Application Note AN1200.76

Integrated Passive Device

LR1110, LR1120, LR1121

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1 Introduction

The LR11xx family is capable of communication in: the sub-GHz ISM bands, the 2.4 GHz ISM band and the GNSS band (which encompasses GPS L1 and Beidou B1 bands). Consequently, the radio features three separate RF front ends, one to address each band. Each radio frontend requires matching and, if transmitting, also requires harmonic transmit filtering. The number of components this requires can lead to issues replicating the Semtech reference design in small, or space constrained applications.

In such cases, to help the designer miniaturize their implementation of the LR11xx family of devices, we have developed an Integrated Passive Device (IPD) reference design in partnership with Johanson Technologies.

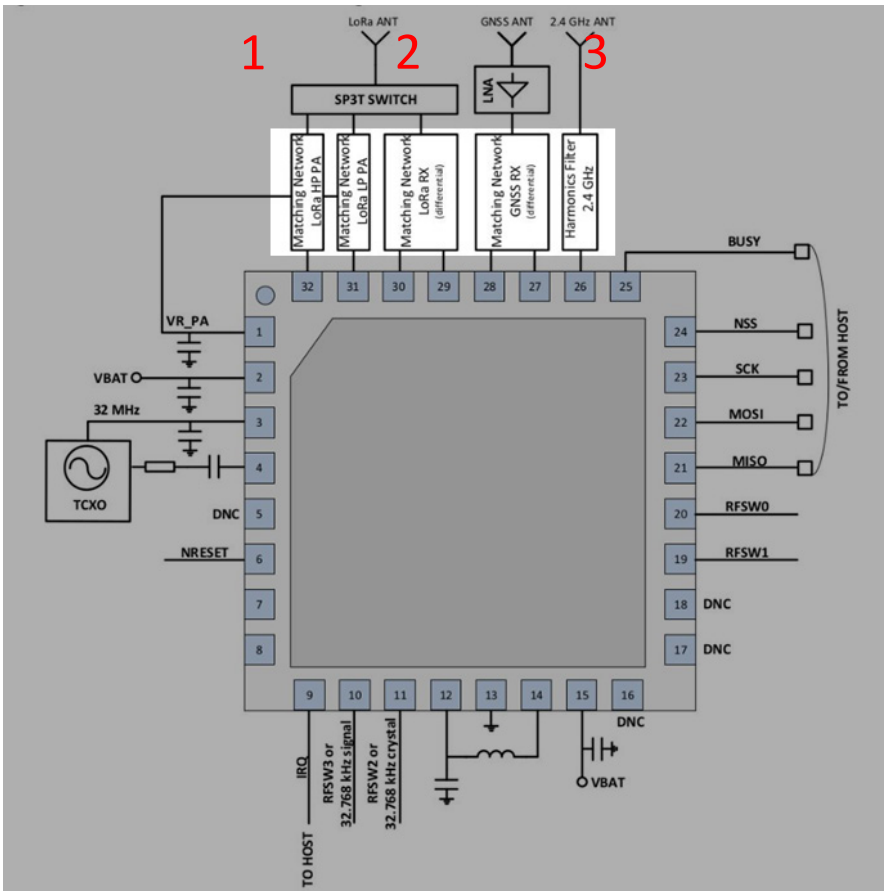

Figure 1. Highlighted block schematic of the RF frontend matching integrated in the IPD.

The concept is shown detail in the following schematics. The IPD design replaces the three separate discrete RF chains with only two devices. One covering sub-GHz communication (**1**), another integrating the 2.4 GHz band (**2**) and finally GNSS band matching and filtering (**3**). Only a single pi-section is required after the RF switch on the sub-GHz communication path (**4**).

