal}$ = 1559 MHz, $f_{2\ gal}$ = 1560 MHz, f_{1gps} = 1575.42 MHz, $f_{2\ gps}$ = 1576.42 MHz, $f_{1GLONASS}$ = 1602 MHz, $f_{2GLONASS}$ = 1603 MHz Input power= -35 dBm
Output IP3 In-band	OIP3	11.8	12.1	12.4	dBm	
Rejection 750MHz[1)]	Rej_{750M}	64.8			dBc	f = 750 MHz
Rejection 900MHz[1)]	Rej_{900M}	51			dBc	f = 806 MHz - 928 MHz
Rejection 1800MHz[1)]	Rej_{1800M}	56.8			dBc	f = 1710 MHz - 1980 MHz
Rejection 2400MHz[1)]	Rej_{2400M}	43.6			dBc	f = 2400 MHz - 2500 MHz
Input P1dB	$IP1dB_{900M}$	31.9			dBm	f = 900 MHz
Input P1dB	$IP1dB_{1710M}$	29.6			dBm	f = 1710 MHz
LTE band-13 2nd Harmonic	H2	-75.1			dBm	f_{IN} = 787.76 MHz, P_{IN} = +15 dBm; f_{H2} = 1575.52 MHz

Table 3 Electrical Characteristics for COMPASS/Galileo at Vcc = Vpon = 1.8 V

Parameter	Symbol	Value	Unit	Comment/Test Condition
Input IP3 Out-of-band	$IIP3_{OOB}$	65.3	dBm	f_1 = 1712.7 MHz, P_{1IN} = +10 dBm; f_2 = 1850 MHz, P_{2IN} = +10 dBm; f_{IIP3} = 1575.4 MHz
Stability	k	>1	--	Unconditionnally Stable from 0 to 10GHz

Table 4 Electrical Characteristics for COMPASS/Galileo at Vcc = Vpon = 2.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	4.0			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	15.4	15.6	14.7	dB	
Noise Figure	NF	2.07	1.75	2.10	dB	PCB and SMA losses 0.1dB are substracted
Input Return Loss	RLin	10.2	13.6	12	dB	
Output Return Loss	RLout	21.9	17.3	20.7	dB	
Reverse Isolation	IRev	24.9	24.2	25	dB	
Input P1dB	IP1dB	-5.2	-4.8	-4.3	dBm	f_{gal} = 1559 MHz f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605 MHz
Output P1dB	OP1dB	9.2	9.8	9.4	dBm	
Input IP3 In-band	IIP3	-3.6	-3.3	-2.8	dBm	$f_{1\ gal}$ = 1559 MHz, $f_{2\ gal}$ = 1560 MHz, f_{1gps} = 1575.42 MHz, f_{2gps} = 1576.42 MHz $f_{1GLONASS}$ = 1602 MHz, $f_{2GLONASS}$ = 1603 MHz Input power= -35 dBm
Output IP3 In-band	OIP3	12	12.3	12.7	dBm	
Rejection 750MHz[1)]	Rej_{750M}	65			dBc	f = 750 MHz
Rejection 900MHz[1)]	Rej_{900M}	50.9			dBc	f = 806 MHz - 928 MHz
Rejection 1800MHz[1)]	Rej_{1800M}	57			dBc	f = 1710 MHz - 1980 MHz
Rejection 2400MHz[1)]	Rej_{2400M}	43.9			dBc	f = 2400 MHz - 2500 MHz
Input P1dB	$IP1dB_{900M}$	32.6			dBm	f = 900 MHz
Input P1dB	$IP1dB_{1710M}$	30.3			dBm	f = 1710 MHz
LTE band-13 2^{nd} Harmonic	H2	-74.9			dBm	f_{IN} = 787.76 MHz, P_{IN} = +15 dBm; f_{H2} = 1575.52 MHz

Table 3 Electrical Characteristics for COMPASS/Galileo at Vcc = Vpon = 1.8 V

Parameter	Symbol	Value	Unit	Comment/Test Condition
Input IP3 Out-of-band	$IIP3_{OOB}$	65.4	dBm	f_1 = 1712.7 MHz, P_{1IN} = +10 dBm; f_2 = 1850 MHz, P_{2IN} = +10 dBm; f_{IIP3} = 1575.4 MHz
Stability	k	>1	--	Unconditionnally Stable from 0 to 10GHz

1) Rejection is defined as following: [Gain at 1575.42 MHz] – [Attenuation@stopband frequency]

3.2 Summary BGM1143N9 as 1550-1615 MHz LNA for GNSS

This application note addresses the issue of out-of-band jammers and improving the immunity of BGM1143N9 against LTE Band-13 jammers.

The jamming resistance of BGM1143N9 against B13 jammer is improved by increasing the attenuation of the circuit at Band-13 (777-787 MHz). This is achieved by placing a notch filter using external SMDs before BGM1143N9. The component values are fine tuned so as to have optimal noise figure, jammer rejection, gain and input matching.

The circuit requires only four 0201 passive components including the notch filters. It has in band gain of 15.6 dB. The circuit achieves input return loss better than 10.2 dB, as well as output return loss better than 17 dB. At room temperature the noise figure is 1.75 dB (SMA and PCB losses are subtracted) for the GPS frequecncy. Furthermore, the circuit is unconditionally stable till 10 GHz.

At GPS frequency, using two tones spacing of 1 MHz, the output third order intercept point IIP3 reaches 12.3 dBm. And for the GLONASS frequency band, OIP3 reaches 12.7 dBm. Input P1dB of the GNSS LNA is about -4.8 dBm for the GPS frequency and -4.3 dBm for GLONASS frequency band. And this circuit shows very good input reffered H2 performance of -74.9 dBm for GPS frequency.

