

## Johanson Technology Matched Balun Filters for CC110x & CC111x

By Richard Wallace

### Keywords

- Single Component Matched Balun Filter (433 MHz or 868 MHz or 915 MHz)
- Matched Balun Filter with external LC filter (868 MHz and 915 MHz)
- Optimized for compact designs
- 433, 868 and 915 MHz ISM Bands
- CC1100
- CC1101
- CC1110
- CC1111
- CC1150

### 1 Introduction

With the Johanson Technology (JTI) matched balun filter component; the component count is significantly reduced whilst still obtaining the high radio performance [desired](#).

This document describes the JTI matched chip balun filters that have been specifically designed for the CC110x and CC111x family of ICs operating in the 433, 868 and 915 MHz ISM bands.

The existing matched filter balun component from JTI required a [single-pole](#) external LC filter and a DC blocking capacitor; part number: 0896BM15A0001 [4]. This part is targeted towards a design that has to be compliant at 868 MHz and 915 MHz with the external LC filter and DC blocking cap (three external 0402 components required).

With the new balun component family, only one component is required to achieve compliance at 433 MHz [6.2] or 868 MHz [6.3] or 915 MHz [6.4]. i.e. no additional external components are required.

It is important to note that the new matched baluns are optimized for a single ISM frequency band.

The three balun-filter parts are available [4]: 433 MHz [6.2] (part number: 0433BM15A0001), 868 MHz [6.3] (part number: 0868BM15C0001) and 915 MHz [6.4] (part number: 0915BM15A0001). All these parts share a common footprint.

The size for the matched balun filter component is only 2.0 mm x 1.25 mm (EIA 0805, Metric 2012) therefore it is recommended for compact designs.

All measurement results presented in this document are based on measurements performed on the CC1101 JTI EM Rev 1.0 Reference Design [6], shown in Figure 1. If the new matched filter balun is used on this board then the external components are not required.

The comparison performance of the JTI Reference Design and the Discrete Reference Designs will be discussed in this document.



Figure 1. CC1101 868 / 915 MHz JTI Balun EM

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## 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
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
WW	Wire-Wound Inductor

## 3 Reference Designs Available

There are basically three reference designs available for CC110x, CC111x and CC11xL; each reference design has its own particular advantage.

### 3.1 Discrete Reference Design

The traditional 868/915 MHz reference design for the CC110x and CC111x has been the discrete solution [8] shown in Figure 2; 315/433 MHz reference design has been the discrete solution [9] shown in Figure 3. 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**.

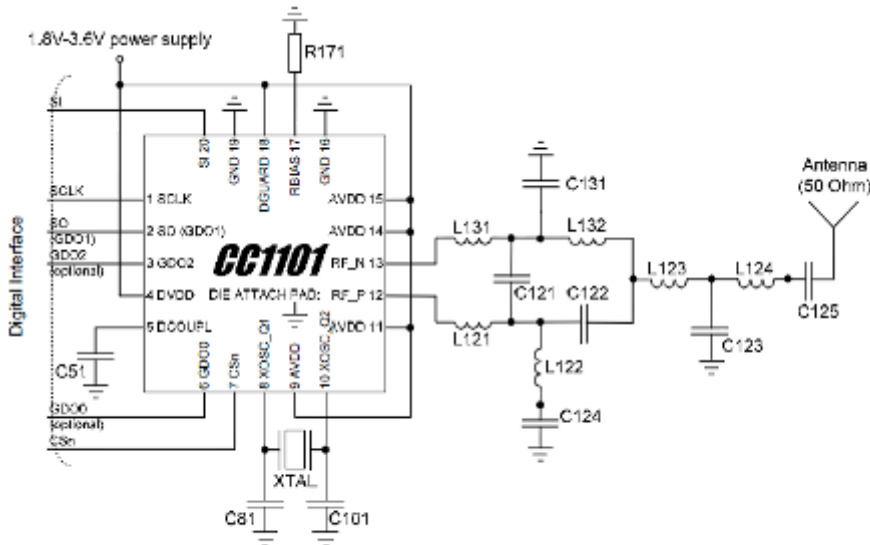


Figure 2. Discrete Reference Design for the CC110x and CC111x 868/915 MHz (no decoupling capacitors shown)

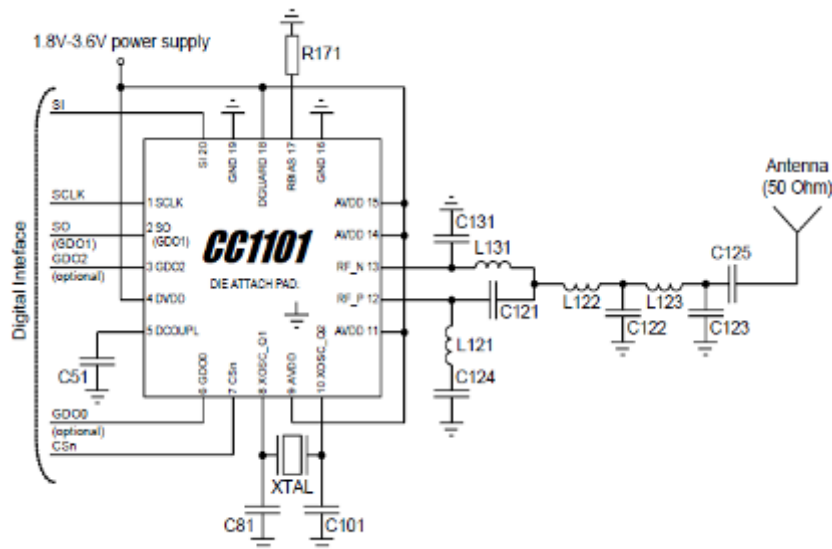


Figure 3. Discrete Reference Design for the CC110x and CC111x 315/433 MHz (no decoupling capacitors shown)

## 3.2 ValueLine Reference Design

The integrated inductor ValueLine Reference designs offer the lowest possible cost. The schematics are similar to those shown in Figure 2 and Figure 3 with the exception that the inductors have been integrated into the PCB. This gives a cost advantage but also means that the reference design must be strictly followed by using the same PCB thickness otherwise the performance will change.