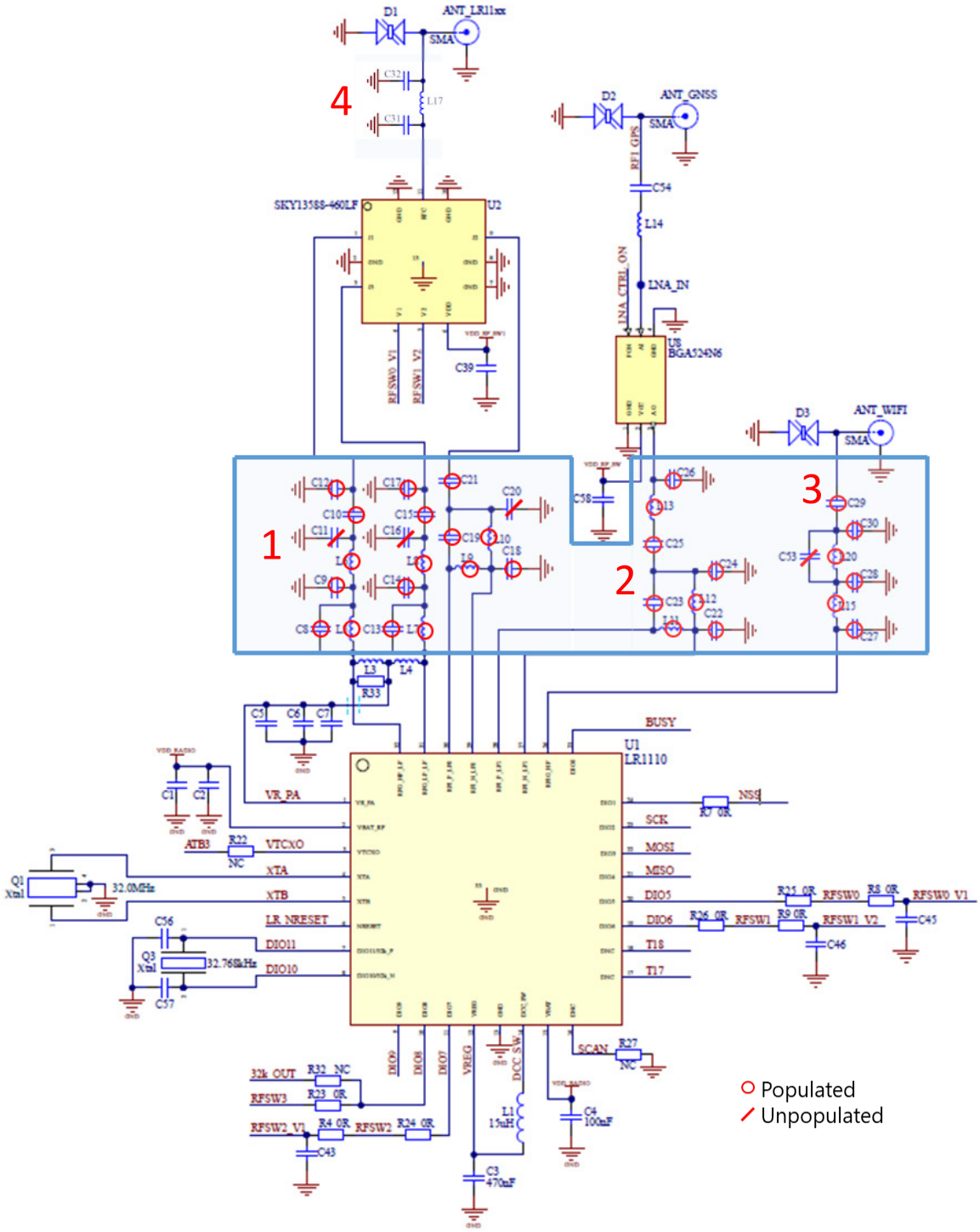

Figure 2. The IPD integrates 35 component footprints in the original reference design schematic, 31 of which are populated.

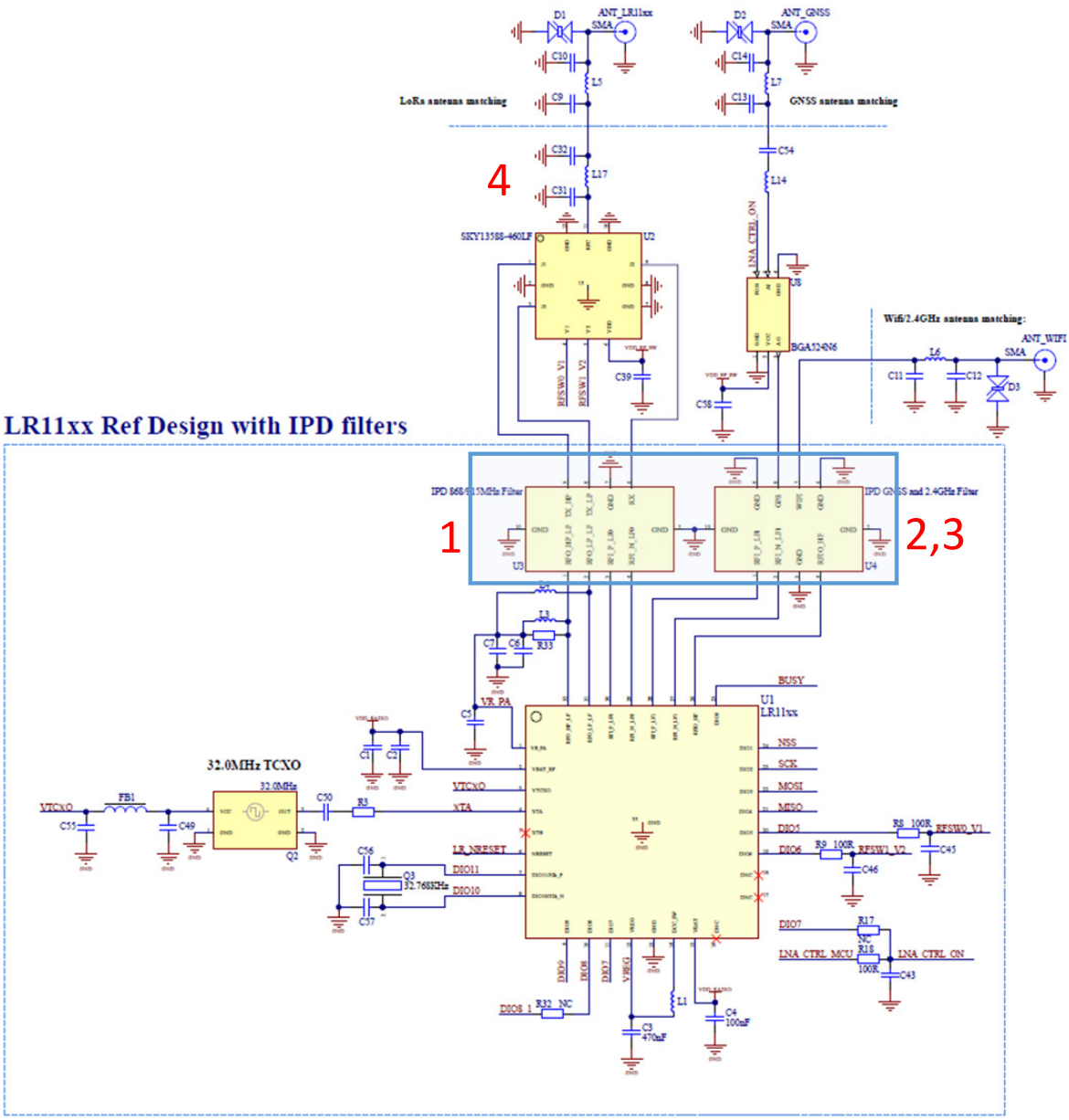

Figure 3. The LR11xx IPD reference design integrates 34 passive components into only 2 devices.

The space saving possibilities that the IPD reference design affords is further illustrated in the layout comparison shown below. The highlighted region shows the region occupied by the passive footprints and the IPDs respectively.