3.3 Schematics and Bill-of-Materials

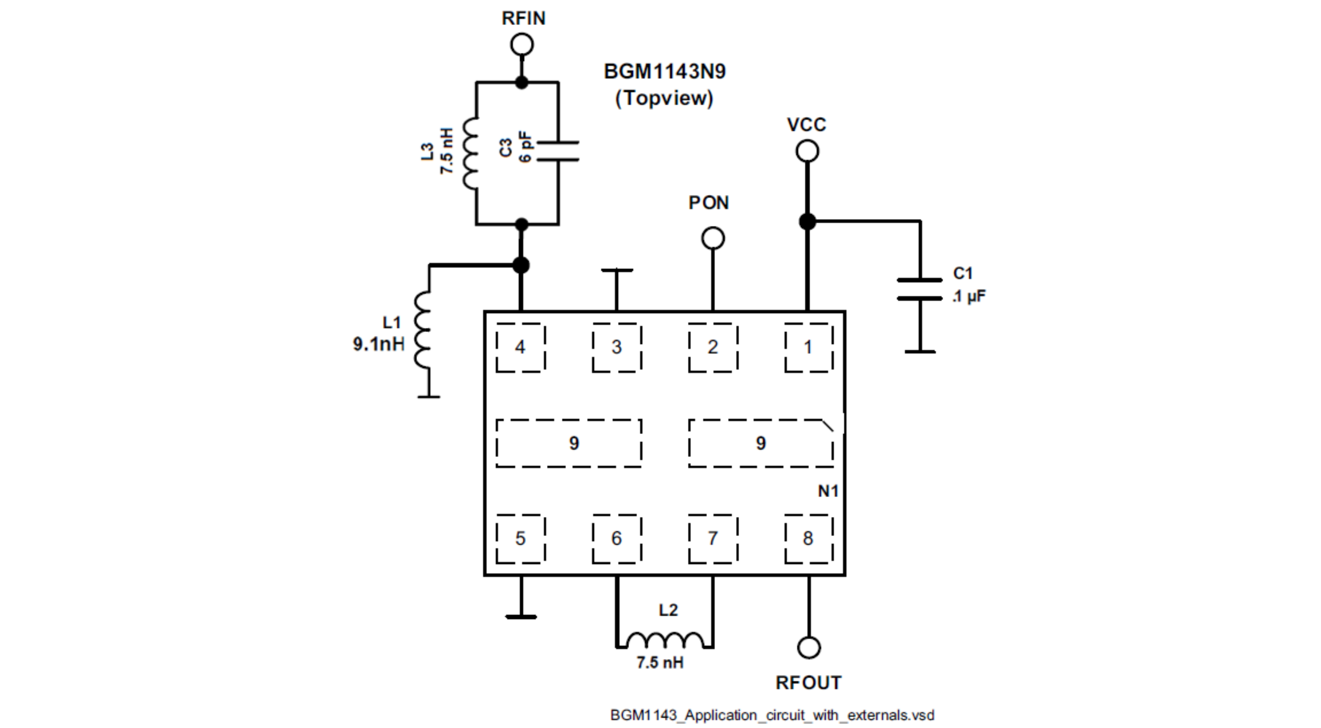

Figure 5 Schematic of the BGM1143N9 Application Circuit

Table 5 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	0.1	uF	0201	Various	RF bypass
C3	6	pF	0201	Various	787.76 MHz Notch
L1	9.1	nH	0201	Murata LQP type	Matching/ESD protection inductor
L2	7.5	nH	0201	Murata LQP type	LNA Input Matching
L3	7.5	nH	0201	Murata LQP type	787.76 MHz Notch
N1	BGM1143N9		TSNP-6-2	Infineon	SiGe LNA

4 Measurement Graphs

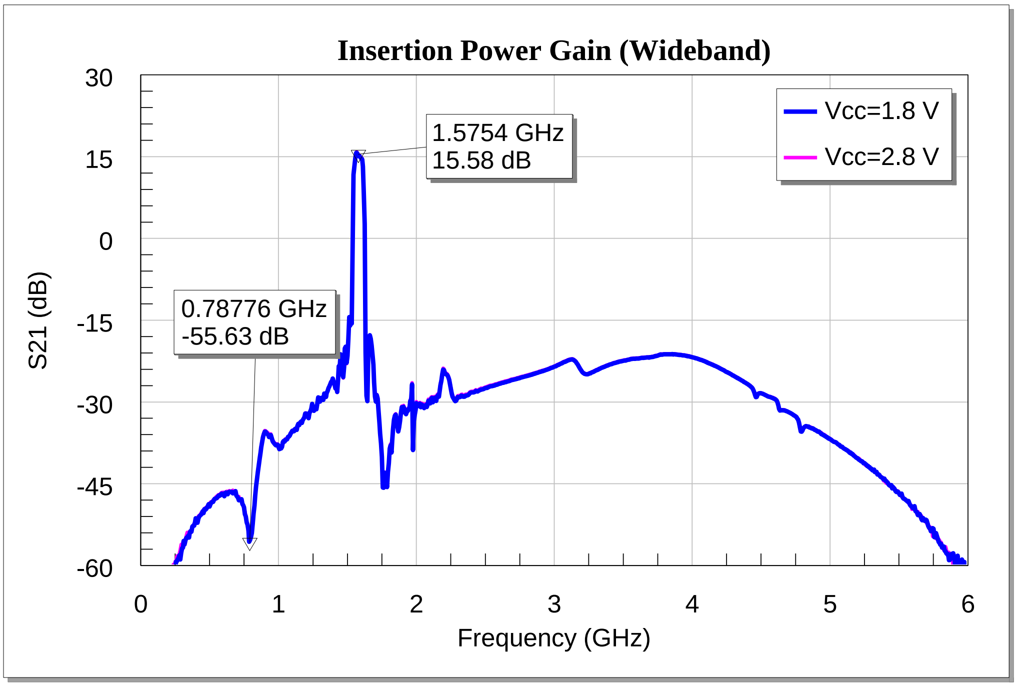

Figure 6 Power gain of BGM1143N9 for COMPASS, Galileo, GPS and GLONASS bands

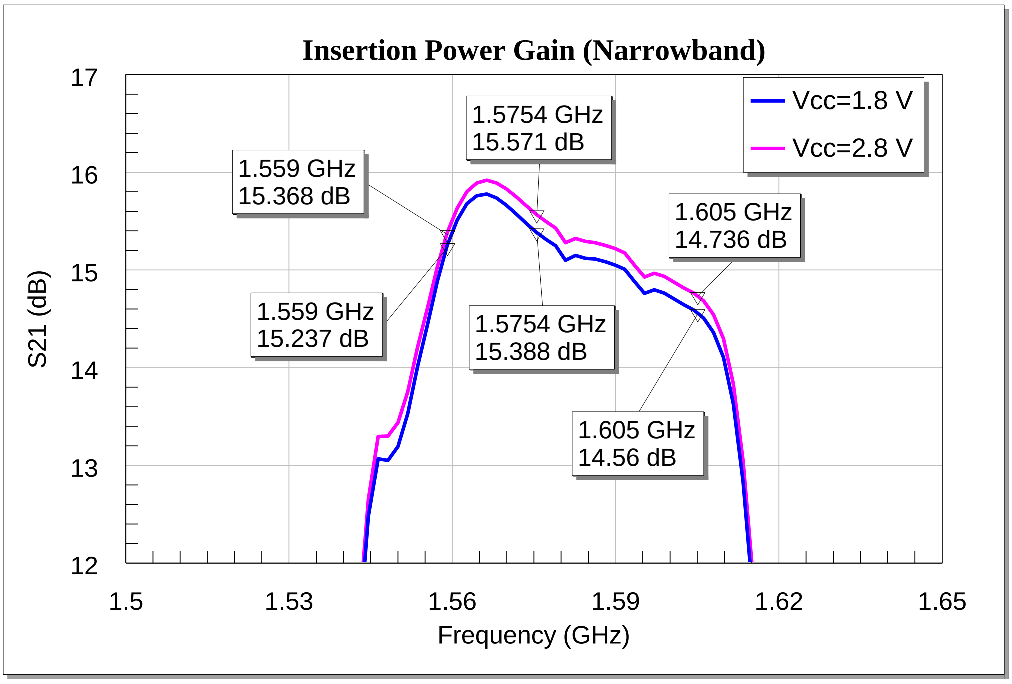

Figure 7 Narrowband power gain of BGM1143N9 for COMPASS, Galileo, GPS and GLONASS bands