The integrated inductor ValueLine reference designs have the **lowest cost but are also the largest in size.**

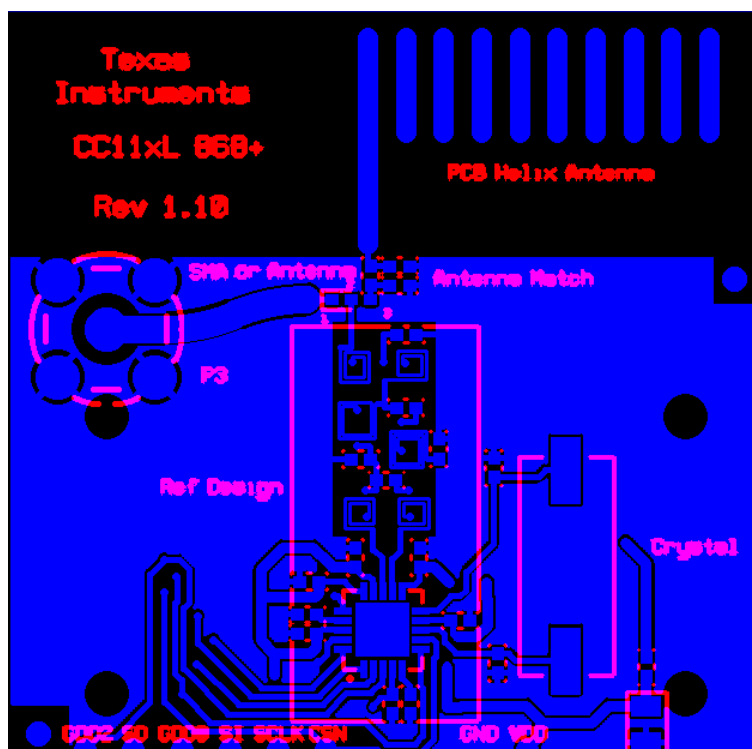


Figure 4. Top Layer integrated inductor ValueLine Reference Design for the CC110x and CC111x 868/915 MHz

## 3.3 JTI Matched Filter Balun Reference Designs

### 3.3.1 JTI Matched Filter Balun for 868 MHz and 915 MHz (Dual Band)

Johanson Technology has developed a solution with a chip balun that is especially matched for the CC110x and CC111x chips. Please refer to Appendix A [6.1] for data sheet of the matched balun filter component (the full specification is available from the Johanson Technology web site [4]).

The JTI matched balun filter solution [6] implemented on the CC1101 868/915 MHz JTI Balun reference design consists of the Matched Balun Filter and an external LC filter which is valid for all CC110x and CC111x. The need of the LC filter is discussed in more detail in Section 3.3.1.3 in this document.

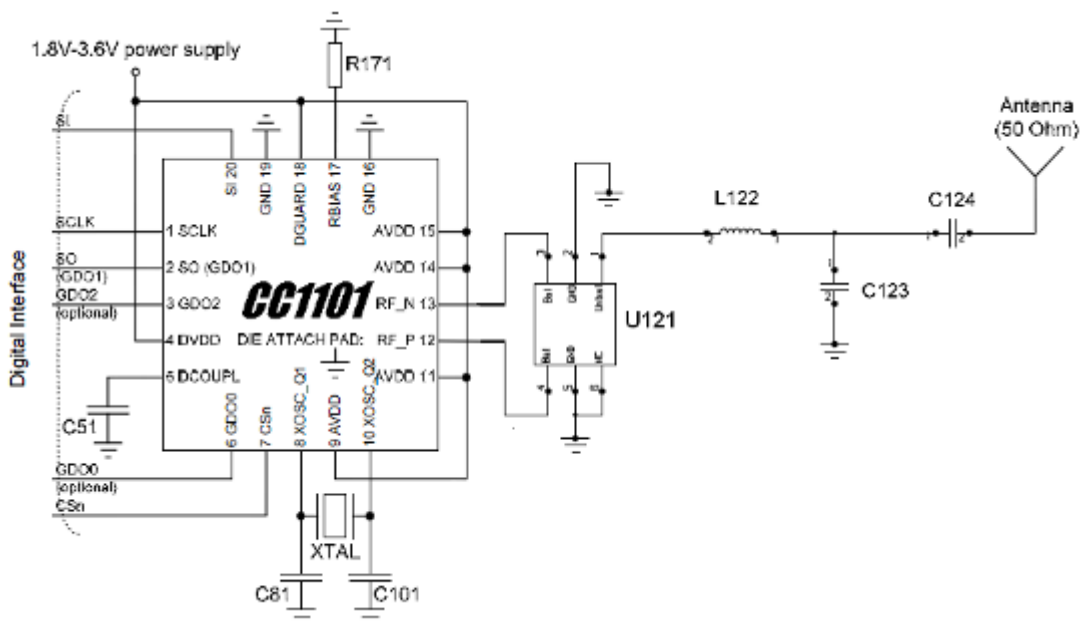


Figure 5. JTI Reference Design for the CC110x and CC111x 868/915 MHz (no decoupling capacitors shown)

Referring to Figure 5, U121 is the JTI Matched Balun Filter 0896BM15A0001. Inductor L122 is 5.6 nH and capacitor C123 is 1.8 pF; these two components form the LC filter. C124 is a DC blocking capacitor and should be NPO type to minimize losses; recommended value of 100 pF. The DC block is only needed when there is a DC path in the antenna. Recommended part numbers from Johanson Technology for the inductor (L122) is L-07C5N6SV4 and the capacitor (C123) is 500R07S1R8BV4.