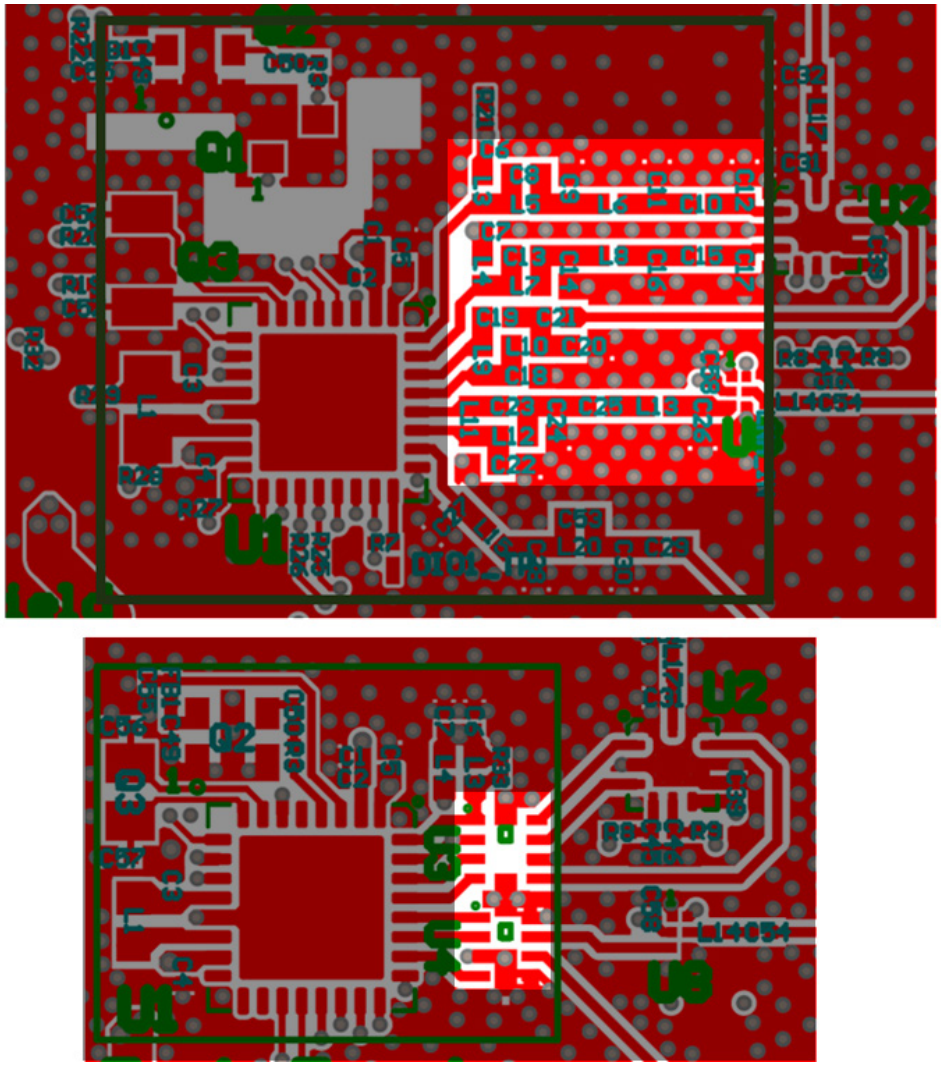

Figure 4. The use of the IPD reduces the reference design footprint to 11.8 x 9.6 mm.

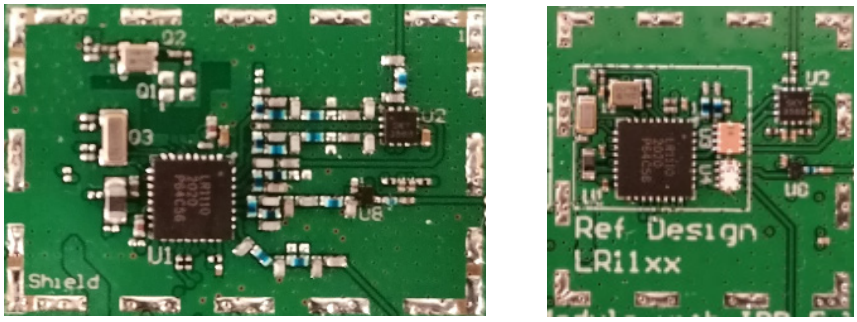

Figure 5. Photographs show the comparative size of the two designs (note that the RF switching and LNA use may vary by design).

2 Methodology

To validate the IPD reference design performance a series of conducted tests were performed. All testing was performed to the datasheet specifications [1, 3] using the standard interface and setup as defined in the LR11xx user manuals [2, 4].

2.1 Transmit Testing

All transmit testing was performed using conducted power measurements made by a spectrum analyzer, the setup is shown below. Note the inclusion of the 20 dB attenuator to ensure a true 50 ohms is presented to the device under test (DUT).

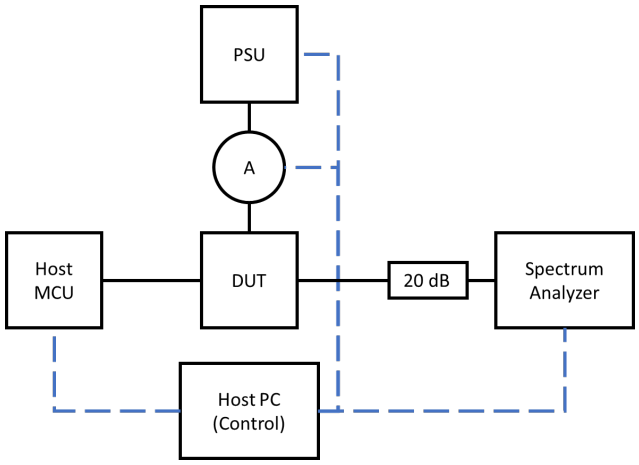

Figure 6. Conducted transmit measurement setup.

2.2 Receiver Testing

All receiver testing was performed by conducted measurement as shown below. The generator used for testing being capable of sending LoRa, WiFi and GNSS test signals for receiver performance characterization.

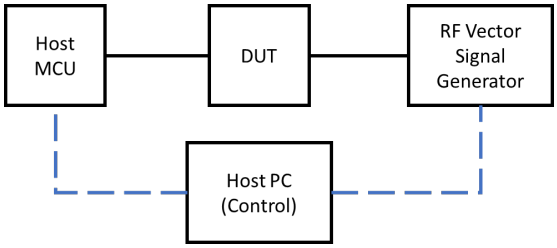

Figure 7 Conducted receive measurement setup.

The results of the testing using these setups are detailed in this report.

3 Sub-GHz ISM Band

3.1 Capabilities

The sub-GHz radio transceiver, in conjunction with the IPD, is specified to provide the full device performance to within ±1 dB of the datasheet performance, whilst maintaining current consumption that is within the specification limits.