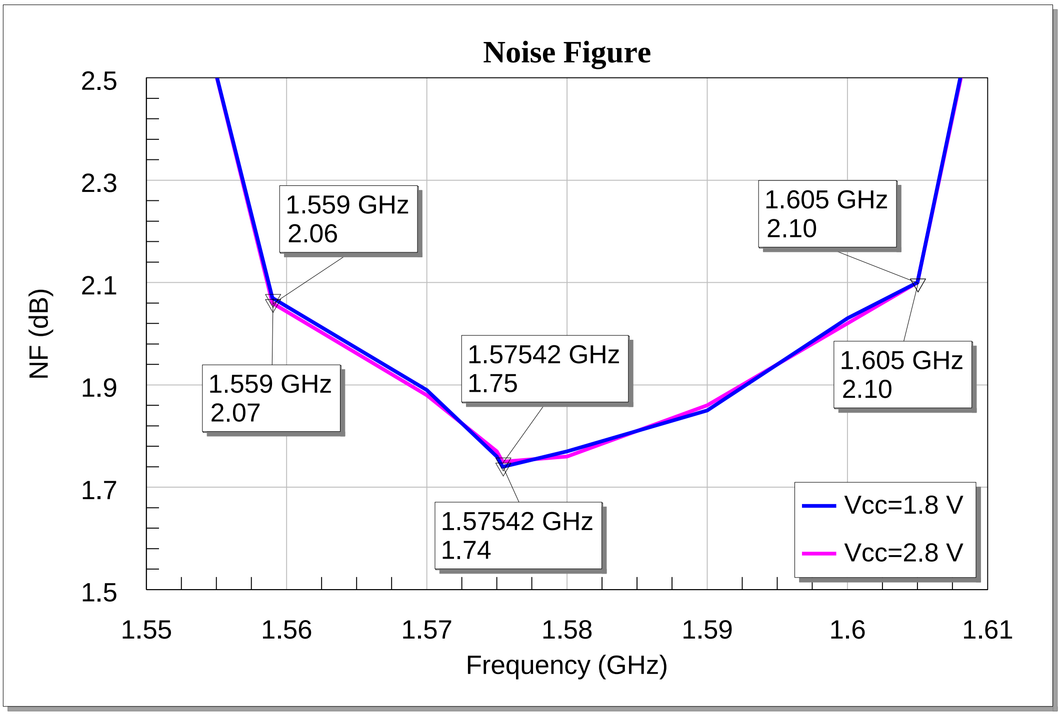

Figure 8 Noise figure of BGM1143N9 for COMPASS, Galileo, GPS and GLONASS bands

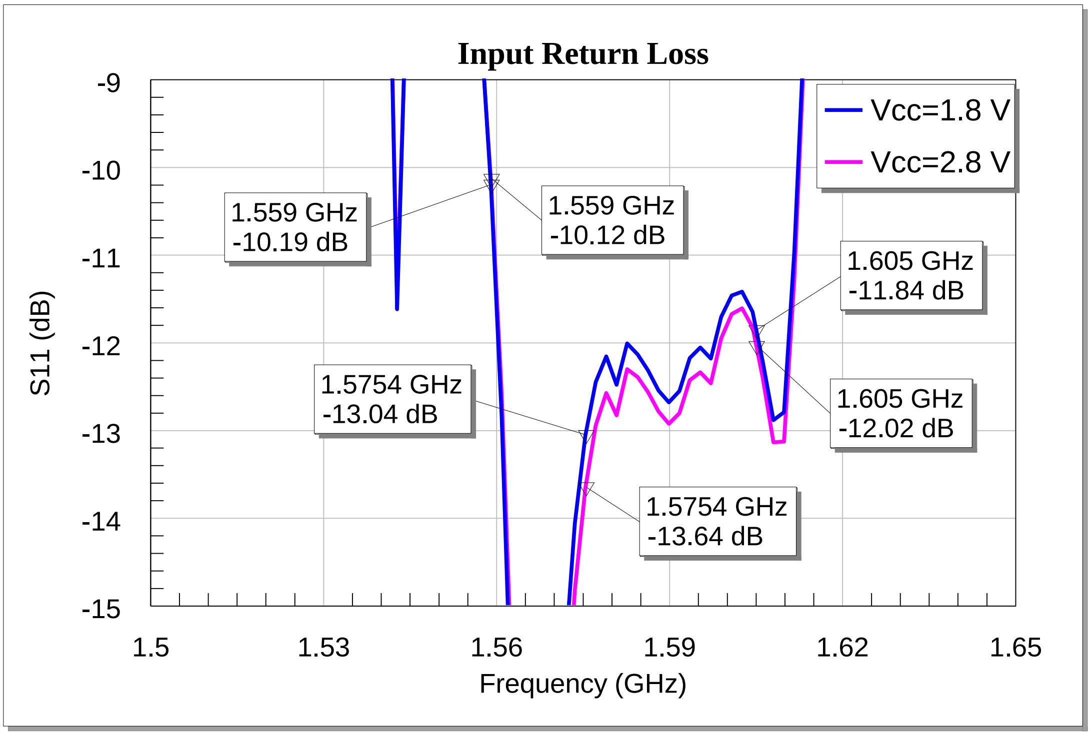

Figure 9 Input matching of BGM1143N9 for COMPASS, Galileo, GPS and GLONASS bands

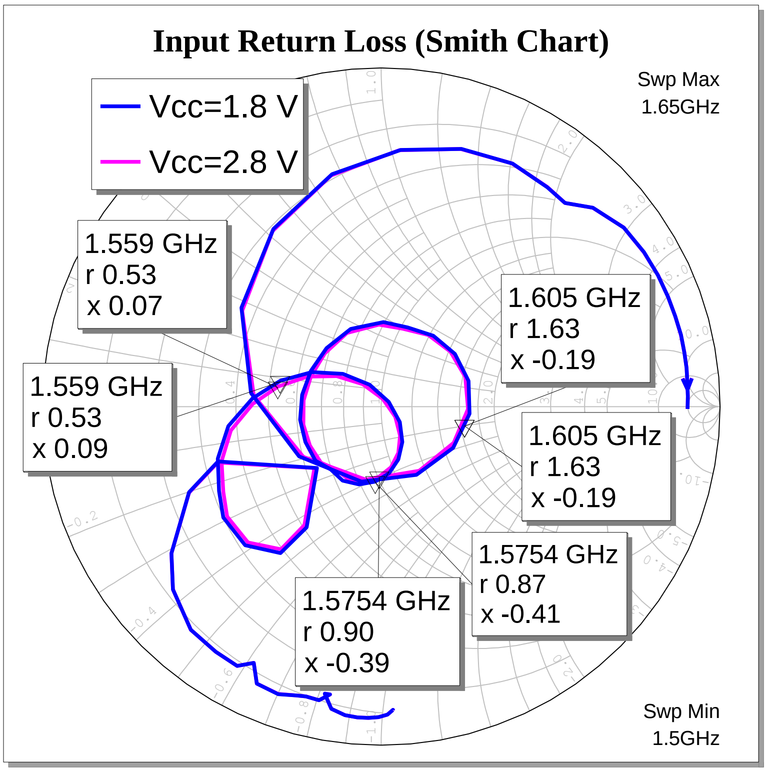

