

## Matched Integrated Passive Component for 868 / 915 MHz operation with the CC112x, CC117x & CC12xx high performance radio series

By Richard Wallace

### Keywords

- *Single Matched Integrated Passive Component*
- *Optimized for compact designs*
- *868 and 915 MHz ISM Bands*
- *Dual source IPC with common footprint*
- *CC112x, CC117x & CC12xx*
- *Murata (Partnr: LFD21868MMF1D386)*
- *JTI (Partnr: 0900PC15J0013)*

## 1 Introduction

With the Matched Integrated Passive Component (IPC); the component count is significantly reduced whilst still obtaining high radio performance.

This document describes the IPC that has been specifically designed for the CC112x, CC117x and CC12xx family of ICs operating in the 868 and 915 MHz ISM bands.

The existing discrete solution requires 13 components for the RF Front End filter as illustrated in Figure 2. The IPC replaces these 13 discrete components with a single component as can be seen in Figure 3.

Test results of the discrete solution are presented with both the wire-wound inductor solution and with multi-layer inductor solution on the 4-layer discrete reference design.

Results of the IPC reference designs are presented with the standard 4-layer ref design [7] and with a 2-layer reference design [8]. All the reference designs

performance are compared and discussed in this document.

Part number for the Murata IPC is LFD21868MMF1D386 and the part number from Johanson Technology (JTI) is 0900PC15J0013; these are available directly from Murata [5] or JTI [6] or their distributors.

The size for the matched balun filter component is only 2.0 mm x 1.25 mm (EIA 0805, Metric 2012) therefore it is highly recommended for compact designs and designs which are sensitive to production assembly pick-and-place costs.

All measurement results presented in this document are based on measurements performed on the CC112x IPC EM Rev 1.0 Reference Designs; 4-layer [7] as shown in Figure 1 and 2-layer [8],

Since the CC112x and CC117x have the same RF section as the CC12xx; the IPC part can be used with the CC12xx family series as well.

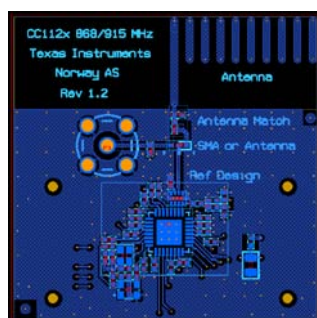


Figure 1. CC112x & CC117x IPC EM Reference Design

## Table of Contents

<b>KEYWORDS</b> .....	<b>1</b>
<b>1 INTRODUCTION</b> .....	<b>1</b>
<b>2 ABBREVIATIONS</b> .....	<b>3</b>
<b>3 REFERENCE DESIGNS AVAILABLE</b> .....	<b>4</b>
3.1 DISCRETE REFERENCE DESIGN.....	4
3.2 IPC REFERENCE DESIGNS.....	5
3.2.1 Schematic.....	5
3.2.2 Component Placement.....	6
3.2.3 Layout.....	6
3.2.3.1 2-Layer.....	7
3.2.3.2 4-Layer.....	8
3.3 MEASUREMENT RESULTS.....	10
3.3.1 Sensitivity (1.2kbps data rate).....	10
3.3.1.1 WW-Inductor Discrete Reference Design Based on 4-Layer PCB.....	10
3.3.1.2 ML-Inductor Discrete Reference Design Based on 4-Layer PCB.....	10
3.3.1.3 JTI IPC Reference Design Based on 4-Layer PCB.....	10
3.3.1.4 Murata IPC Reference Design Based on 4-Layer PCB.....	11
3.3.1.5 Murata IPC Reference Design Based on 2-Layer PCB.....	11
3.3.1.6 Summary of Sensitivity Measurements of the Various Reference Designs.....	11
3.3.2 Output Power and Harmonics (Max power setting).....	12
3.3.2.1 WW-Inductor Discrete Reference Design Based on 4-Layer PCB.....	12
3.3.2.2 ML-Inductor Discrete Reference Design Based on 4-Layer PCB.....	13
3.3.2.3 JTI IPC Reference Design Based on 4-Layer PCB.....	14
3.3.2.4 Murata IPC Reference Design Based on 4-Layer PCB.....	15
3.3.2.5 Murata IPC Reference Design Based on 2-Layer PCB.....	16
3.3.2.6 Summary of Output Power and Harmonics Measurements.....	17
3.3.2.7 Overview of Harmonic Emission Regulatory Requirements.....	17
3.3.3 Link Budget Calculations of the Various Reference Designs.....	18
<b>4 CONCLUSION</b> .....	<b>19</b>
<b>5 REFERENCES</b> .....	<b>20</b>
<b>6 GENERAL INFORMATION</b> .....	<b>20</b>
6.1 DOCUMENT HISTORY.....	20

## 2 Abbreviations

DC	Direct Current
EM	Evaluation Module
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FR4	Material type used for producing PCB
ISM	Industrial, Scientific, Medical
IPC	Integrated Passive Component
JTI	Johanson Technology
LC	Inductor (L) Capacitor (C) configuration
ML	Multi-Layer Inductor
NM	Not Mounted
PCB	Printed Circuit Board
SoC	System on Chip
SRD	Short Range Devices
TCXO	Temperature Compensated Crystal Oscillator
WW	Wire-Wound Inductor
XTAL	Crystal Oscillator

### 3 Reference Designs Available

There are basically two types of reference designs available for CC112x [1][2][3], and CC117x [4]; one solution is based upon discrete components [9] and the other is based upon an IPC [7]. Each reference design has its own particular advantage.

#### 3.1 Discrete Reference Design

The traditional 868/915 MHz reference design for the CC112x and CC117x has been the discrete solution [9] shown in Figure 2. This design can use either multi-layer inductors or wire-wound inductors; when using wire-wound inductors, this is the **best reference design for performance**.