3.2 Operation

An important differentiation between operation of the LR11xx with the discrete reference design and with the IPD, is that we draw a delineation between use of the HP path for 915 MHz (FCC) operation and the LP path for 868 MHz (ETSI) usage. The settings used to obtain the results shown here are:

Table 1. PA Settings used for ETSI LP path measurements.

Configuration	TxPower	PaSel	RegPASupply	PaDutyCycle	PaHPSel	Path
+15 dBm ETSI	+14 dBm	6	0	0	0	LP

3.3 LP Path: Conducted ETSI Band Performance

3.3.1 +15 dBm Transmit Performance

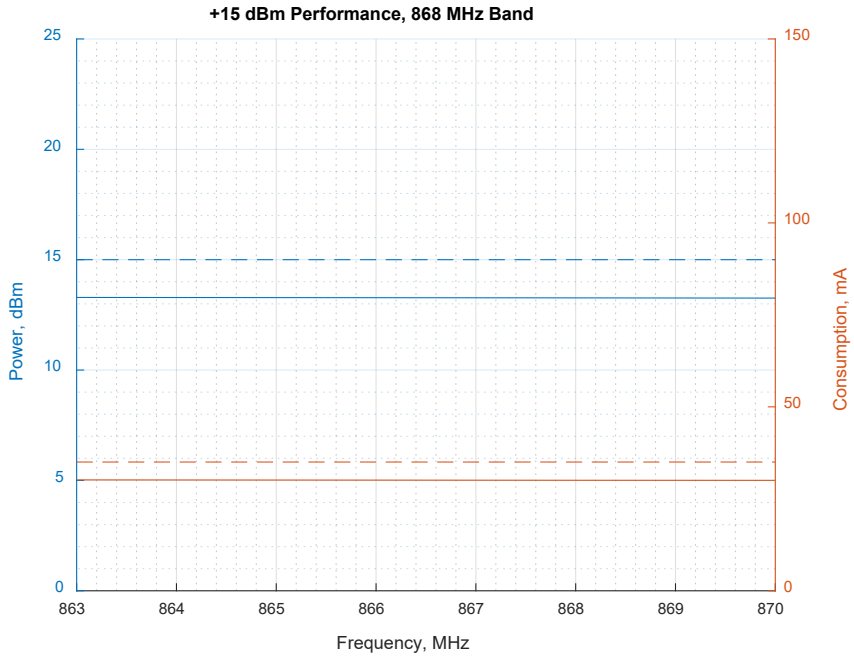

Figure 8. Measured RF output power and consumption performance of the IPD of 13.4 dBm at 30 mA (solid line) versus the specification (broken line) at +15 dBm.

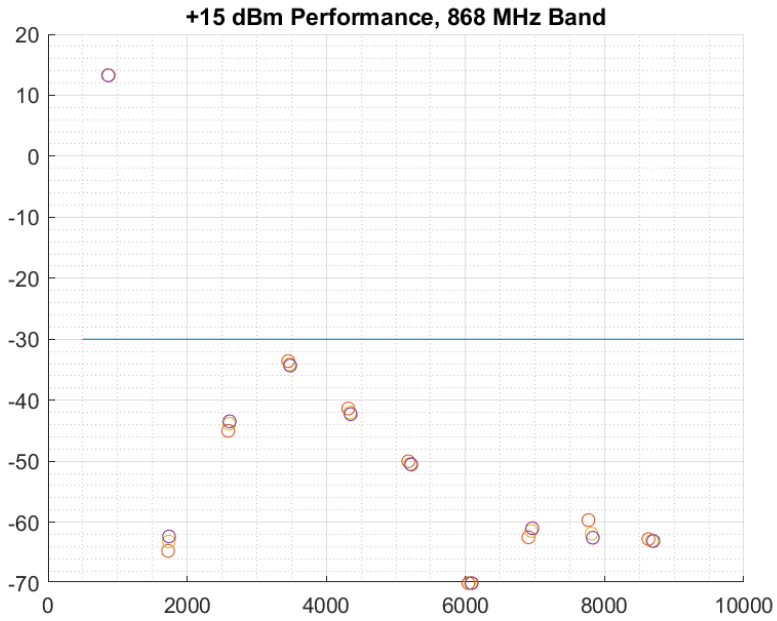

Figure 9. The compliant harmonic output power at +15 dBm versus the regulatory limit of -30 dBm/MHz.

3.3.2 ETSI Receiver Performance

The receiver performance tested at 3 spot frequencies is compared with the performance of the evaluation kit (EVK) in the plot below. The tuning of the IPD results in a higher receiver sensitivity than both the design specification and EVK.

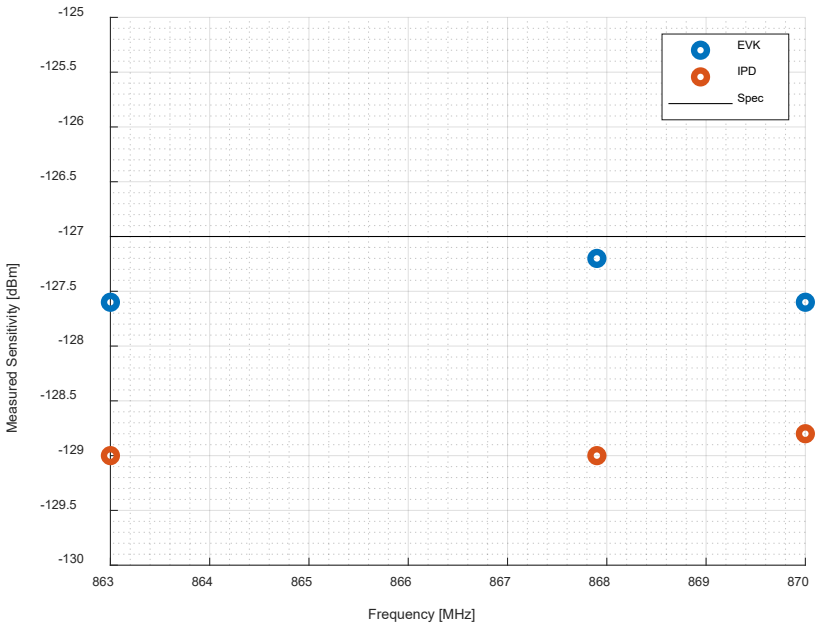

Figure 10. Receiver sensitivity measured across the ETSI ISM band.