3.3.1.1 Component Placement

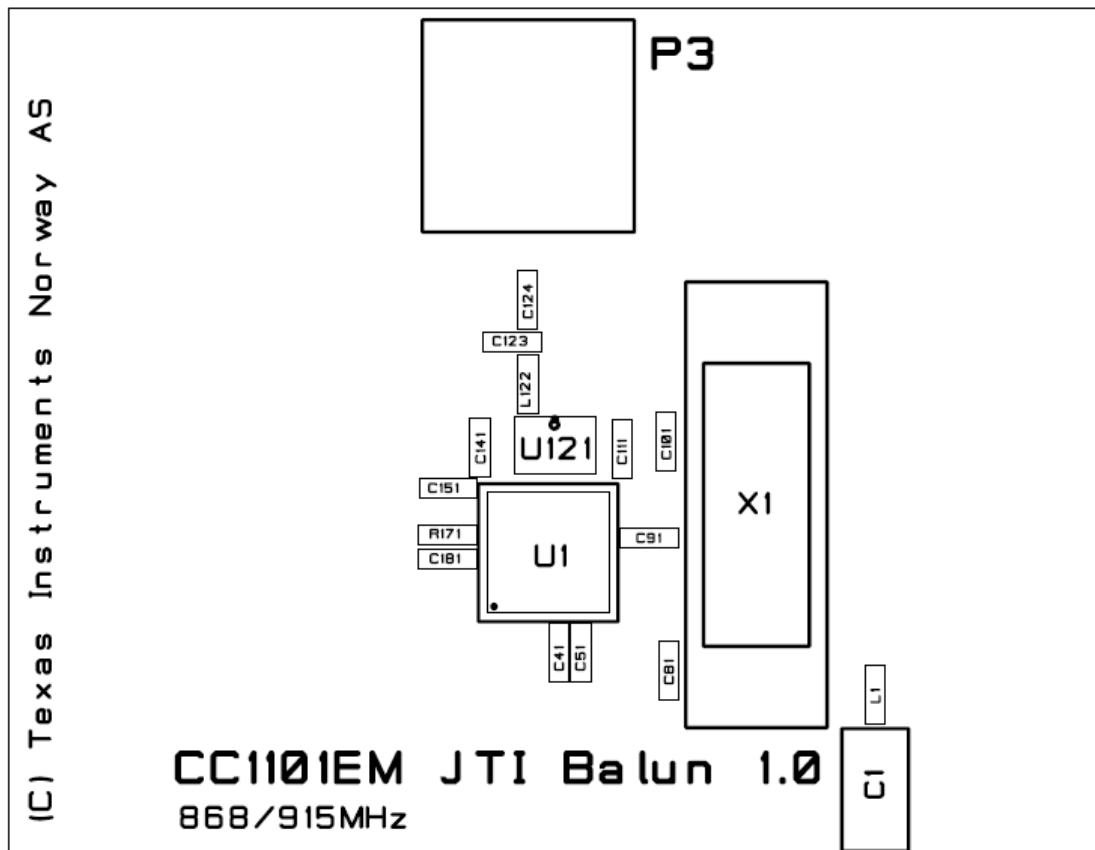
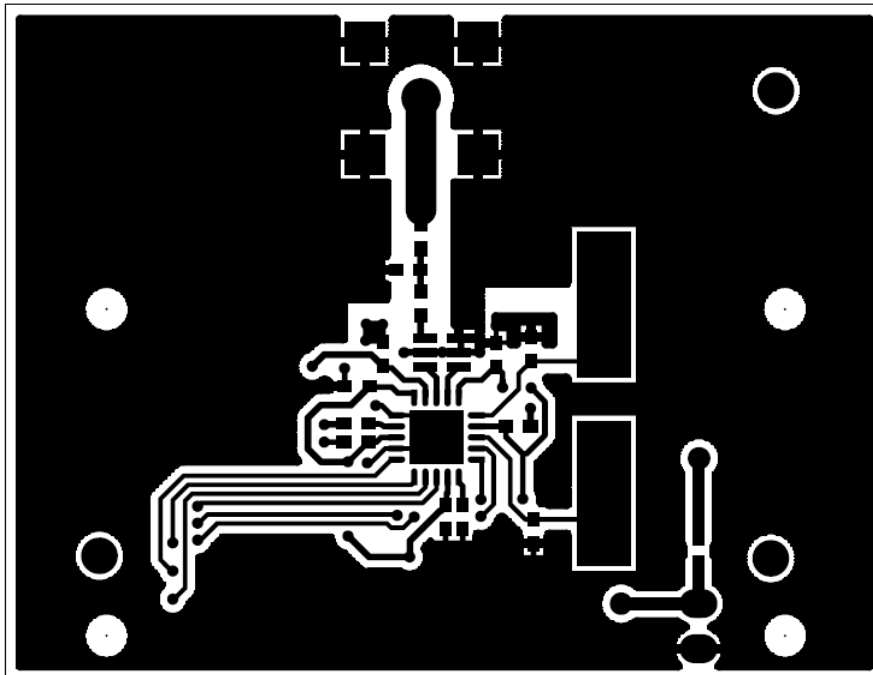


Figure 6. Component Placement

The component placement influences the RF performance. In the event that the reference design [6] can not be copied then it is important to position the inductor L122 so that the coupling effects to the Matched Balun Filter U121 are minimized as much as possible. Experiments with placing L122 in parallel to U121 showed that coupling was evident and the Matched Balun Filter performance was not optimum. Keep the inductor L122 at 90 degrees to the balun as shown in Figure 6 or position it on the left side of U121 to avoid coupling to pin 6 of U121.

## 3.3.1.2 Layout

The layout greatly influences the RF performance. TI recommends to always copy our reference design [6] as closely as possible.