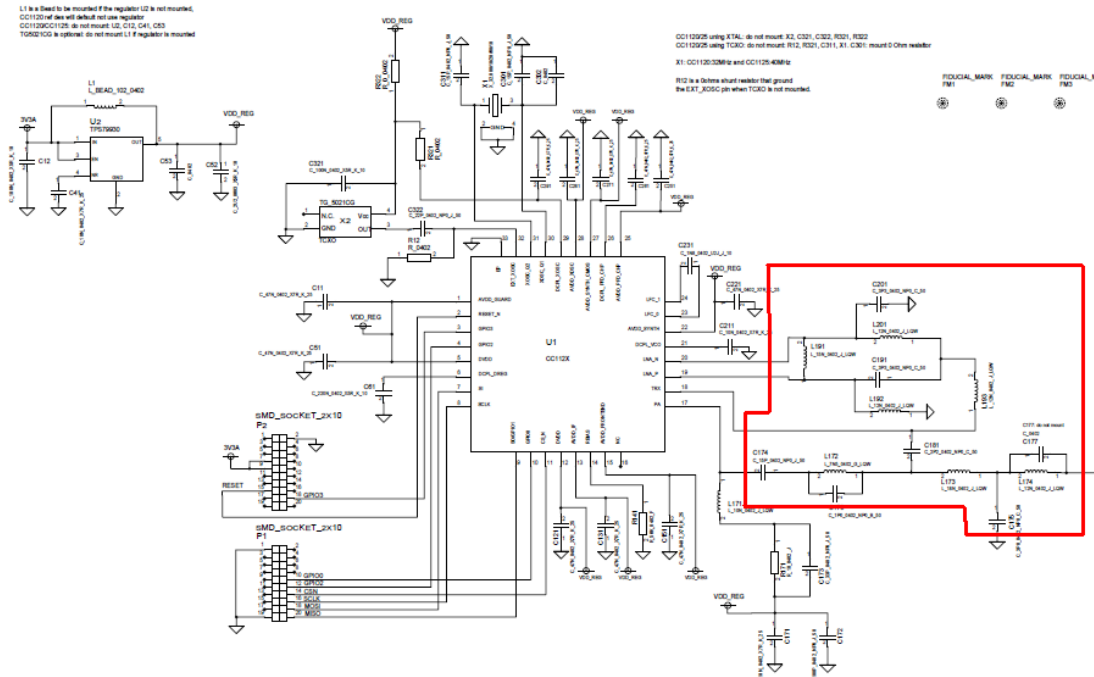


Figure 2. Discrete Reference Design for the CC112x and CC117x 868/915 MHz

The schematic shown in Figure 2 and Figure 3 have the option to choose between a TCXO and a XTAL. The discrete components shown within the red marking in Figure 2 are the components that can be replaced the IPC.

### 3.2 IPC Reference Designs

#### 3.2.1 Schematic

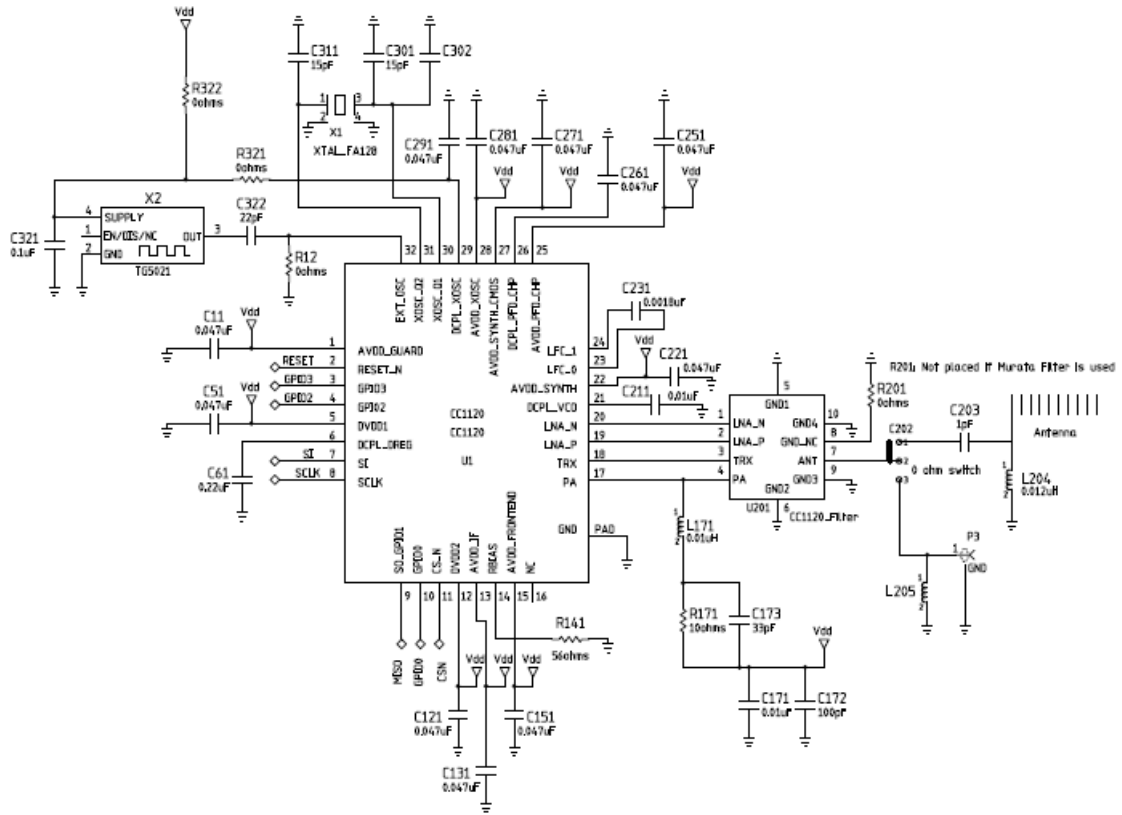


Figure 3. Schematic for the 2-Layer & 4-Layer Reference Design

Component R201 in Figure 3 is only used to shorten the IPC pin to GND with a 0ohm resistor or to be left as not connected. The Murata IPC requires pin 8 on the IPC to be not connected whereas the JTI IPC requires this pin to be connected to GND. R201 is only required if the final pcb will accommodate both vendors of the IPC.

Referring to Figure 3, components C203 and L204 are a part of the antenna matching network for the integrated PCB helix antenna used on the EM. L205 is not used.

The output impedance from the IPC, pin 7 is 50 ohms.

## 3.2.2 Component Placement



Figure 4. Component Placement for the 2-Layer & 4-Layer Reference Design

## 3.2.3 Layout

The layout greatly influences the RF performance. TI recommends to always copy our reference design [7] as closely as possible.

In the event that the reference design [7] cannot be copied then the routing from the RF pins RF\_P & RF\_N must be symmetrical to the IPC, U201. The length of the tracks should be kept to a minimum and preferably the same length that is used in the reference design [7]. If this routing is not symmetrical; then the output power will be reduced and the harmonics will increase.

All component ground pads should have the own ground via which should be positioned as close as possible to the ground pad. When positioning the ground vias for the component pad grounds it is important to try to keep the return path loop to ground as little as possible in order to prevent unnecessary radiated emissions.

On the layer directly underneath the RF network; it is important to have a solid ground plane and to avoid any routing. The power routing has been routed in a star formation on the 2-layer design as shown in Figure 5 and as a local power plane on the 4-layer design as shown in Figure 9. The power tracks must always be routed to the decoupling capacitor first; then from the decoupling capacitor to the pad of the CC112x.