Figure 10 Input matching smith chart for COMPASS, Galileo, GPS and GLONASS bands

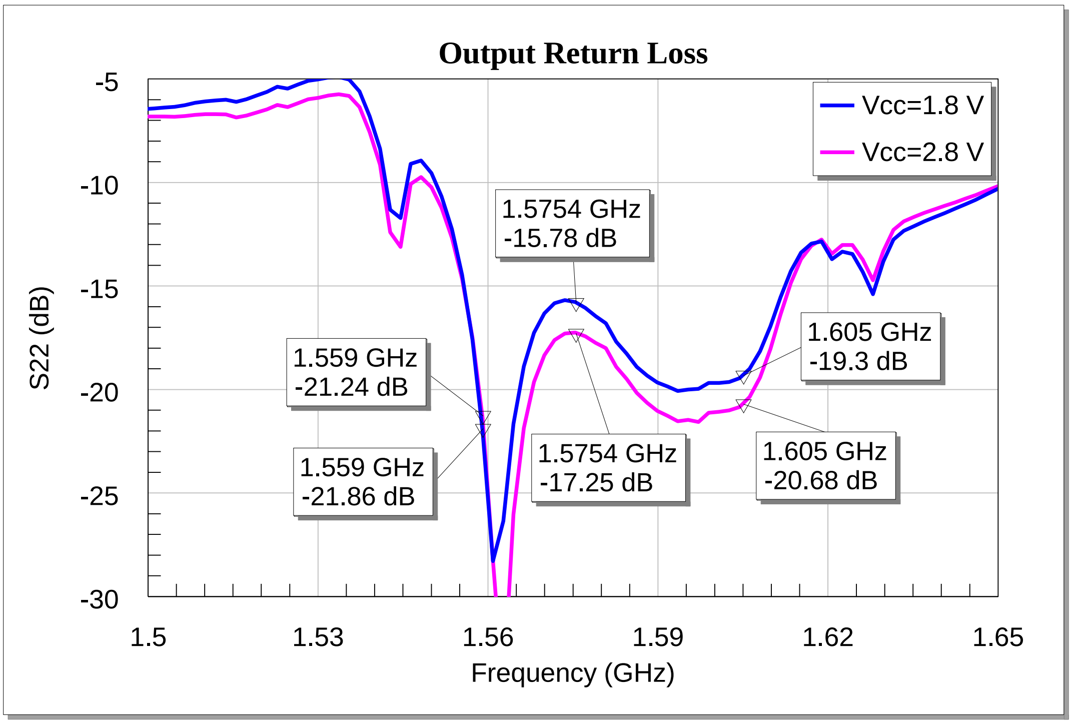

Figure 11 Output matching of BGM1143N9 for COMPASS, Galileo, GPS and GLONASS bands

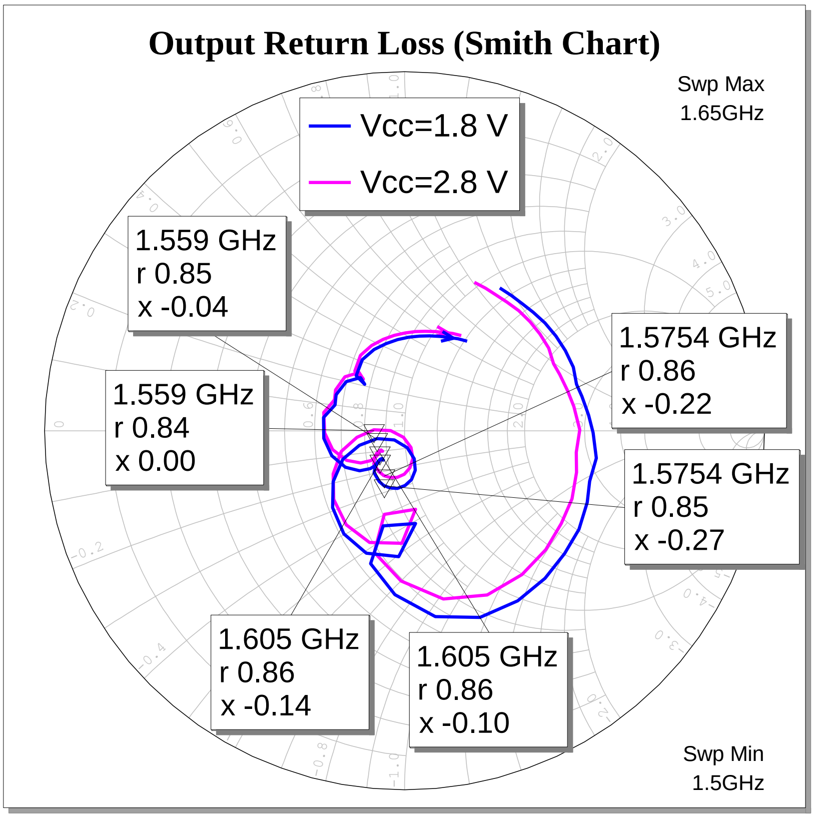

Figure 12 Output matching smith chart for COMPASS, Galileo, GPS and GLONASS bands