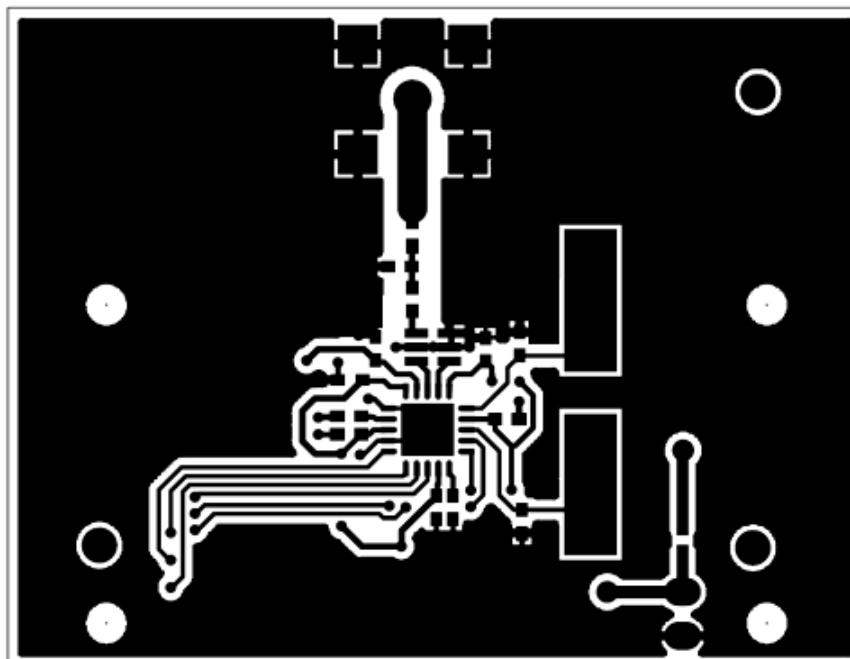


**Figure 7. Layer 1 of CC1101 JTI 868/915 MHz Reference Design Layout**

The ground from the decoupling capacitors has been divided from the remaining ground on layer1. Tests from the lab have proven that this is not necessary and the ground can be solid as shown in Figure 8. As previously mentioned, the most important critical part of the layout is the positioning of the inductor L122 in order to minimize the coupling effect to the Matched Balun Filter.

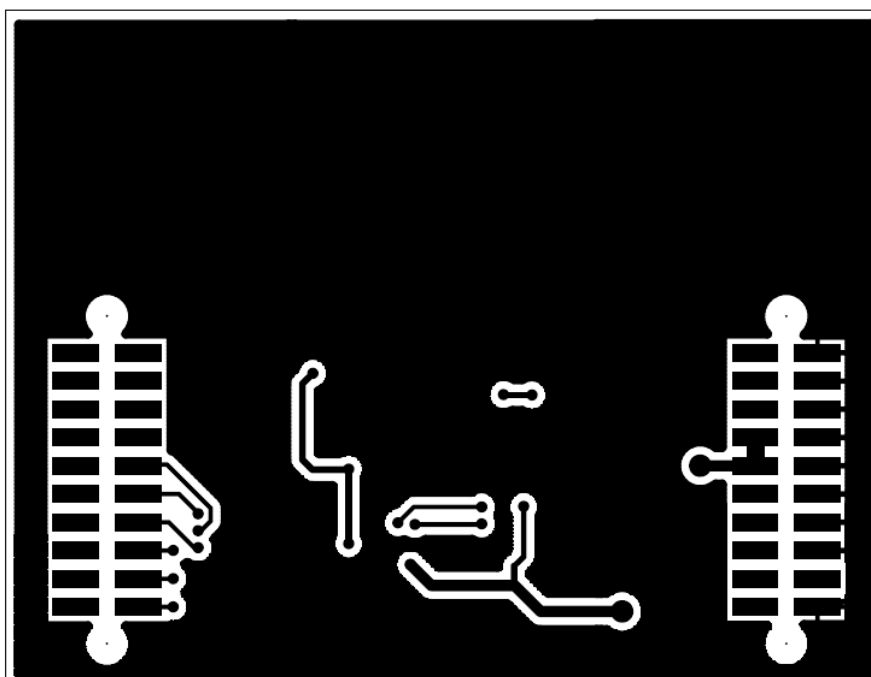
In the event that the reference design [6] can not be copied then the routing from the RF pins RF\_P & RF\_N must be symmetrical to the Matched Balun Filter component, U121. The length of the tracks should be kept to a minimum and preferably the same length that is used in the reference design [6]. If 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.



**Figure 8. Alternative Grounding on Layer 1**

The routing in Figure 8 is the same as Figure 7 apart from the ground fill around the balun.



**Figure 9. Layer 2 of CC1101 JTI 868/915 MHz Reference Design Layout**

On the second layer; it is important to have a solid ground plane underneath the RF structure and to avoid any routing directly underneath the RF. The power routing has been routed in a star formation and the power tracks must always be routed to the decoupling capacitor first; then from the decoupling capacitor to the pad of the CC1101.



## 3.3.1.3 Measurement Results

All results presented in this chapter are based on measurements performed with CC1101 JTI EM Rev 1.0 Reference Design board [6]. A minimum of six units have been measured in order to obtain an average result which is presented in this report. All measurement results presented are the average of each batch tested from typical devices.

The output power and harmonics measurements were performed with four different power PATABLE settings: 0xC0 and 0xC2 for 10 dBm applications and 0x8E and 0x50 for 0 dBm applications.

**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.

### 3.3.1.3.1 Sensitivity

Freq. Band	868 MHz				915 MHz			
Data Rate [kBaud]	1.2	38.4	250	500	1.2k	38.4	250	500
JTI with LC	-111.6	-103.6	-94.8	-87.2	-111.4	-103.2	-94.4	-87.3
Discrete ML	-111.0	-103.0	-94.0	-87.0	-111.0	-103.0	-94.0	-87.0

**Table 1. Average Sensitivity Values Obtained**

As can be seen from Table 1; the JTI reference design with LC has the same or better sensitivity than the discrete solution with Multi-Layer (ML) inductors.

Freq. Band	868 MHz				915 MHz			
Data Rate [kBaud]	1.2	38.4	250	500	1.2k	38.4	250	500
JTI no LC	-111.4	-103.1	-94.4	-86.5	-111.3	-102.2	-93.8	-86.2
JTI with LC	-111.6	-103.6	-94.8	-87.2	-111.4	-103.2	-94.4	-87.3
Difference	-0.2	-0.5	-0.4	-0.7	-0.1	-0.9	-0.6	-1.1

**Table 2. Difference in Sensitivity Values with and without LC Filter**

As can be seen from Table 1 and Table 2; the sensitivity is same or better with the LC filter.