3.2.3.1 2-Layer

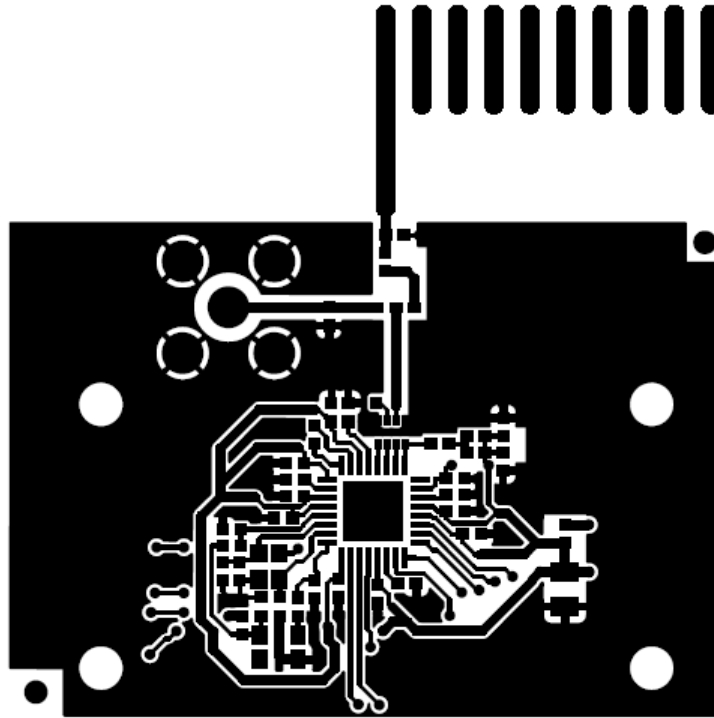


Figure 5. Layer 1 Layout of the 2-Layer IPC Reference Design

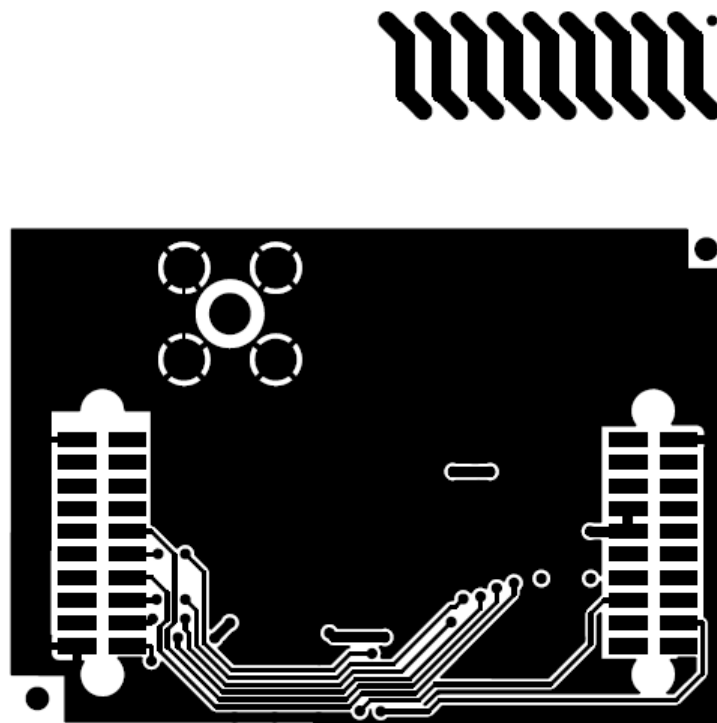


Figure 6. Layer 2 Layout of the 2-Layer IPC Reference Design

3.2.3.2 4-Layer

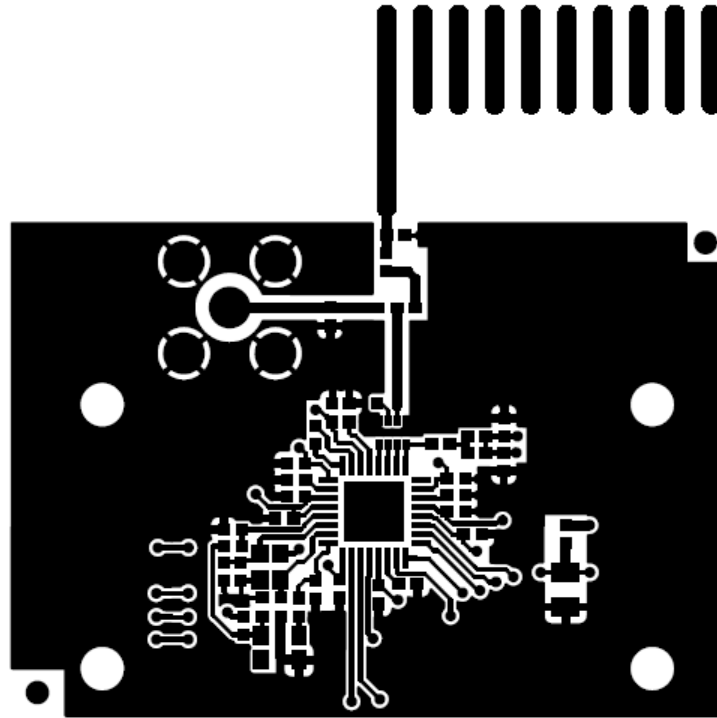


Figure 7. Layer 1 Layout of the 4-Layer IPC Reference Design

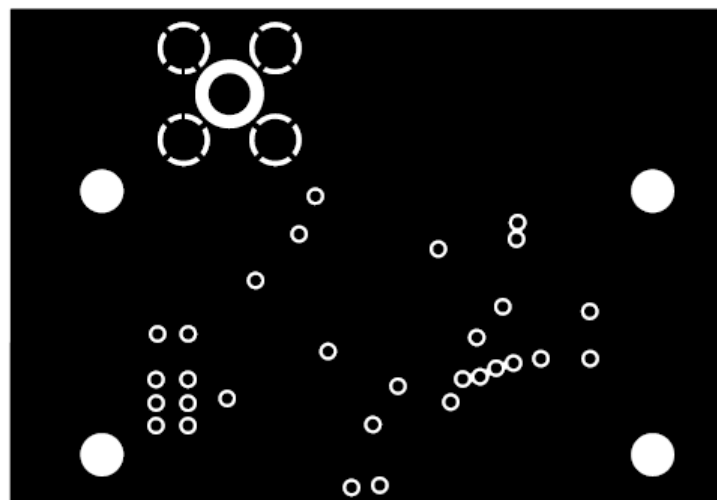


Figure 8. Layer 2 Layout of the 4-Layer IPC Reference Design



.....  
.....