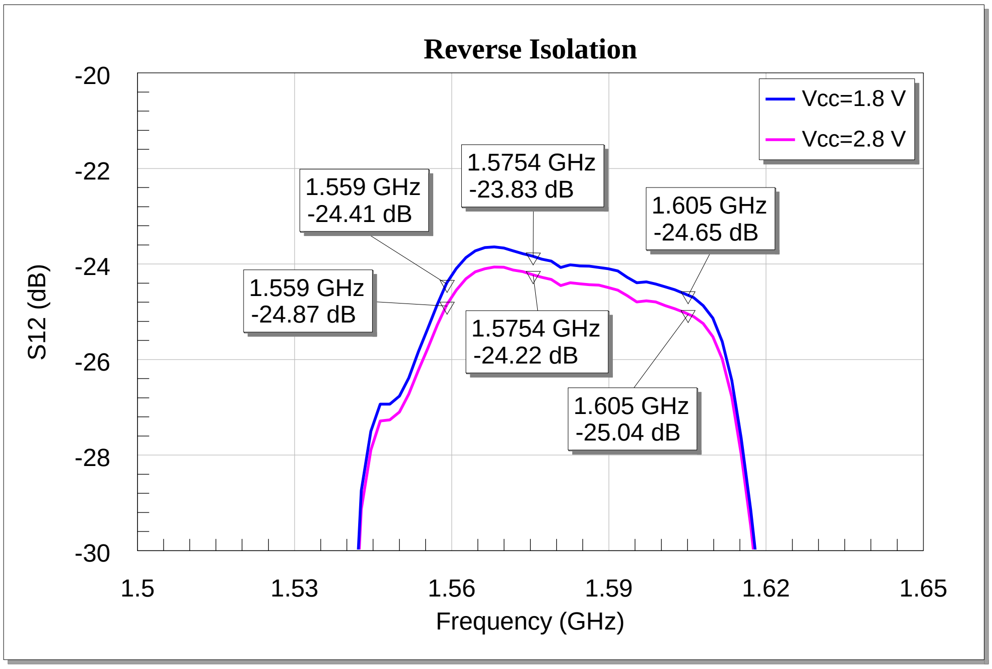

Figure 13 Reverse isolation of BGM1143N9 for COMPASS, Galileo, GPS and GLONASS bands