3.4 HP Path: Conducted FCC Band Performance

Recalling that the HP path in the IPD reference design is dedicated to 915 MHz (FCC) operation, the programmed settings used to obtain the performance results shown here are:

Table 2. PA Settings used for HP path FCC measurements.

Configuration	TxPower	PaSel	RegPASupply	PaDutyCycle	PaHPSel	Path
+22 dBm FCC	+22 dBm	1	1	4	7	HP
+17 dBm FCC	+22 dBm	1	1	5	3	HP
+15 dBm FCC	+22 dBm	1	1	1	3	HP

3.4.1 +22 dBm Transmit Performance

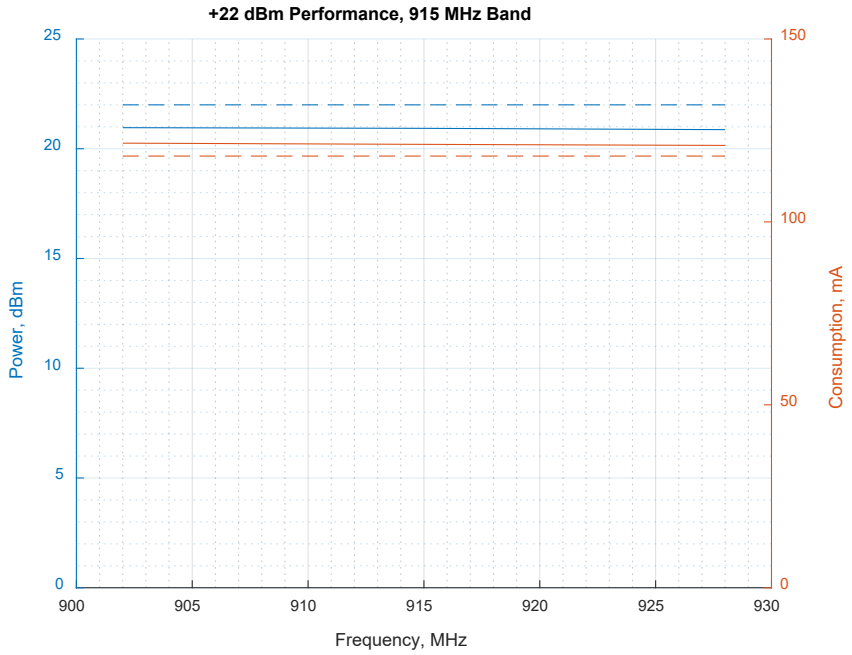

Figure 11. Measured RF output power and consumption performance of the IPD (solid line 20.93 dBm at 121 mA) versus the specification (broken line) at +22 dBm.

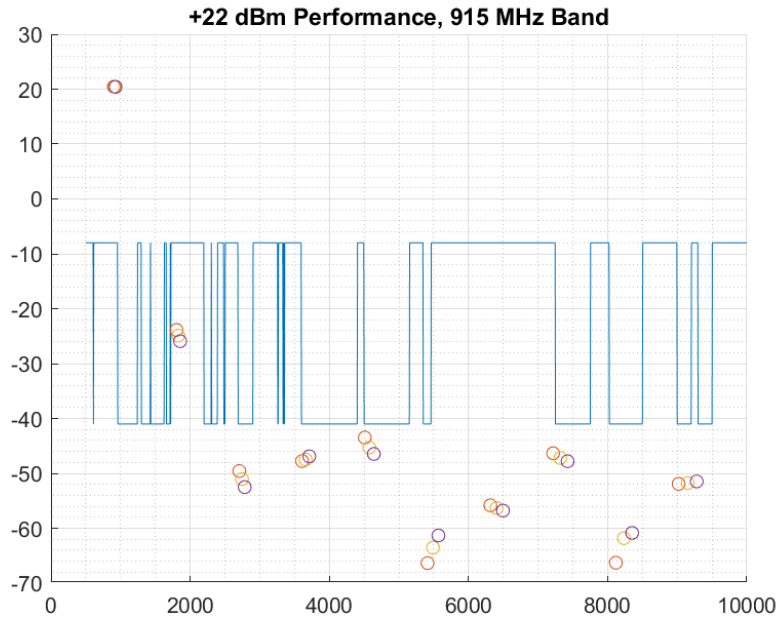

Figure 12. Measured harmonic output at +22 dBm versus the FCC Part 15.205 restricted bands.

3.4.2 +17 dBm Transmit Performance

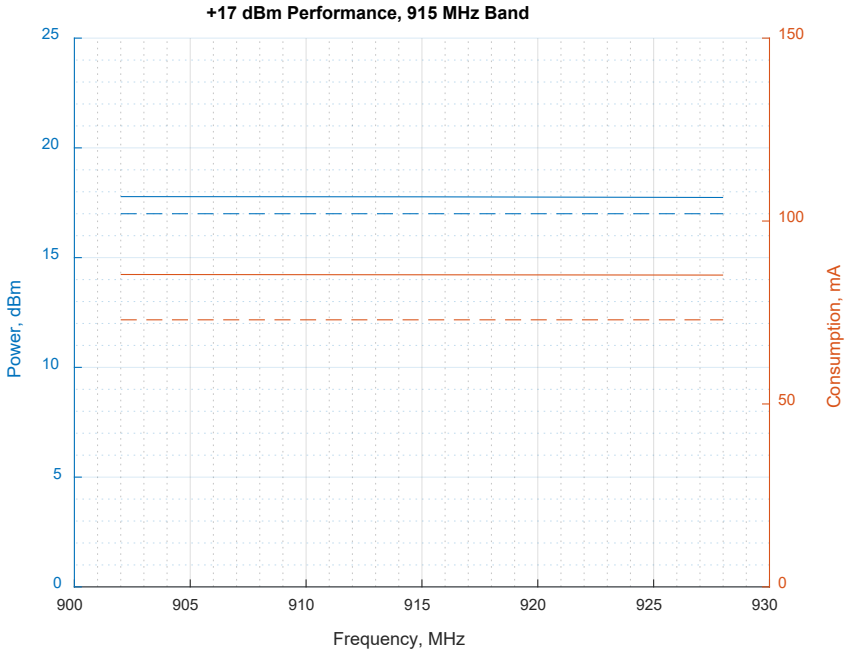

Figure 13. Measured RF output power and consumption performance of the IPD 17.77 dBm for 85 mA (solid line) versus the specification (broken line) at +17 dBm.