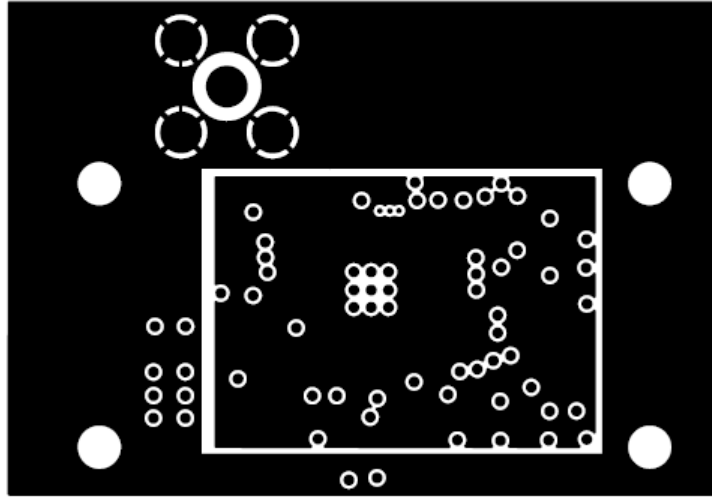


Figure 9. Layer 3 Layout of the 4-Layer IPC Reference Design

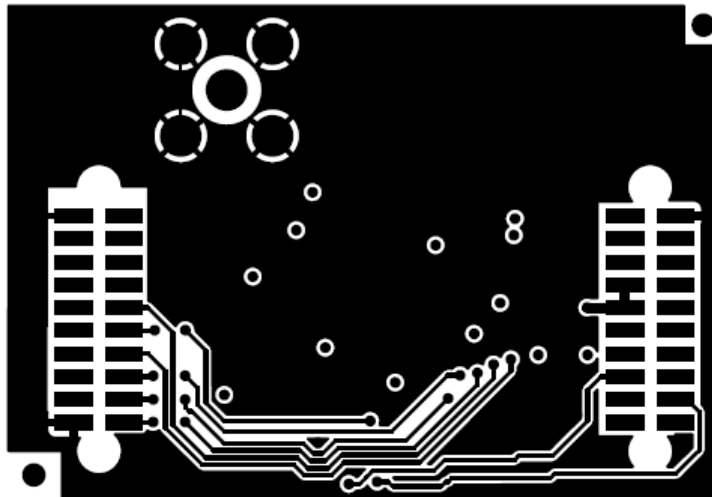


Figure 10. Layer 4 Layout of the 4-Layer IPC Reference Design

## 3.3 Measurement Results

All results presented in this chapter are based on measurements performed with CC112x IPC EM reference design board [7] or the standard discrete reference design [9]. For the discrete and Murata IPC solution, a minimum of six units have been measured in order to obtain an average result which is presented in this report. Only one unit has been measured for the JTI IPC.

All measurement results presented are the average of each batch tested from typical devices. The devices have been tested in full temperature (85°C, 25°C & -40°C) and full voltage range (2.0V, 3.0V & 3.6V).

**Note: all values are in dBm if not otherwise stated.**

SmartRF04<sup>®</sup> RF studio was used to configure the devices. The settings for the registers are the default settings used.

### 3.3.1 Sensitivity (1.2kbps data rate)

#### 3.3.1.1 WW-Inductor Discrete Reference Design Based on 4-Layer PCB

Temp	Solution	Freq. Band: 868 MHz				Freq. Band: 915 MHz			
		2.0Vcc	3.0Vcc	3.6Vcc	Avg	2.0V	3.0V	3.6V	Avg
-40°C	WW dis 4-L	-124.4	-124.3	-124.4	-124.4	-124.1	-123.8	-123.9	-123.9
25°C	WW dis 4-L	-123.2	-123.2	-123.2	-123.2	-122.4	-122.7	-122.5	-122.5
85°C	WW dis 4-L	-121.4	-121.3	-121.2	-121.3	-120.6	-120.4	-120.8	-120.6
All	WW dis 4-L	-123.0	-122.9	-122.9	<b>-123.0</b>	-122.4	-122.3	-122.4	<b>-122.4</b>

Table 1. Average Sensitivity Values Obtained for WW Discrete 4-Layer

#### 3.3.1.2 ML-Inductor Discrete Reference Design Based on 4-Layer PCB

Temp	Solution	Freq. Band: 868 MHz				Freq. Band: 915 MHz			
		2.0Vcc	3.0Vcc	3.6Vcc	Avg	2.0V	3.0V	3.6V	Avg
-40°C	ML dis 4-L	-123.5	-123.6	-123.6	-123.6	-122.6	-122.6	-122.7	-122.6
25°C	ML dis 4-L	-121.9	-122.1	-122.2	-122.1	-121.0	-121.2	-121.0	-121.1
85°C	ML dis 4-L	-120.3	-120.2	-120.5	-120.4	-119.3	-119.6	-119.5	-119.5
All	ML dis 4-L	-121.9	-122.0	-122.1	<b>-122.0</b>	-121.0	-121.1	-121.1	<b>-121.1</b>

Table 2. Average Sensitivity Values Obtained for ML Discrete 4-Layer

#### 3.3.1.3 JTI IPC Reference Design Based on 4-Layer PCB

Temp	Solution	Freq. Band: 868 MHz				Freq. Band: 915 MHz			
		2.0Vcc	3.0Vcc	3.6Vcc	Avg	2.0V	3.0V	3.6V	Avg
-40°C	JTI IPC 4-L	-123.0	-123.0	-123.4	-123.1	-123.8	-123.4	-123.8	-123.7
25°C	JTI IPC 4-L	-121.6	-122.2	-122.0	-121.9	-121.8	-122.2	-122.2	-122.1
85°C	JTI IPC 4-L	-121.0	-120.6	-120.6	-120.7	-120.6	-120.8	-120.8	-120.7
All	JTI IPC 4-L	-121.9	-121.9	-122.0	<b>-121.9</b>	-122.1	-122.1	-122.3	<b>-122.2</b>

Table 3. Average Sensitivity Values Obtained for Murata IPC 4-Layer

3.3.1.4 Murata IPC Reference Design Based on 4-Layer PCB

Temp	Solution	Freq. Band: 868 MHz				Freq. Band: 915 MHz			
		2.0Vcc	3.0Vcc	3.6Vcc	Avg	2.0V	3.0V	3.6V	Avg
-40°C	Murata IPC 4-L	-123.7	-123.5	-123.7	-123.6	-122.6	-122.8	-123.0	-122.8
25°C	Murata IPC 4-L	-122.0	-122.3	-121.8	-122.1	-121.3	-121.1	-121.2	-121.2
85°C	Murata IPC 4-L	-120.3	-120.3	-120.3	-120.3	-119.7	-119.6	-119.9	-119.7
All	Murata IPC 4-L	-122.0	-122.1	-122.9	<b>-122.0</b>	-121.2	-121.2	-121.4	<b>-121.2</b>

Table 4. Average Sensitivity Values Obtained for Murata IPC 4-Layer

3.3.1.5 Murata IPC Reference Design Based on 2-Layer PCB

Temp	Solution	Freq. Band: 868 MHz				Freq. Band: 915 MHz			
		2.0Vcc	3.0Vcc	3.6Vcc	Avg	2.0V	3.0V	3.6V	Avg
-40°C	Murata IPC 2-L	-123.6	-123.7	-123.4	-123.6	-122.7	-122.4	-122.4	-122.5
25°C	Murata IPC 2-L	-122.0	-121.9	-122.3	-122.1	-120.9	-121.0	-121.2	-121.0
85°C	Murata IPC 2-L	-120.6	-120.4	-120.3	-120.3	-119.7	-119.6	-119.9	-119.7
All	Murata IPC 2-L	-122.1	-122.0	-122.2	<b>-122.1</b>	-121.0	-120.9	-121.1	<b>-121.0</b>