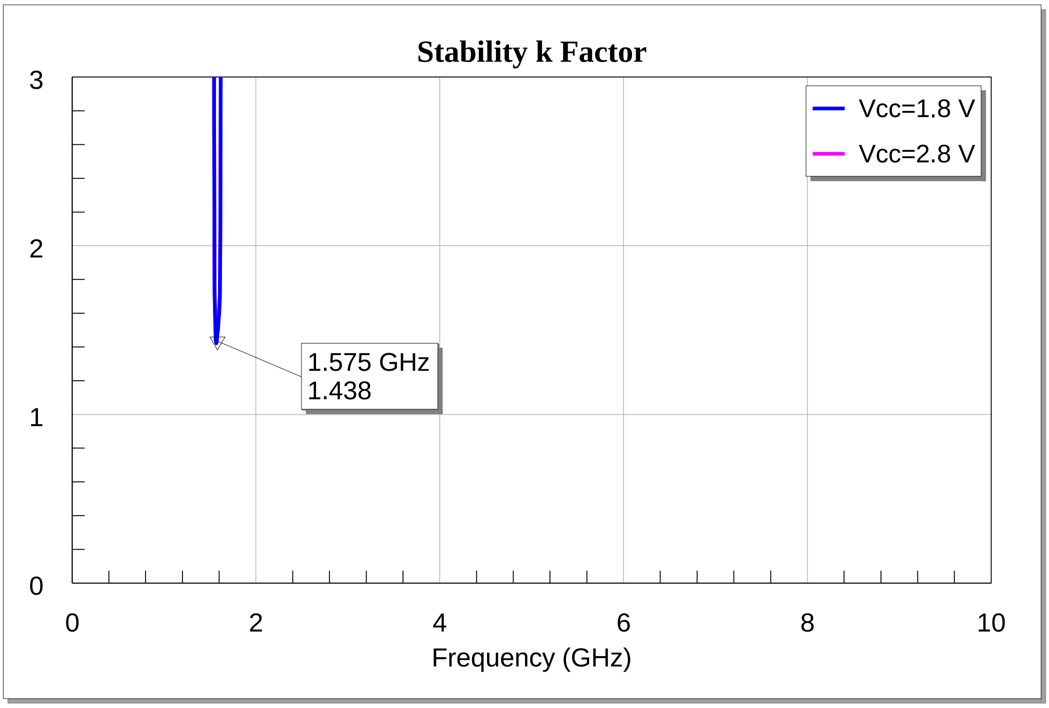

Figure 14 Stability factor k of BGM1143N9 upto 10 GHz

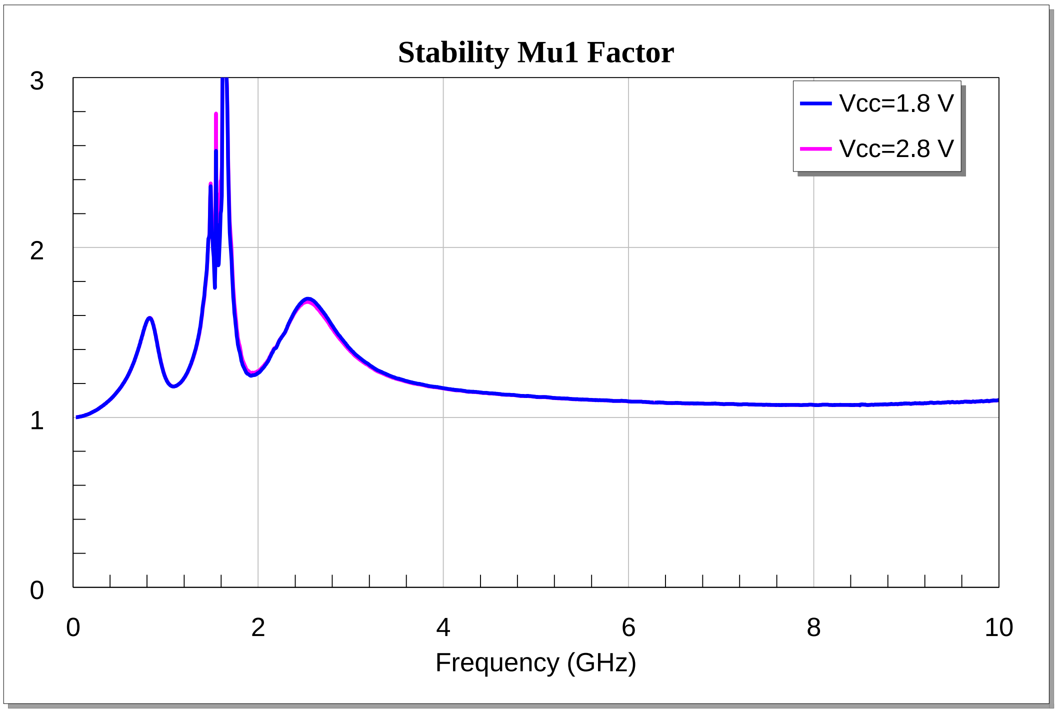

Figure 15 Stability factor μ1 of BGM1143N9 upto 10 GHz

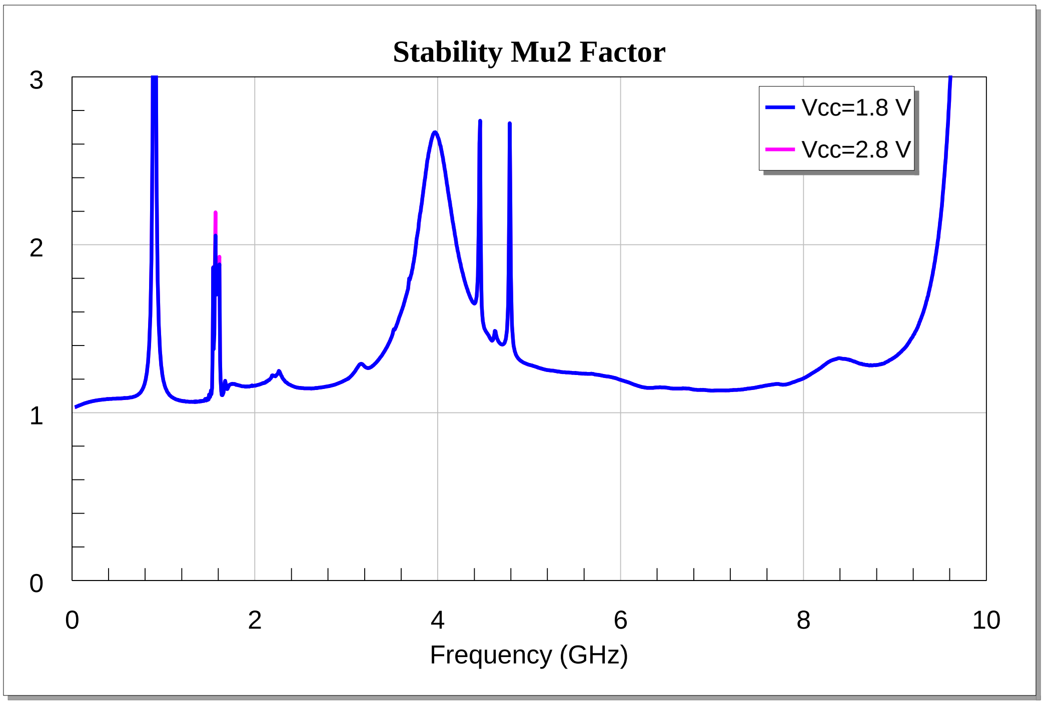

Figure 16 Stability factor µ2 of BGM1143N9 upto 10 GHz

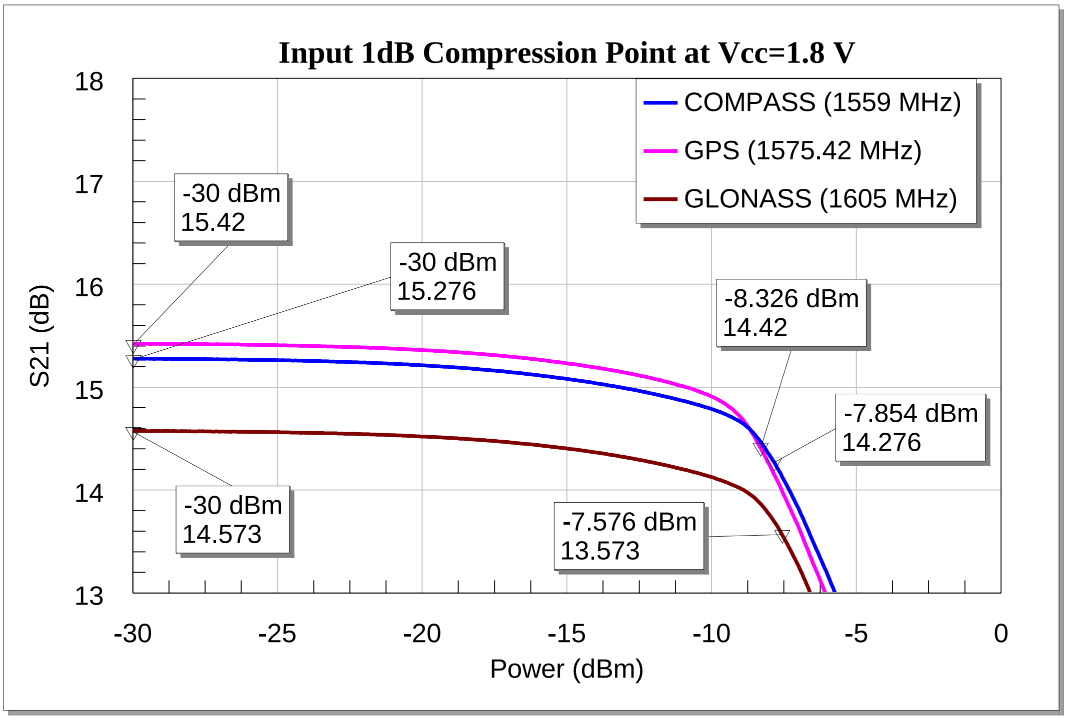

Figure 17 Input 1 dB compression point of BGM1143N9 at supply voltage of 1.8 V for COMPASS, Galileo, GPS and GLONASS bands