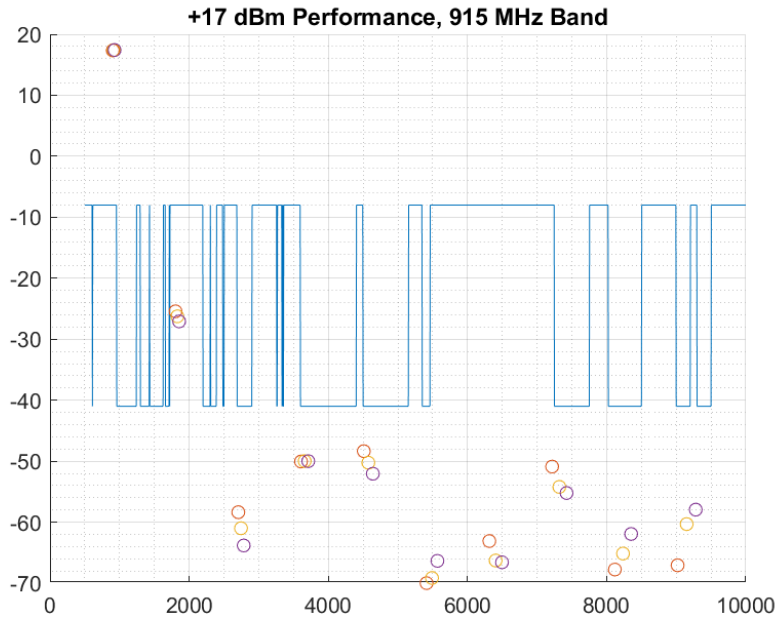

Figure 14. Measured harmonic output at +17 dBm versus the FCC Part 15.205 restricted bands.

3.4.3 +15 dBm Transmit Performance

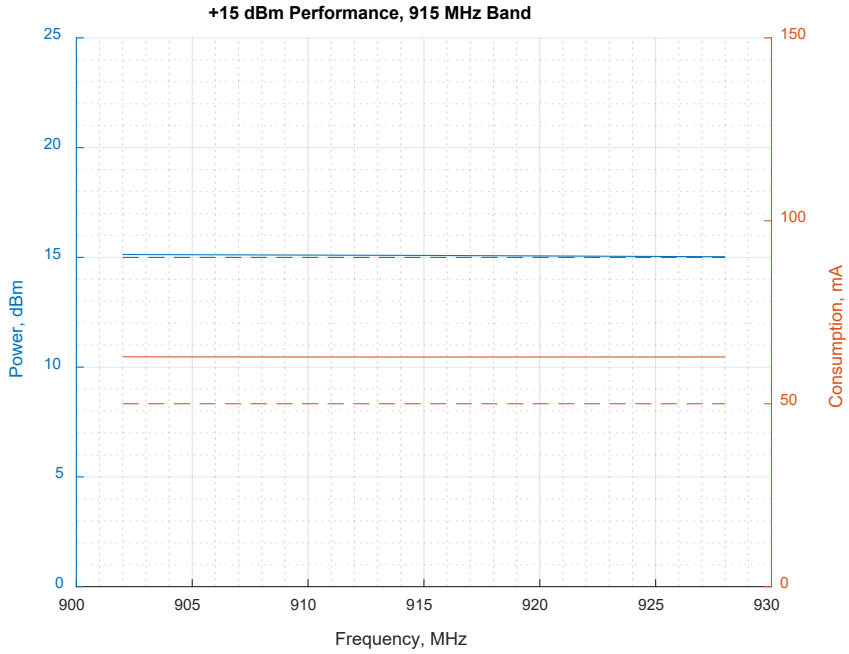

Figure 15. Measured RF output power and consumption performance of the IPD of 15.1 dBm at 62 mA (solid line) versus the specification (broken line) at +15 dBm.

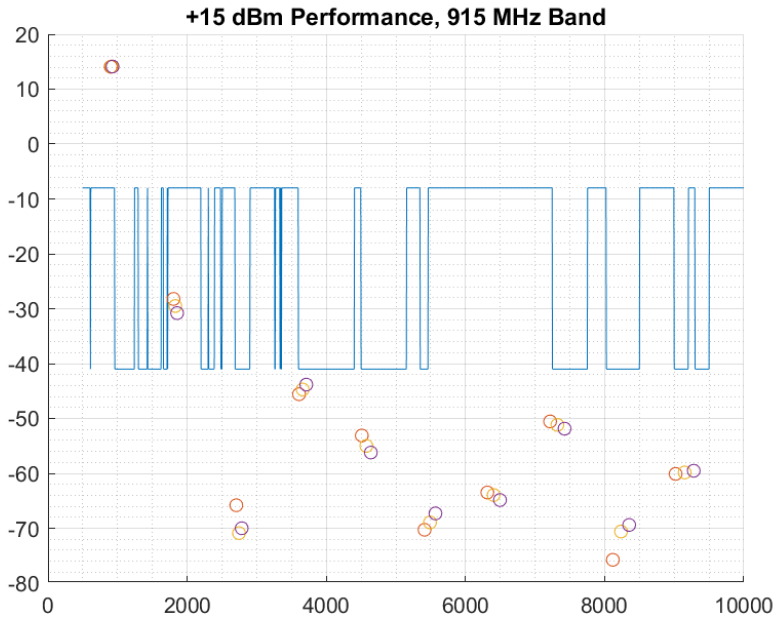

Figure 16. Measured harmonic output at +15 dBm versus the FCC Part 15.205 restricted bands.

3.4.4 Receiver Performance

The following plot shows the receiver performance, which gives similar performance to the measured sensitivity of the EVK, both in outperforming the datasheet specification.