Table 5. Average Sensitivity Values Obtained for Murata IPC 2-Layer

3.3.1.6 Summary of Sensitivity Measurements of the Various Reference Designs

Temp	Solution	Freq. Band: 868 MHz				Freq. Band: 915 MHz			
		2.0Vcc	3.0Vcc	3.6Vcc	Avg	2.0V	3.0V	3.6V	Avg
All	WW dis 4-L	-123.0	-122.9	-122.9	<b>-123.0</b>	-122.4	-122.3	-122.4	<b>-122.4</b>
All	Murata IPC 2-L	-122.1	-122.0	-122.2	<b>-122.1</b>	-121.0	-120.9	-121.1	<b>-121.0</b>
All	Murata IPC 4-L	-122.0	-122.1	-122.9	<b>-122.0</b>	-121.2	-121.2	-121.4	<b>-121.2</b>
All	ML dis 4-L	-121.9	-122.0	-122.1	<b>-122.0</b>	-121.0	-121.1	-121.1	<b>-121.1</b>
All	JTI IPC 4-L	-121.9	-121.9	-122.0	<b>-121.9</b>	-122.1	-122.1	-122.3	<b>-122.2</b>

Table 6. Sensitivity Measurements Summary

3.3.2 Output Power and Harmonics (Max power setting)

3.3.2.1 WW-Inductor Discrete Reference Design Based on 4-Layer PCB

Freq. Band: 868 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	WW dis 4-L	2	11.7	-75.3	-74.9	-75.2	-74.6	-74.4	39.8
-40°C	WW dis 4-L	3	14.6	-48.2	-45.3	-60.7	-72.9	-74.4	48.0
-40°C	WW dis 4-L	3.6	15.5	-46.4	-44.7	-59.1	-72.0	-74.1	51.0
-40°C	WW dis 4-L Average	All	13.9	-56.7	-55.0	-65.0	-73.1	-74.3	46.3
25°C	WW dis 4-L	2	11.0	-54.8	-47.3	-67.3	-74.9	-74.6	40.3
25°C	WW dis 4-L	3	13.8	-49.8	-47.1	-62.3	-74.2	-74.5	47.5
25°C	WW dis 4-L	3.6	14.7	-48.1	-46.4	-60.7	-73.4	-74.7	50.5
25°C	WW dis 4-L Average	All	13.1	-50.9	-46.9	-63.4	-74.1	-74.6	46.1
85°C	WW dis 4-L	2	10.1	-56.1	-51.1	-68.4	-74.6	-74.4	40.0
85°C	WW dis 4-L	3	12.6	-51.5	-50.4	-64.5	-74.7	-74.3	46.9
85°C	WW dis 4-L	3.6	13.5	-49.9	-49.9	-63.6	-74.7	-74.2	49.6
85°C	WW dis 4-L Average	All	12.1	-52.5	-50.5	-65.5	-74.7	-74.3	45.5
All	WW dis 4-L Average	All	13.1	-53.3	-50.8	-64.6	-74.0	-74.4	45.9
Freq. Band: 915 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	WW dis 4-L	2	11.6	-75.8	-75.3	-75.1	-74.3	-72.7	39.5
-40°C	WW dis 4-L	3	14.3	-54.4	-43.5	-61.3	-74.2	-72.8	47.1
-40°C	WW dis 4-L	3.6	15.2	-52.4	-42.8	-60.0	-73.7	-72.8	50.1
-40°C	WW dis 4-L Average	All	13.7	-60.8	-53.9	-65.5	-74.1	-72.8	45.6
25°C	WW dis 4-L	2	10.7	-60.7	-47.6	-67.8	-74.5	-72.9	39.8
25°C	WW dis 4-L	3	13.3	-55.7	-46.6	-63.7	-74.6	-73.0	46.2
25°C	WW dis 4-L	3.6	14.2	-53.9	-45.9	-62.4	-74.3	-72.8	49.2
25°C	WW dis 4-L Average	All	12.7	-56.8	-46.7	-64.6	-74.4	-72.9	45.1
85°C	WW dis 4-L	2	9.6	-61.7	-53.4	-70.1	-75.3	-73.5	39.3
85°C	WW dis 4-L	3	11.9	-57.3	-51.6	-67.1	-74.5	-73.0	45.4
85°C	WW dis 4-L	3.6	12.7	-55.7	-51.2	-66.1	-74.4	-72.7	48.0
85°C	WW dis 4-L Average	All	11.4	-58.2	-52.1	-67.8	-74.8	-73.1	44.3
All	WW dis 4-L Average	All	12.6	-58.6	-50.9	-66.0	-74.4	-72.9	45.0

Table 7. Output Power and Harmonics - WW Discrete 4-Layer

3.3.2.2 ML-Inductor Discrete Reference Design Based on 4-Layer PCB

Freq. Band: 868 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	ML dis 4-L	2	11.6	-75.1	-74.7	-74.7	-74.4	-73.8	37.9
-40°C	ML dis 4-L	3	14.5	-62.5	-66.8	-64.1	-74.6	-66.6	46.3
-40°C	ML dis 4-L	3.6	15.4	-60.8	-66.0	-62.9	-73.8	-65.7	49.5
-40°C	ML dis 4-L Average	All	13.9	-66.1	-69.2	-67.2	-74.3	-68.7	44.6
25°C	ML dis 4-L	2	10.8	-68.9	-69.3	-71.5	-74.3	-72.3	38.2
25°C	ML dis 4-L	3	13.5	-64.1	-68.8	-66.1	-74.1	-68.1	45.4
25°C	ML dis 4-L	3.6	14.4	-61.9	-68.7	-64.7	-74.7	-67.3	48.4
25°C	ML dis 4-L Average	All	12.9	-64.9	-68.9	-67.4	-74.4	-69.2	44.0
85°C	ML dis 4-L	2	9.6	-69.5	-72.8	-72.1	-75.3	-74.2	38.1
85°C	ML dis 4-L	3	12.0	-65.8	-72.1	-69.4	-74.3	-71.8	43.9
85°C	ML dis 4-L	3.6	12.8	-64.6	-71.6	-68.3	-74.5	-71.7	46.6
85°C	ML dis 4-L Average	All	11.5	-66.7	-72.2	-69.9	-74.7	-72.6	42.9
All	ML dis 4-L Average	All	12.7	-65.9	-70.1	-68.2	-74.5	-70.2	43.8
Freq. Band: 915 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	ML dis 4-L	2	10.4	-75.4	-74.9	-74.8	-74.4	-72.4	35.6
-40°C	ML dis 4-L	3	13.1	-63.7	-69.3	-64.8	-73.6	-65.4	42.5
-40°C	ML dis 4-L	3.6	14.0	-62.4	-68.1	-63.3	-72.5	-64.1	45.4
-40°C	ML dis 4-L Average	All	12.5	-67.2	-70.7	-67.6	-73.5	-67.3	41.2
25°C	ML dis 4-L	2	9.5	-67.1	-72.0	-72.4	-74.8	-69.0	36.1
25°C	ML dis 4-L	3	12.1	-64.5	-70.4	-66.6	-73.8	-66.4	41.9
25°C	ML dis 4-L	3.6	13.0	-63.2	-70.0	-65.0	-73.9	-65.5	44.7
25°C	ML dis 4-L Average	All	11.5	-64.9	-70.8	-68.0	-74.2	-67.0	40.9
85°C	ML dis 4-L	2	8.3	-68.7	-74.6	-75.1	-84.5	-77.1	36.4
85°C	ML dis 4-L	3	10.4	-65.3	-73.7	-70.3	-74.0	-72.4	41.2
85°C	ML dis 4-L	3.6	11.2	-64.1	-73.4	-69.8	-74.1	-72.0	43.6
85°C	ML dis 4-L Average	All	10.0	-66.0	-73.9	-71.7	-77.5	-73.8	40.4
All	ML dis 4-L Average	All	11.3	-66.1	-71.8	-69.1	-75.1	-69.4	40.8