# Design Note DN025

## 3.3.1.3.2 Output Power and Harmonics

	868 MHz (0896BM15A0001)			915 MHz (0896BM15A0001)		
	JTI with LC	JTI no LC	ETSI Limit	JTI with LC	JTI no LC	FCC Limit
<b>Fundamental</b>						
C0	10.8	11.4		11.2	11.4	
C2	10.0	10.7		10.4	10.7	
8E	1.5	1.4		0.8	0.8	
50	0.3	0.3		0.0	-0.1	
<b>2<sup>nd</sup> harmonic</b>						
C0	<b>-28.9</b>	<b>-25.2</b>	-30	-28.1	-25.7	-20 dBc
C2	-34.0	<b>-29.7</b>	-30	-32.9	-30.1	-20 dBc
8E	-40.8	-42.0	-30	-43.1	-45.8	-41.2
50	-35.9	-33.8	-30	<b>-37.2</b>	<b>-35.7</b>	-41.2
<b>3<sup>rd</sup> harmonic</b>						
C0	-48.3	-42.3	-30	-49.4	<b>-40.4</b>	-41.2
C2	-48.6	-42.7	-30	-49.9	<b>-41.2</b>	-41.2
8E	-55.4	-53.4	-30	-56.3	-52.8	-41.2
50	-55.1	-53.2	-30	-56.1	-53.1	-41.2
<b>4<sup>th</sup> harmonic</b>						
C0	-48.5	<b>-29.6</b>	-30	-49.9	<b>-30.2</b>	-41.2
C2	-51.5	-33.4	-30	-52.2	<b>-33.7</b>	-41.2
8E	-54.6	-40.2	-30	-53.7	<b>-37.8</b>	-41.2
50	-55.5	-42.5	-30	-54.8	<b>-41.0</b>	-41.2
<b>5<sup>th</sup> harmonic</b>						
C0	-52.2	-44.5	-30	-52.4	-44.4	-41.2
C2	-52.6	-44.8	-30	-52.6	-45.0	-41.2
8E	-55.1	-53.4	-30	-54.5	-53.5	-41.2
50	-55.0	-53.4	-30	-54.5	-53.7	-41.2
<b>6<sup>th</sup> harmonic</b>						
C0	-53.4	-43.3	-30	-52.0	-43.7	-41.2
C2	-53.5	-46.4	-30	-52.1	-46.7	-41.2
8E	-53.6	-48.3	-30	-52.2	-47.3	-41.2
50	-53.6	-51.2	-30	-52.1	-49.5	-41.2
<b>7<sup>th</sup> harmonic</b>						
C0	-51.9	-50.8	-30	-50.9	-50.7	-20 dBc
C2	-51.9	-50.7	-30	-50.9	-50.6	-20 dBc
8E	-51.9	-52.0	-30	-50.8	-50.9	-41.2
50	-51.9	-52.0	-30	-50.9	-51.0	-41.2
<b>8<sup>th</sup> harmonic</b>						
C0	-49.4	-47.6	-30	-52.6	-48.5	-41.2
C2	-49.4	-49.1	-30	-53.8	-51.5	-41.2
8E	-49.4	-48.9	-30	-54.0	-51.7	-41.2
50	-49.3	-49.5	-30	-54.6	-54.0	-41.2

9 <sup>th</sup> harmonic						
C0	-52.4	-52.4	-30	-52.6	-53.3	-41.2
C2	-52.4	-52.2	-30	-52.3	-53.2	-41.2
8E	-52.6	-52.5	-30	-53.5	-53.6	-41.2
50	-52.6	-52.7	-30	-53.5	-53.6	-41.2

**Table 3. Output Power and Conducted Harmonic Values Obtained**

All values are in dBm unless stated. The values shown in red exceed the regulatory requirements. If the recommended values and configuration are followed as specified in Table 5 then the regulatory requirements will be fulfilled.

Limit values shown in Table 3 are taken from the ETSI EN 300 220 regulations for 868 MHz and FCC 15.247 for 915 MHz.

### 3.3.1.3.3 Overview of Harmonic Emission Regulatory Requirements

Harmonic emission will depend on ground plane geometry, encapsulation etc. Table 4 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 4, if duty cycling is being used. The second harmonic would only be an issue when qualifying under FCC part 15.249 since 15.247 only requires 20 dBc.

Limit	Harmonics							
	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>
<b>FCC 15.249</b>	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
<b>FCC 15.247</b>	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
<b>ETSI EN 300 220</b>	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-30 dBm

**Table 4. 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 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.

For more information and recommendations on how to comply with the different ETSI sub bands please see Application Note 050 [3]. Application note AN001 [10] covers the regulations in more detail for Short Range Devices (SRD) for license free transceiver operation.

## 3.3.1.3.4 Radiated Emissions

Tests performed with the 0896BM15A0001 and an external LC filter. Figure 10, Figure 11 and Figure 12 are from an anechoic chamber performed with the specified settings stated in the figure text. The tests were not performed according to the ETSI or FCC regulations since this was not possible in the lab that was used. In these tests, the detector on the spectrum analyzer was set to max hold in order to find the worst case limits. These measurements have to be performed on the final application board to be compliant to the ETSI and FCC regulations so these measurements are just for pre-qualification purposes. The charts are only showing a maximum of -10 dBm; this is due to the software used to record the graphs; 10 dBm and 0 dBm was transmitted for the tests.

The reference design boards are 2-layer, 0.8 mm thick, FR4 PCB. The radiated emission level will be dependant on the ground plane, decoupling capacitors, power routing and thickness of the PCB. The choice of antenna will also effect the radiated emissions.