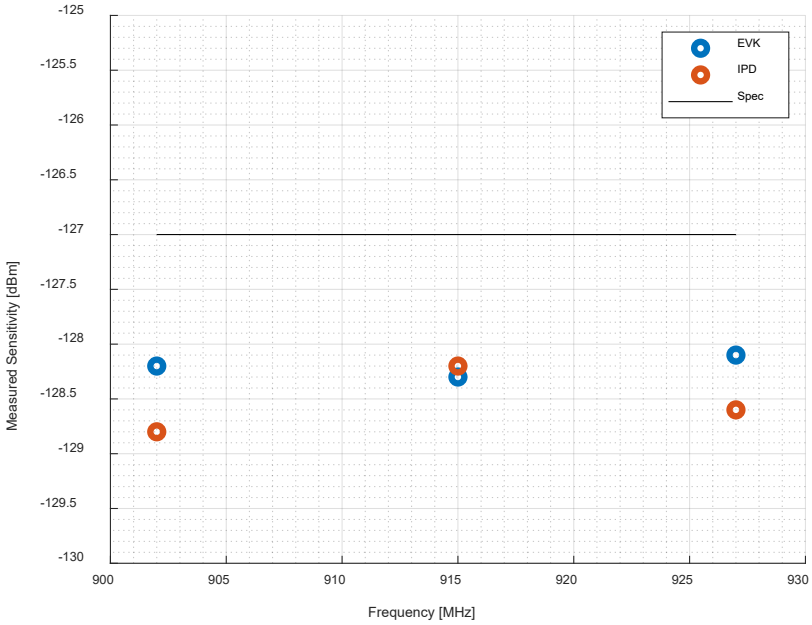

Figure 17. Receiver sensitivity measured across the FCC ISM band.

4 2.4 GHz ISM Band

4.1 Operation

The LR1120 and LR1121 are both capable of 2.4 GHz transmit operation. Because the 2.4 GHz band permits global operation, it is necessary for the IPD to comply with both FCC and ETSI regulations. Transmit testing was performed with a programmed output power of +13 dBm (which yields +12 dBm of RF output power in the case of the LR112x EVK).

4.2 Conducted Global 2.4 GHz Band Performance

4.2.1 Transmit Performance +12 dBm

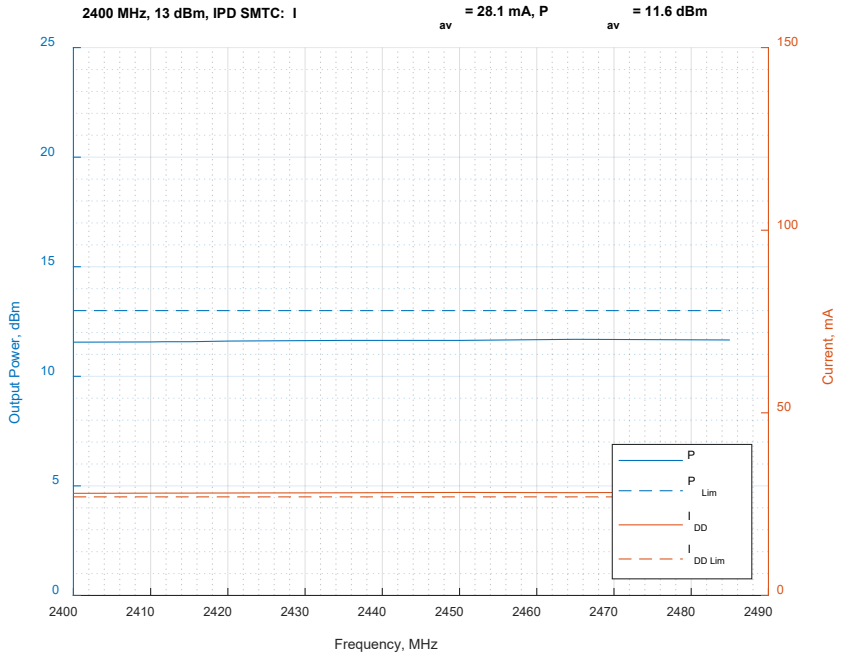

Figure 18. Measured RF output power and consumption performance of the IPD of 11.5 dBm (solid line) versus the specification (broken line) at +13 dBm.

An important point to note in the results of harmonic testing (shown below) is that the part of the 6th harmonic falls into a narrow restricted-band from 14.47-14.5 GHz. The y-axis scaling makes it difficult to see that there is consistently over 3 dB margin to the limit.

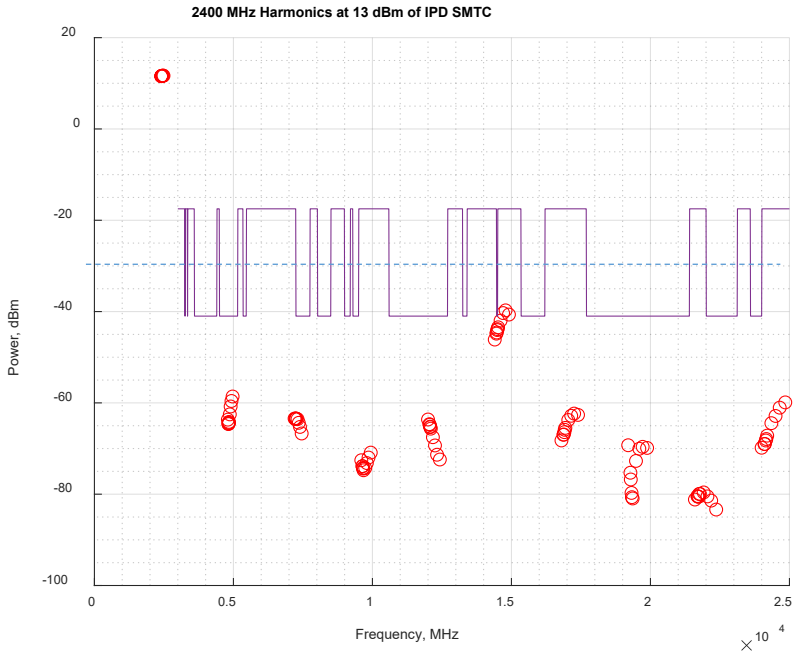

Figure 19. Measured harmonic output at +1 dBm versus the FCC Part 15.205 restricted bands (solid line) and the ETSI limit (dashed line).

4.2.2 Receiver Performance

The receiver performance was tested using the Wi-Fi MAC sensing function of the LR11xx. For clarity results of both the discrete reference design EVK and IPD design are shown. The EVK delivers a sensitivity of approximately -94.3 dBm versus -94.4 dBm in the case of the IPD reference design.