Table 8. Output Power and Harmonics - ML Discrete 4-Layer

3.3.2.3 JTI IPC Reference Design Based on 4-Layer PCB

Freq. Band: 868 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	JTI IPC 4-L	2	11.2	-55.9	-74.3	-75	-74.5	-74	41.2
-40°C	JTI IPC 4-L	3	14.1	-50.3	-42.6	-56	-55.6	-65.5	51
-40°C	JTI IPC 4-L	3.6	14.9	-50	-41.6	-55.1	-55.2	-63.3	54.9
-40°C	JTI IPC 4-L Average	All	13.4	-52.1	-52.8	-62	-61.7	-67.6	49.0
25°C	JTI IPC 4-L	2	10.2	-52	-47.4	-60.2	-59.7	-70.1	41.7
25°C	JTI IPC 4-L	3	12.9	-50.7	-45.1	-57.6	-58.5	-68.2	50.6
25°C	JTI IPC 4-L	3.6	13.7	-50.3	-44.2	-56.9	-58.3	-66.6	54.3
25°C	JTI IPC 4-L Average	All	12.2	-51	-45.6	-58.2	-58.8	-68.3	48.9
85°C	JTI IPC 4-L	2	8.6	-53.3	-51.8	-66.2	-66.6	-80	40.7
85°C	JTI IPC 4-L	3	10.6	-52.8	-50.4	-64.4	-65	-73.2	47.7
85°C	JTI IPC 4-L	3.6	11.1	-52.8	-49.5	-64.7	-66.3	-73.1	50.3
85°C	JTI IPC 4-L Average	All	10.1	-53.0	-50.6	-65.1	-66.0	-75.4	46.2
All	JTI IPC 4-L Average	All	11.9	-52.0	-49.7	-61.8	-62.2	-70.4	48.0
Freq. Band: 915 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	JTI IPC 4-L	2	10.3	-72.3	-75.1	-74.2	-73.9	-71.6	37.2
-40°C	JTI IPC 4-L	3	13.2	-49.1	-45.8	-59.2	-56.8	-63.1	45.4
-40°C	JTI IPC 4-L	3.6	13.9	-60.3	-67.1	-64.2	-71.9	-63.7	44.7
-40°C	JTI IPC 4-L Average	All	12.5	-60.5	-62.7	-65.9	-67.6	-66.1	42.4
25°C	JTI IPC 4-L	2	9.3	-52.2	-48.4	-68.2	-61.8	-71.5	38
25°C	JTI IPC 4-L	3	11.9	-49.8	-48.1	-61.7	-60	-65.9	45.2
25°C	JTI IPC 4-L	3.6	12.8	-48.9	-47.3	-60.4	-59.5	-66.1	48.3
25°C	JTI IPC 4-L Average	All	11.3	-50.3	-47.9	-63.4	-60.4	-67.8	43.8
85°C	JTI IPC 4-L	2	7.4	-55.7	-54.1	-80.5	-70.7	-83	37.6
85°C	JTI IPC 4-L	3	9.3	-53.1	-53.4	-73.6	-69.6	-73	43.3
85°C	JTI IPC 4-L	3.6	9.8	-53.1	-52.7	-72.2	-69.7	-72.6	45.7
85°C	JTI IPC 4-L Average	All	8.8	-54.0	-53.4	-75.4	-70.0	-76.2	42.2
All	JTI IPC 4-L Average	All	10.9	-54.9	-54.7	-68.2	-66.0	-70.0	42.8

Table 9. Output Power and Harmonics - JTI IPC 4-Layer

3.3.2.4 Murata IPC Reference Design Based on 4-Layer PCB

Freq. Band: 868 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	Murata IPC 4-L	2	11.3	-52.9	-74.7	-75.6	-74.8	-74.5	40.5
-40°C	Murata IPC 4-L	3	14.3	-37.8	-40.8	-41.0	-39.8	-53.7	48.9
-40°C	Murata IPC 4-L	3.6	15.1	-36.8	-40.3	-39.1	-38.3	-52.3	51.8
-40°C	Murata IPC 4-L Average	All	13.6	-42.5	-51.9	-51.9	-51.0	-60.2	47.0
25°C	Murata IPC 4-L	2	10.5	-43.9	-42.4	-45.3	-46.7	-59.8	41.2
25°C	Murata IPC 4-L	3	13.3	-40.4	-42.0	-41.4	-43.2	-56.0	48.7
25°C	Murata IPC 4-L	3.6	14.2	-39.2	-41.4	-39.7	-41.9	-54.9	51.7
25°C	Murata IPC 4-L Average	All	12.7	-41.2	-41.9	-42.2	-43.9	-56.9	47.2
85°C	Murata IPC 4-L	2	9.5	-46.4	-45.5	-46.7	-53.8	-64.3	40.8
85°C	Murata IPC 4-L	3	12.1	-43.2	-44.7	-43.1	-49.5	-60.9	47.8
85°C	Murata IPC 4-L	3.6	13.0	-42.1	-44.4	-41.8	-48.7	-60.8	50.6
85°C	Murata IPC 4-L Average	All	11.6	-43.9	-44.9	-43.9	-50.7	-62.0	46.4
All	Murata IPC 4-L Average	All	12.6	-42.5	-46.2	-46.0	-48.5	-59.7	46.9
Freq. Band: 915 MHz									
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	Murata IPC 4-L	2	10.6	-61.6	-75.1	-75.1	-74.7	-72.6	39.0
-40°C	Murata IPC 4-L	3	13.4	-50.7	-40.7	-33.8	-56.8	-54.6	46.4
-40°C	Murata IPC 4-L	3.6	14.2	-49.5	-40.2	-32.0	-55.4	-53.4	49.1
-40°C	Murata IPC 4-L Average	All	12.7	-53.9	-52.0	-47.0	-62.3	-60.2	44.8
25°C	Murata IPC 4-L	2	9.8	-57.5	-43.0	-39.0	-63.1	-59.9	39.6
25°C	Murata IPC 4-L	3	12.4	-54.1	-42.3	-35.5	-59.1	-56.7	46.2
25°C	Murata IPC 4-L	3.6	13.3	-52.7	-41.8	-34.0	-58.0	-56.1	49.1
25°C	Murata IPC 4-L Average	All	11.8	-54.8	-42.4	-36.2	-60.1	-57.6	45.0
85°C	Murata IPC 4-L	2	8.7	-60.1	-47.3	-42.1	-69.6	-66.2	39.3
85°C	Murata IPC 4-L	3	11.1	-57.1	-46.5	-39.0	-65.2	-63.9	45.2
85°C	Murata IPC 4-L	3.6	11.9	-55.9	-46.2	-38.2	-65.0	-65.3	47.9
85°C	Murata IPC 4-L Average	All	10.6	-57.7	-46.7	-39.8	-66.6	-65.2	44.2
All	Murata IPC 4-L Average	All	11.7	-55.5	-47.0	-41.0	-63.0	-61.0	44.7