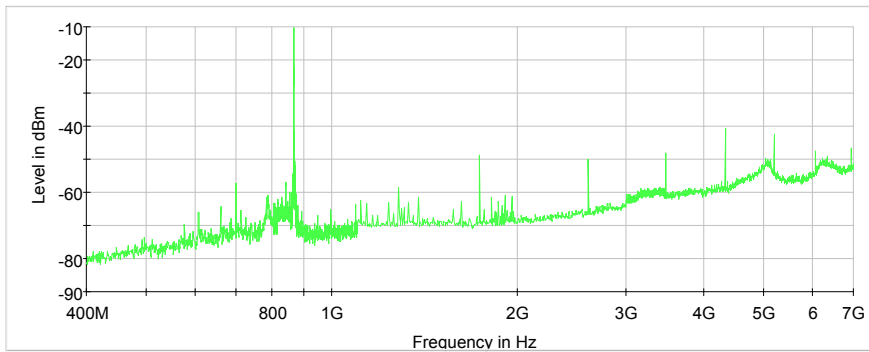


Figure 10. 10 dBm Output Power (0xC2); 868 MHz Un-modulated Static TX Carrier

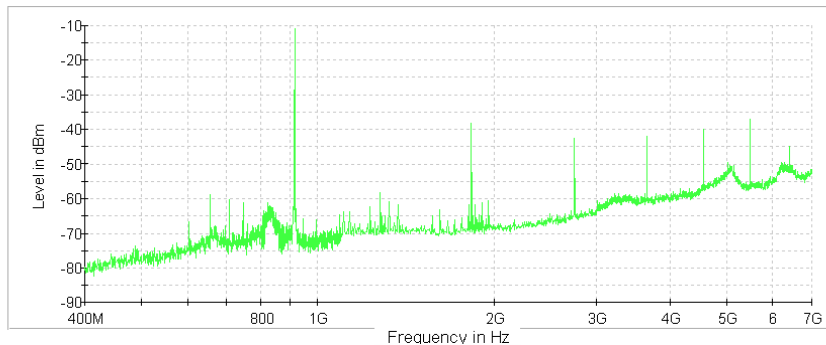


Figure 11. 10 dBm Output Power (0xC0); 915 MHz Un-modulated Static TX Carrier

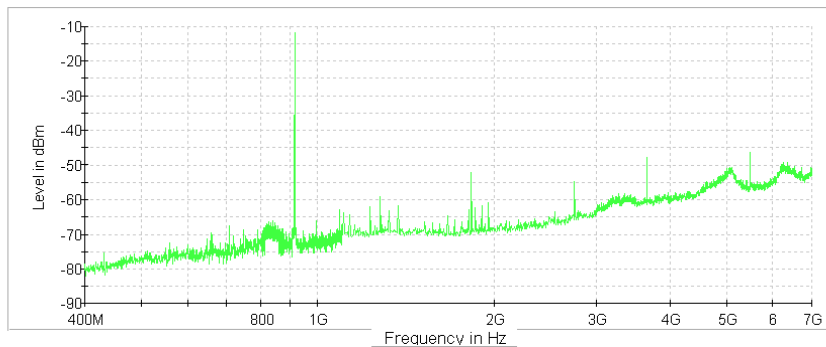


Figure 12. 0 dBm Output Power (0xC0); 915 MHz Un-modulated Static TX Carrier

# Design Note DN025

As can be seen in Figure 11; there are some higher order harmonics that exceed the FCC limit of -41.2 dBm. If this was the case in the application; then equation 1 could be used to correlate the level by not continuously transmitting.

In theory, performing the test with a 4-layer FR4 PCB with a ground plane on layer 2, will give a better performance since the pre-preg is typically 80-100 um thick and this will give a better grounding and amount of radiated energy will be less compared to a similar design on a 2-layer. Even when several pre-preg layers will be used between layer 1 and layer 2 on a 4-layer FR4 PCB; the thickness will generally be less than 0.8 mm, so the radiated performance will be better.

### 3.3.1.4 Summary of Measurements

Use of an LC filter does not affect the sensitivity or the output power measurements significantly. For the total link budget, there is an advantage using the LC filter for the sensitivity and a slight power loss for the output power. Therefore, the total effect of the LC filter on the system performance will be the same. However, the main benefits of the LC filter are the suppression of the harmonics.

When deciding which configuration should be used, the following should be considered:

There are mainly two power applications categories with 10 dBm and 0 dBm; there are FCC and ETSI regulatory requirements; and also if conducted emissions will also be tested in the final application (i.e. no internal antenna available, only RF connector). The level of the output power setting will also affect the levels of the harmonics as can be seen in Table 3.

Refer to Table 5, to summarize all the previous mentioned application variables to obtain the recommended application settings. The recommended power setting is also included in Table 5.

	ETSI Internal Antenna		ETSI (RF Connector)	
<b>10 dBm</b>	JTI with LC	0xC0: 10.8 dBm	JTI with LC	0xC2:10 dBm
<b>0 dBm</b>	JTI no LC	0x50: 0.3 dBm	JTI no LC	0x50: 0.3 dBm
	FCC Internal Antenna		FCC (RF Connector)	
<b>10 dBm</b>	JTI with LC	0xC0: 11.2 dBm (1)	JTI with LC	0xC0: 11.2 dBm
<b>0 dBm</b>	JTI with LC	0x8E: 0.8 dBm	JTI with LC	0x8E: 0.8 dBm

**Table 5. Recommended Output Power Settings and Application Configuration**

For example; a customer with PCB size restrictions has an integrated antenna [7], 0 dBm output power; targeting only the ETSI market. With reference to Table 5; the LC filter will not be required for regulatory issues and with a power setting of 0x50, the expected power should be around 0.3 dBm.

Good practice would be to incorporate the LC filter into the first prototype. The filter can always be removed by using a 100 pF capacitor or 0 ohm resistor instead of using the 5.6 nH inductor and leaving the 1.8 pF capacitor un-mounted.