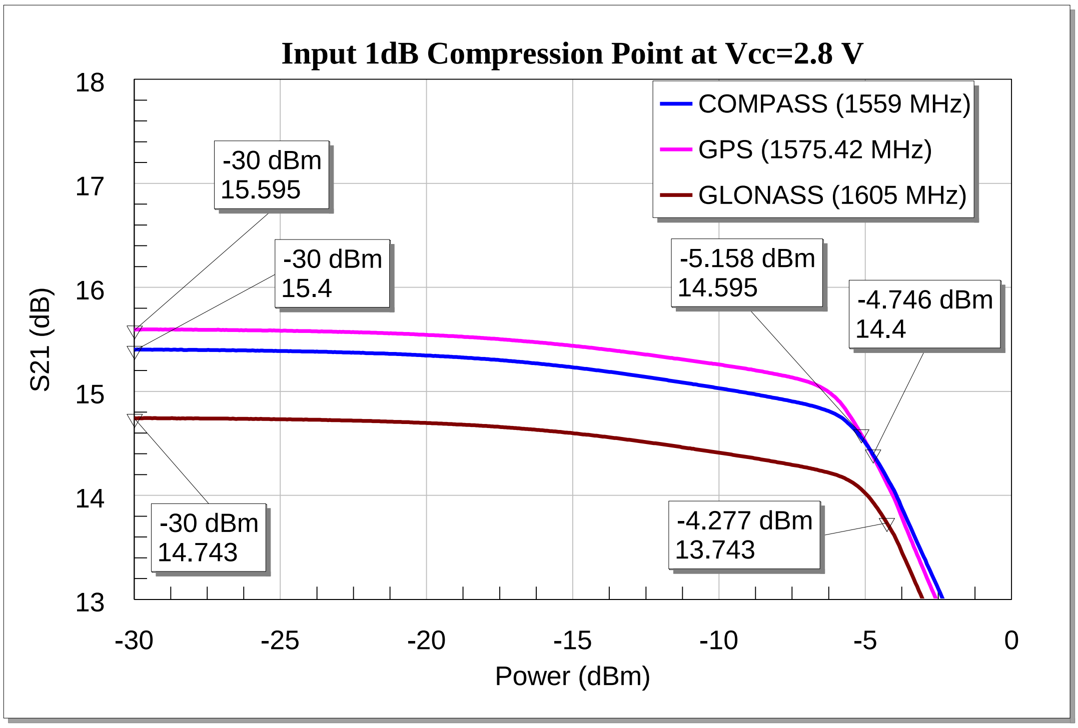

Figure 18 Input 1 dB compression point of BGM1143N9 at supply voltage of 2.8 V for COMPASS, Galileo, GPS and GLONASS bands

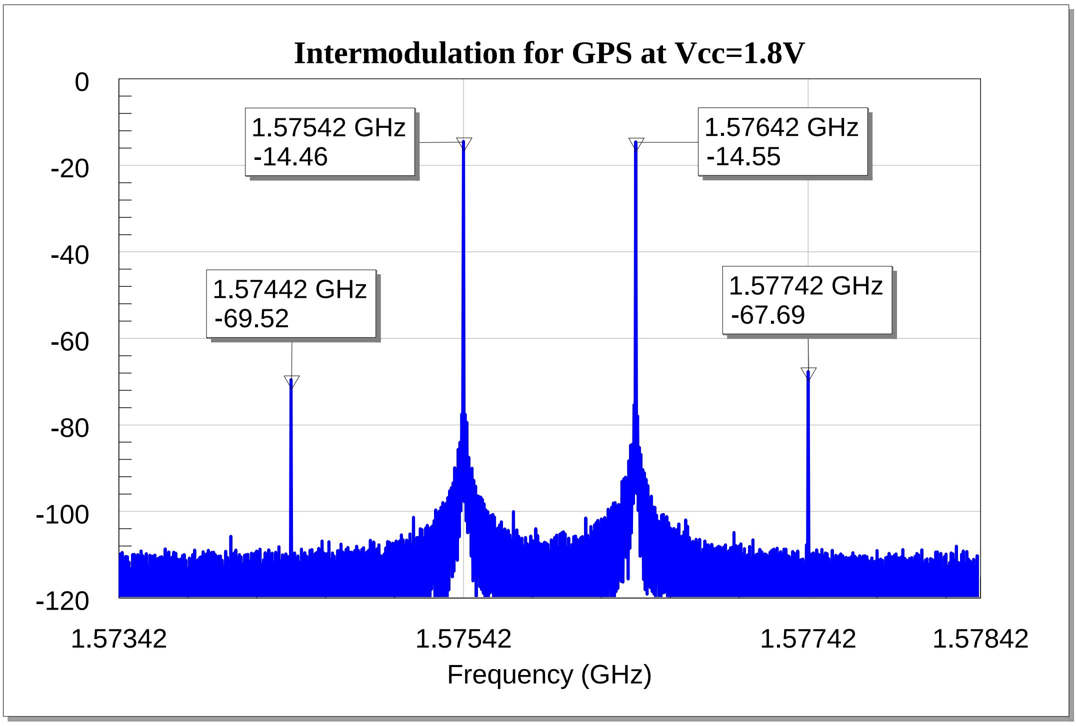

Figure 19 Carrier and intermodulation products of BGM1143N9 for GPS band at Vcc=1.8 V

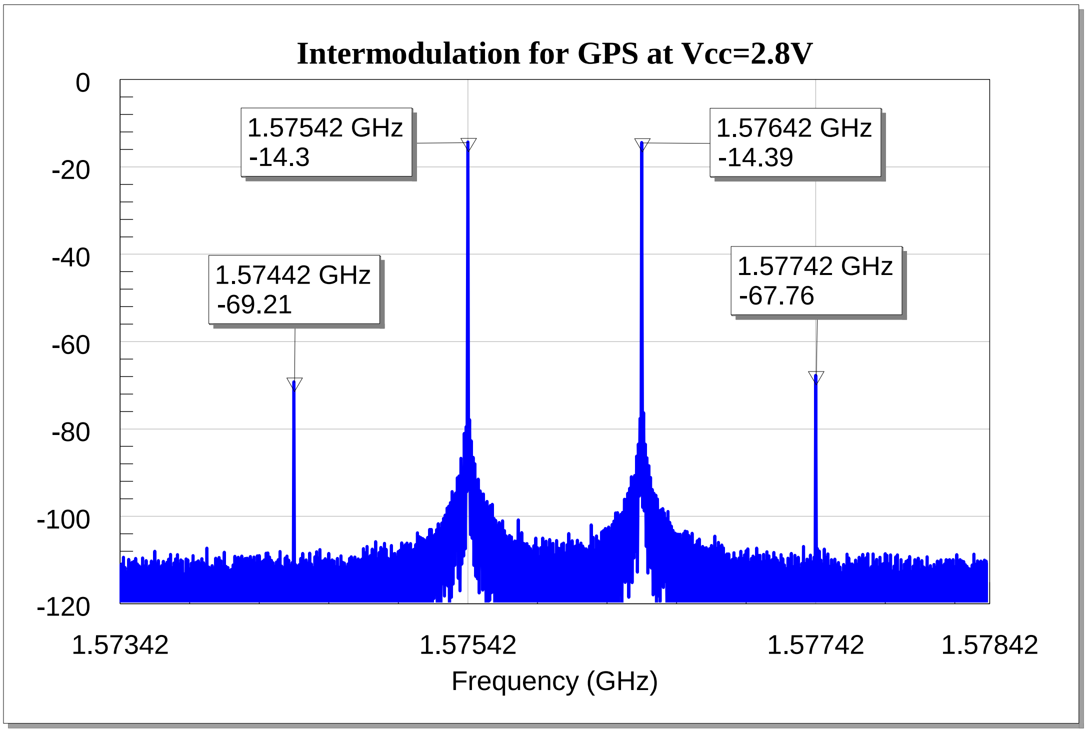

Figure 20 Carrier and intermodulation products of BGM1143N9 for GPS band at Vcc=2.8 V