Table 10. Output Power and Harmonics - Murata IPC 4-Layer

3.3.2.5 Murata IPC Reference Design Based on 2-Layer PCB

		Freq. Band: 868 MHz							
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	Murata IPC 2-L	2	10.6	-65.0	-75.1	-75.5	-74.4	-74.3	38.8
-40°C	Murata IPC 2-L	3	13.3	-38.2	-37.7	-37.0	-40.7	-57.3	45.6
-40°C	Murata IPC 2-L	3.6	14.1	-37.1	-37.2	-35.2	-39.5	-56.2	48.0
-40°C	Murata IPC 2-L Average	All	12.6	-46.8	-50.0	-49.2	-51.5	-62.6	44.1
25°C	Murata IPC 2-L	2	9.9	-44.1	-40.0	-42.0	-48.1	-62.5	39.7
25°C	Murata IPC 2-L	3	12.6	-40.6	-39.0	-37.8	-44.3	-59.1	46.3
25°C	Murata IPC 2-L	3.6	13.4	-39.4	-38.5	-36.2	-43.3	-58.4	49.0
25°C	Murata IPC 2-L Average	All	11.9	-41.3	-39.2	-38.6	-45.2	-60.0	45.0
85°C	Murata IPC 2-L	2	9.1	-46.6	-42.6	-43.7	-54.7	-66.2	39.9
85°C	Murata IPC 2-L	3	11.6	-43.1	-41.6	-39.6	-50.2	-63.4	46.4
85°C	Murata IPC 2-L	3.6	12.4	-41.9	-41.2	-38.5	-49.4	-63.3	49.1
85°C	Murata IPC 2-L Average	All	11.0	-43.8	-41.8	-40.6	-51.4	-64.3	45.1
All	Murata IPC 2-L Average	All	11.9	-44.0	-43.6	-42.8	-49.4	-62.3	44.8
		Freq. Band: 915 MHz							
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
-40°C	Murata IPC 2-L	2	10.5	-72.5	-74.7	-73.9	-74.6	-73.1	38.6
-40°C	Murata IPC 2-L	3	12.9	-52.3	-37.7	-30.8	-56.4	-56.5	44.7
-40°C	Murata IPC 2-L	3.6	13.7	-51.0	-37.2	-29.2	-55.5	-55.8	47.2
-40°C	Murata IPC 2-L Average	All	12.4	-58.6	-49.9	-44.6	-62.2	-61.8	43.5
25°C	Murata IPC 2-L	2	9.7	-56.8	-40.8	-36.5	-62.9	-61.9	39.3
25°C	Murata IPC 2-L	3	12.1	-53.2	-39.6	-33.0	-59.2	-59.2	45.2
25°C	Murata IPC 2-L	3.6	13.0	-51.9	-39.0	-31.5	-58.3	-58.6	47.8
25°C	Murata IPC 2-L Average	All	11.6	-54.0	-39.8	-33.7	-60.1	-59.9	44.1
85°C	Murata IPC 2-L	2	8.7	-58.1	-44.4	-39.9	-69.6	-68.2	39.3
85°C	Murata IPC 2-L	3	11.0	-54.6	-43.2	-36.5	-65.0	-65.7	44.9
85°C	Murata IPC 2-L	3.6	11.8	-53.4	-42.9	-35.6	-64.2	-65.9	47.5
85°C	Murata IPC 2-L Average	All	10.5	-55.4	-43.5	-37.3	-66.3	-66.6	43.9
All	Murata IPC 2-L Average	All	11.5	-56.0	-44.4	-38.5	-62.9	-62.8	43.8

Table 11. Output Power and Harmonics - Murata IPC 2-Layer



3.3.2.6 Summary of Output Power and Harmonics Measurements

		Freq. Band: 868 MHz							
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
All	WW dis 4-L Average	All	13.1	-53.3	-50.8	-64.6	-74.0	-74.4	45.9
All	ML dis 4-L Average	All	12.7	-65.9	-70.1	-68.2	-74.5	-70.2	43.8
All	Murata IPC 4-L Average	All	12.6	-42.5	-46.2	-46.0	-48.5	-59.7	46.9
All	Murata IPC 2-L Average	All	11.9	-44.0	-43.6	-42.8	-49.4	-62.3	44.8
All	JTI IPC 4-L Average	All	11.9	-52.0	-49.7	-61.8	-62.2	-70.4	48.0
		Freq. Band: 915 MHz							
Temp	Solution	Vcc	fc	2	3	4	5	6	mA
All	WW dis 4-L Average	All	12.6	-58.6	-50.9	-66.0	-74.4	-72.9	45.0
All	Murata IPC 4-L Average	All	11.7	-55.5	-47.0	-41.0	-63.0	-61.0	44.7
All	Murata IPC 2-L Average	All	11.5	-56.0	-44.4	-38.5	-62.9	-62.8	43.8
All	ML dis 4-L Average	All	11.3	-66.1	-71.8	-69.1	-75.1	-69.4	40.8
All	JTI IPC 4-L Average	All	10.9	-54.9	-54.7	-68.2	-66.0	-70.0	42.8

Table 12. Output Power and Harmonics Summary

Limit values used in Table 7, Table 8, Table 9, Table 10, Table 11 and Table 12 are taken from the ETSI EN 300 220 regulations for 868 MHz and FCC 15.247 for 915 MHz. The harmonic values shown in red exceed the conducted regulatory requirements; this is only an issue when an external antenna will be used in the final application. For applications which require conducted requirements then an external LC can be used.