## 3.3.2 JTI Matched Filter Balun for 433 MHz or 868 MHz or 915 MHz

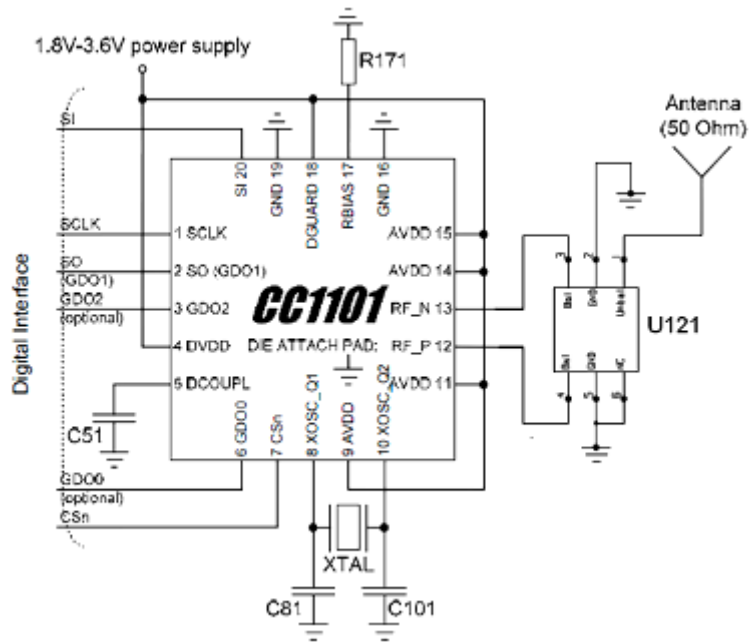


Figure 13. JTI Reference Design for 433 MHz or 868 MHz or 915 MHz (no decoupling capacitors shown)

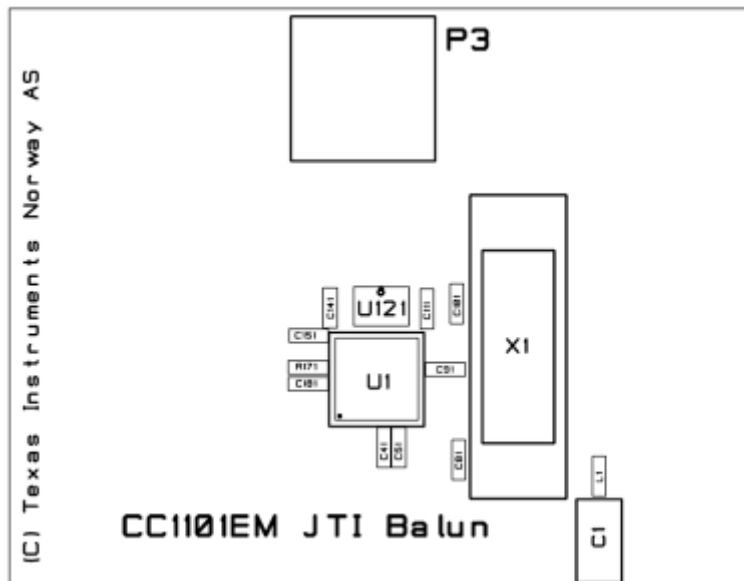
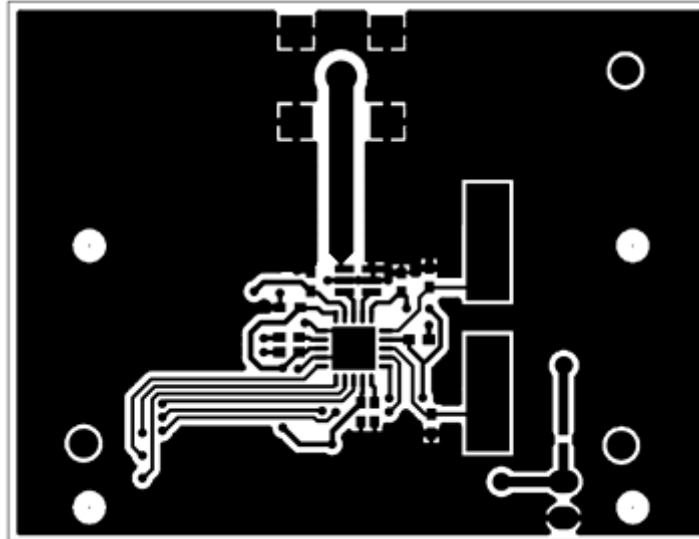
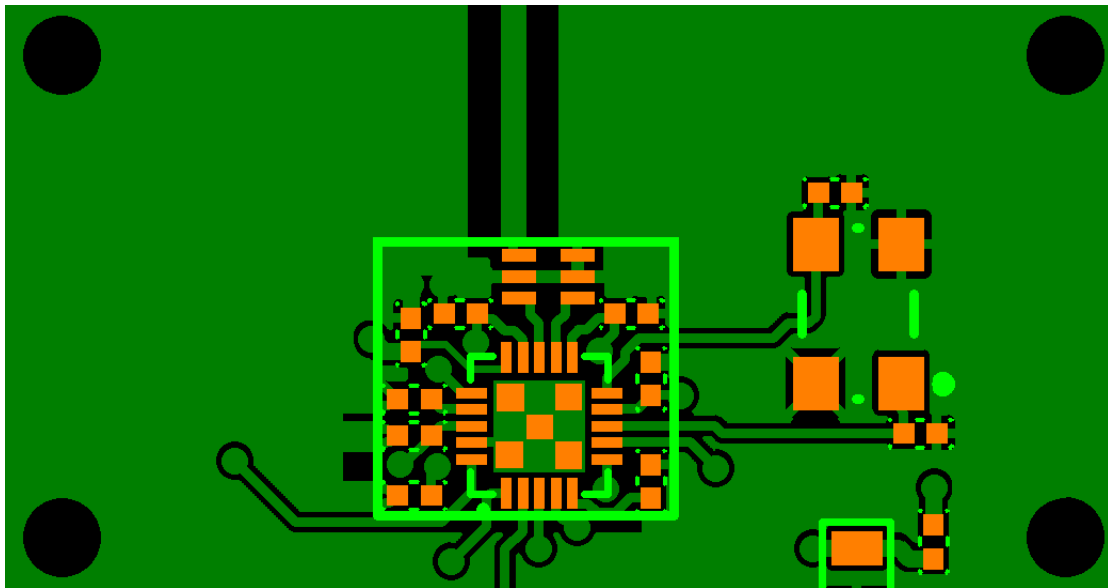