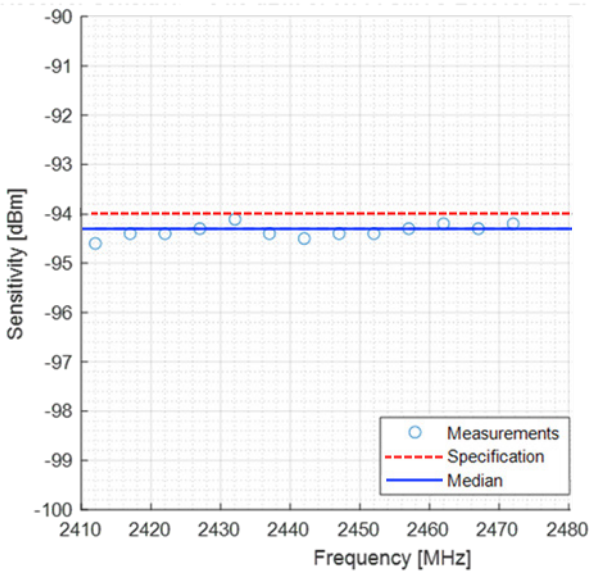

Figure 20. Wi-Fi receiver sensitivity of the discrete EVK, measured across the Global 2.4 GHz ISM band.

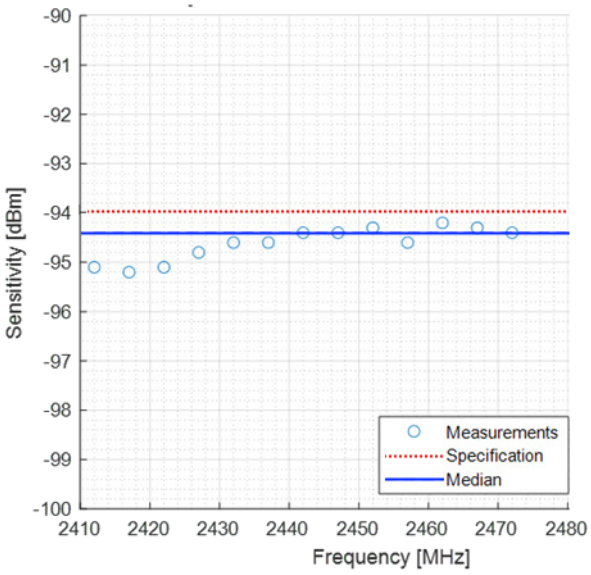

Figure 21. Wi-Fi receiver sensitivity of the IPD reference design, measured across the Global 2.4 GHz ISM band.

5 GNSS Band

5.1 Operation

The GNSS portion of the LR11xx is a receive only device, so does not feature any transmit results. The testing here shows the results of a GNSS scan of the detection of a single simulated space vehicle in the L1 GPS band. The sensitivity of the discrete EVK is also shown for comparison (at -133.9 dBm) with the IPD reference design, which has a sensitivity of -134.3 dBm.

5.2 Receiver Performance

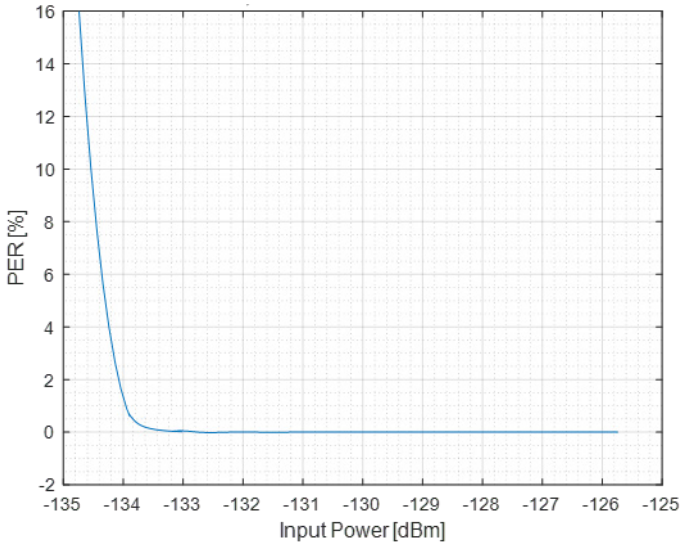

Figure 22. GNSS receiver PER curve of the discrete reference design measured for the GPS L1 band.

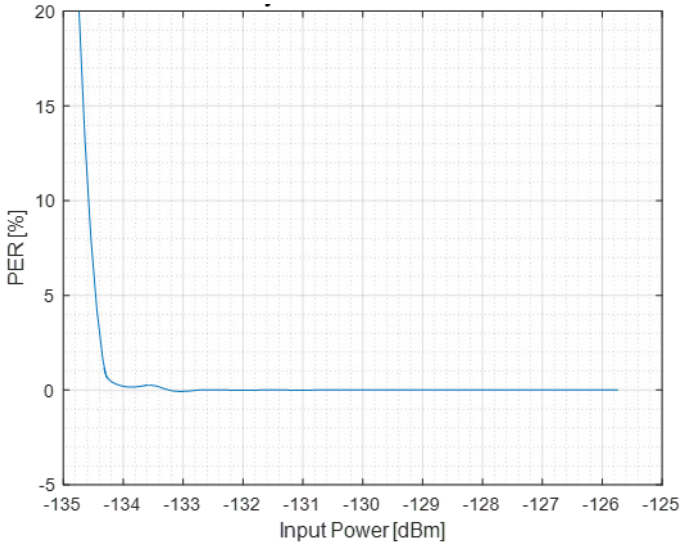

Figure 23. GNSS receiver PER curve of the IPD reference design measured for the GPS L1 band.

6 Conclusion

We have presented the performance of the LR11xx IPD reference design in the principal configurations in which it will be employed in FCC and ETSI regional operation. The device performance reported here:

- Broadly conforms to meeting the datasheet design specification to within ±1 dB (typically with higher receive sensitivity but marginally reduced output power),
- with full regulatory compliance,
- integrating 34 passive components and,
- reducing the full design area to only 11.8 x 9.6 mm.

7 References

[1] LR1110 Data Sheet Link

[2] LR1110 User Manual Link

[3] LR1120 Data Sheet Link

[4] LR1120 User Manual Link

8 Revision History

Version	ECO	Date	Changes and/or Modifications
1.0	066182	Nov 2023	First Release

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