The average current consumption of the JTI IPC is slightly higher than the Murata IPC and the discrete solution.

3.3.2.7 Overview of Harmonic Emission Regulatory Requirements

Harmonic emission will depend on ground plane geometry, encapsulation etc. Table 13 shows the FCC- and ETSI limits. Above 1 GHz, FCC allows the radiation to be up to 20 dB above the limits given in Table 13, if duty cycling is being used.

	Harmonics							
Limit	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>
FCC 15.249	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m
FCC 15.247	20 dBc	54 dB $\mu$ V/m	54 dB $\mu$ V/m	54 dB $\mu$ V/m	20 dBc	20 dBc	54 dB $\mu$ V/m	54 dB $\mu$ V/m
ETSI EN 300 220	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm

Table 13. ETSI and FCC Limits for Harmonic Radiation

The programmed output power and size of the ground plane will affect the level of the harmonics and thus determine the necessary duty cycling.

The allowed additional emission, or correction factor, is calculated based on maximum transmission time during 100 ms. Equation 1 can be used to calculate the correction factor, where t is equal to maximum transmission time during 100 ms. From Equation 1, it can be

# Design Note DN039

calculated that a maximum transmission time of 50 ms, during 100 ms, will permit all radiation above 1 GHz to be 6 dB above the given limits.

$$CF = -20 \bullet \log\left(\frac{t}{100ms}\right)$$

**Equation 1. FCC Correction Factor**

Even when an averaging detector is utilised, there is still a limit on emissions measured using a peak detector function with a limit 20 dB above the average limit.

### 3.3.3 Link Budget Calculations of the Various Reference Designs

Freq. Band: 868 MHz							
Temp	Solution	Vcc (V)	Rx (dBm)	I_stx (mA)	Power_stx (dBm)	link budget (dB)	Comments
All	WW dis 4-L Average	All	-123.0	45.9	13.1	136.1	ETSI and FCC approved
All	ML dis 4-L Average	All	-122.0	43.8	12.7	134.7	ETSI and FCC approved
All	Murata IPC 4-L Average	All	-122.0	46.9	12.6	134.6	ETSI approved
All	Murata IPC 2-L Average	All	-122.1	44.8	11.9	134.0	ETSI approved
All	JTI IPC 4-L Average	All	-121.9	48	11.9	133.8	ETSI and FCC approved
Freq. Band: 915 MHz							
Temp	Solution	Vcc (V)	Rx (dBm)	I_stx (mA)	Power_stx (dBm)	link budget (dB)	Comments
All	WW dis 4-L Average	All	-122.4	45	12.6	135.0	ETSI and FCC approved
All	JTI IPC 4-L Average	All	-122.2	42.8	10.9	133.1	ETSI and FCC approved
All	Murata IPC 4-L Average	All	-121.2	44.7	11.7	132.9	Limitations with 3rd & 4th FCC conducted harmonic
All	Murata IPC 2-L Average	All	-121.0	43.8	11.5	132.5	Limitations with 3rd & 4th FCC conducted harmonic
All	ML dis 4-L Average	All	-121.1	40.8	11.3	132.4	ETSI and FCC approved

**Table 14. Link Budget Calculations of the Various Reference Designs**

## 4 Conclusion

As an alternative to the traditional discrete reference designs as shown in Figure 2, the IPC reference designs can match the performance of the discrete multi-layer inductor reference design with a lower component count. The 868 / 915 MHz discrete solution has a total of 13 components in the RF section compared to the IPC solution of a singular component.

Both the Murata and JTI IPC device have the same footprint and pin-out; each device can be a second source pending assembly of R201 as shown in Figure 3. If second source is not critical for the IPC part then resistor R201 is not needed.

The majority of application have an internal antenna but for applications that require conducted emissions approval (application with an external RF connector); an external LC filter may be required to pass 3<sup>rd</sup> and 4<sup>th</sup> conducted emissions for the Murata IPC part.

For best-in-class RF performance; the discrete wire-wound inductor solution is still recommended but for compact and cost sensitive solutions the IPC reference designs should be considered. Refer to Table 15 for recommended usage for the various reference designs.

Freq. Band: 868 MHz					
Solution	Application Recommendations	RF Component Count	Cost	link budget (dB)	Comments
WW dis 4-L	RF Best-in-class performance	13	Middle	136.1	ETSI and FCC approved
ML dis 4-L	-	13	Low	134.7	ETSI and FCC approved
Murata IPC 4-L	Recommended for compact and cost sensitive solutions at 868 MHz	1	Lowest	134.6	ETSI approved
Murata IPC 2-L	Recommended for 2-layer solutions at 868 MHz	1	Lowest	134.0	ETSI approved
JTI IPC 4-L	-	1	Middle	133.8	ETSI and FCC approved
Freq. Band: 915 MHz					
Solution	Application Recommendations	RF Component Count	Cost	link budget (dB)	Comments
WW dis 4-L	RF Best-in-class performance	13	Middle	135.0	ETSI and FCC approved
JTI IPC 4-L	Recommended for compact solutions at 915 MHz	1	Middle	133.1	ETSI and FCC approved
Murata IPC 4-L	Recommended for cost sensitive solutions at 915 MHz	1	Lowest	132.9	Limitations with 3rd & 4th FCC conducted harmonic
Murata IPC 2-L	Recommended for 2-layer solutions at 915 MHz	1	Lowest	132.5	Limitations with 3rd & 4th FCC conducted harmonic
ML dis 4-L	-	13	Low	132.4	ETSI and FCC approved

Table 15. Recommendations and Link Budget for the Various Reference Designs

## 5 References

- [1] CC1120 Data Sheet ([cc1120.pdf](#))
- [2] CC1121 Data Sheet ([cc1121.pdf](#))
- [3] CC1125 Data Sheet ([cc1125.pdf](#))
- [4] CC1175 Data Sheet ([cc1175.pdf](#))
- [5] Murata contact information: <http://www.murata.com/contact/index.html>
- [6] JTI contact information: <http://www.johansontechnology.com/en/contact.html>
- [7] CC112x IPC 868/915 MHz 4-Layer Ref. Design Rev1.0 ([swrr107.zip](#))
- [8] CC112x IPC 868/915 MHz 2-Layer Ref. Design Rev1.0 ([swrr106.zip](#))
- [9] CC112x EM 868/915 MHz Reference Design ([swrc224.zip](#))

## 6 General Information

### 6.1 Document History

Revision	Date	Description/Changes
SWRA407	2012.08.20	Initial release.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46C and to discontinue any product or service per JESD48B. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

**TI E2E Community** [e2e.ti.com](http://e2e.ti.com)