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB material: Rogers

ε_r of PCB material: 3.4

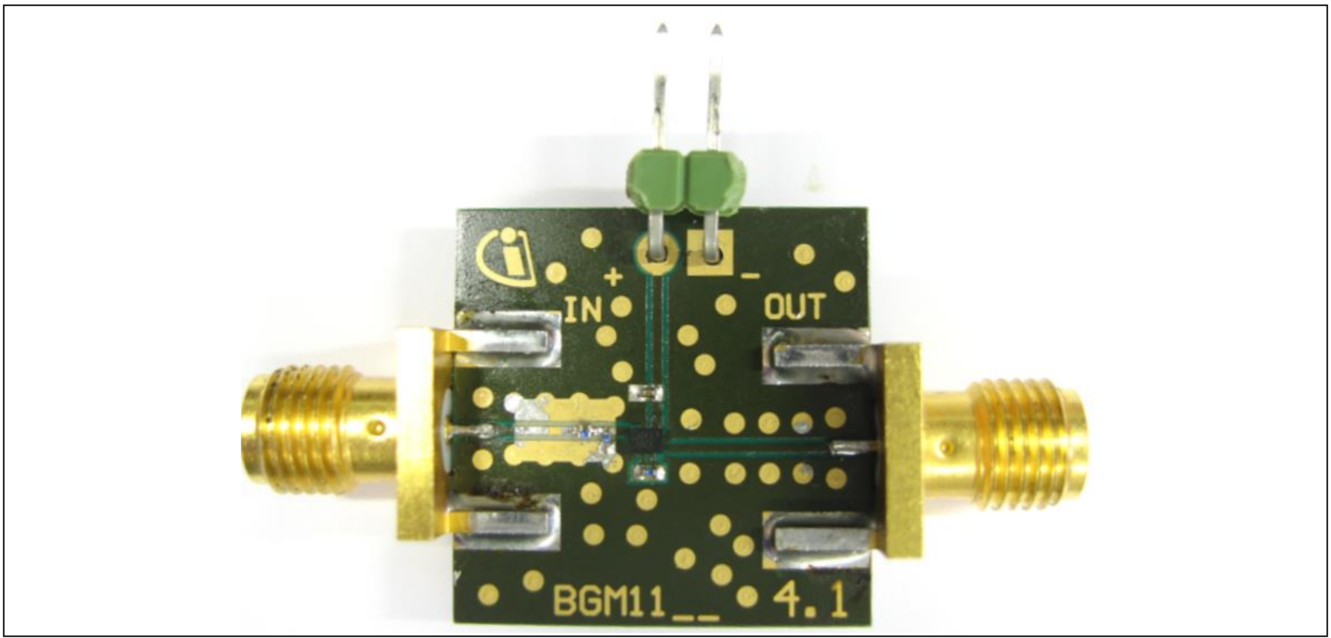

Figure 21 Picture of Evaluation Board (overview)

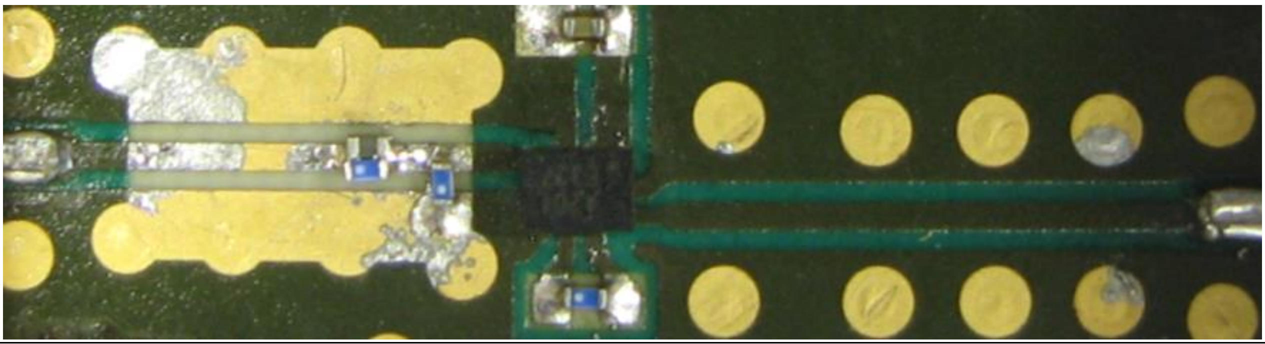

Figure 22 Picture of Evaluation Board (detailed view)

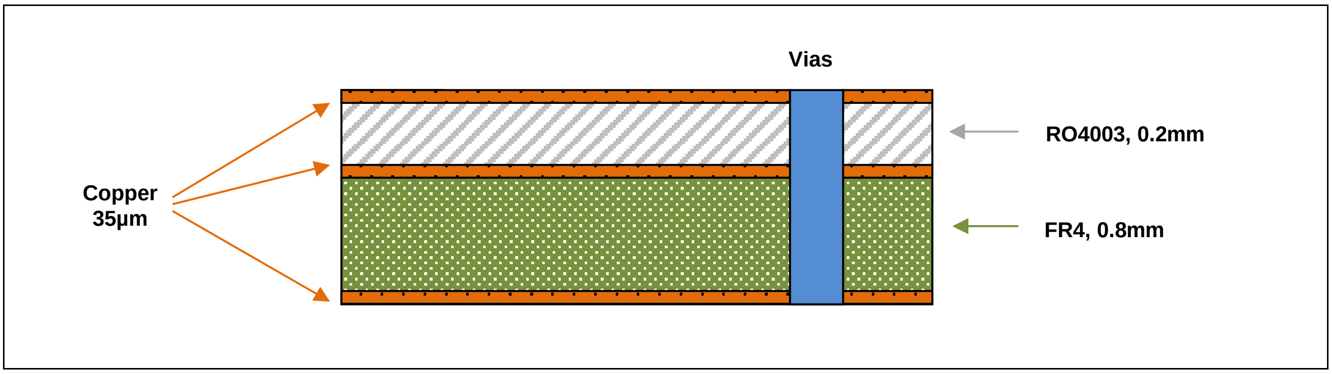

Figure 23 PCB Layer Information

6 Authors

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Jagjit Singh Bal, Application Engineer of Business Unit “RF and Protection Devices”

7 Remark

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

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