Figure 14. Component Placement Recommendations

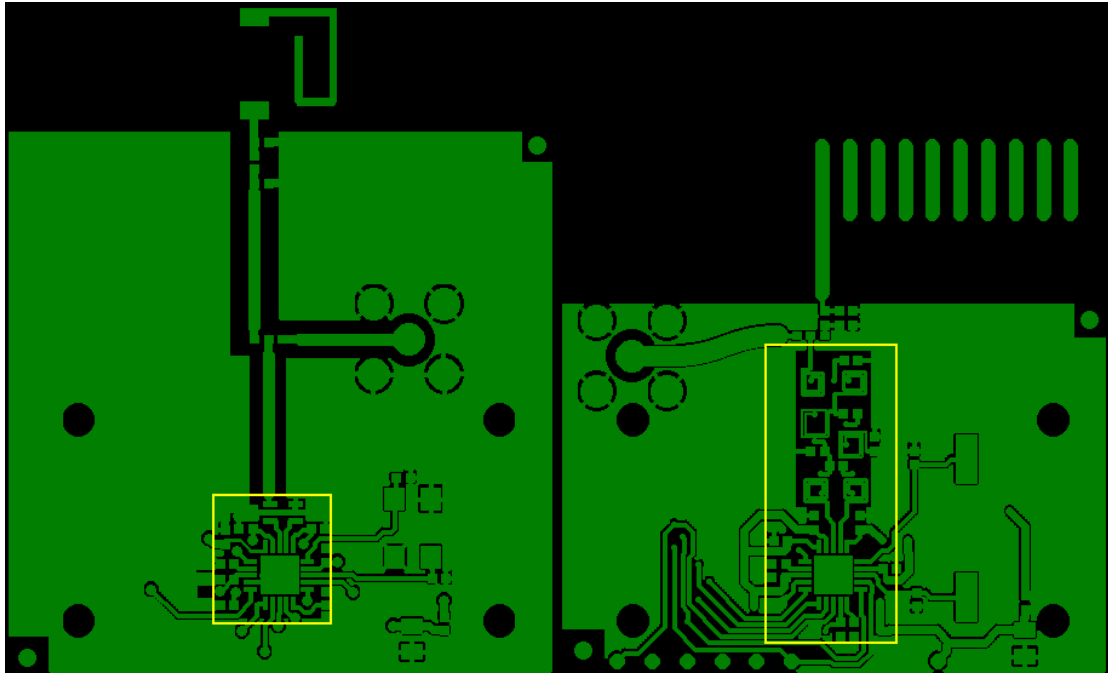


**Figure 15. Top Layer Routing Recommendations**

Refer to Figure 9, for the bottom layer layout recommendations. On the second layer; it is important to have a solid ground plane underneath the RF structure and to avoid any routing directly underneath the RF. The power routing has been routed in a star formation and the power tracks must always be routed to the decoupling capacitor first; then from the decoupling capacitor to the pad of the CC1101.



**Figure 16. Top Layer for Ultimate Compact Solutions, 4-layer design**



**Figure 17. Effective PCB Size Comparisons between for JTI Ultimate Compact Solution and Integrated Inductor Valueline Design**

Referring to Figure 17, the JTI design on the left side is 8.6 mm x 8.6 mm ~74 mm<sup>2</sup>; the ValueLine design is 9.7 mm x 21.7 mm ~210 mm<sup>2</sup>. The discrete design size is 9.7 mm x 16.1 mm ~156 mm<sup>2</sup>.

### 3.3.2.1 JTI Matched Filter Balun 433 MHz

#### 3.3.2.1.1 Output Power and Harmonics

Solution	433 MHz	866 MHz	1299 MHz	1732 MHz	2165 MHz	2598 MHz	3031 MHz	3464 MHz
Discrete (ML)	8.4	-46	-51	-62	-62	-64	-57	-63
JTI	8.2	-47	-49	-54	-49	-44	-37	-38
Limits	10	-36	-30	-30	-30	-30	-30	-30

All values are in dBm.

Similar performance as multi-layer discrete solution. Lower 8th & 9th harmonic attenuation but still good enough margins



# Design Note DN025

## 3.3.2.2 JTI Matched Filter Balun 868 MHz

Power Setting 868 MHz	0868BM15C0001	0896BM15A0001 with LC + C	ETSI Limit
C0	9.4	10.8	
8E	-1	1.5	
<b>1736 MHz</b>			
C0	-35	<b>-28.9</b>	-30
8E	-50.8	-40.8	-30
<b>2604 MHz</b>			
C0	-42	-48.3	-30
8E	-61	-55.4	-30
<b>3472 MHz</b>			
C0	-33.6	-48.5	-30
8E	-44.1	-54.6	-30
<b>4340 MHz</b>			
C0	-36	-52.2	-30
8E	-61	-55.1	-30
<b>5208 MHz</b>			
C0	-42.9	-53.4	-30
8E	-50.5	-53.6	-30
<b>6076 MHz</b>			
C0	-56	-51.9	-30
8E	-65	-51.9	
<b>6944 MHz</b>			
C0	-50	-49.4	-30
8E	-56	-49.4	
<b>7812 MHz</b>			
C0	-62	-52.4	-30
8E	-65	-52.6	-30
<b>fc-169 (C0)</b>	-70	<b>-53.5</b>	-57

All values are in dBm unless stated. The values shown in red exceed the regulatory requirements.

The matched balun filter (0868BM15C0001) passes all the harmonic requirements. The IL has increased since the dual band version (0896BM15A0001) but this is understandable considering that the attenuation is increased for the harmonics and a notch has been included to eliminate the fundamental – 169 MHz spur.

# Design Note DN025

## 3.3.2.3 JTI Matched Filter Balun 915 MHz

### 3.3.2.3.1 Output Power and Harmonics

Power Setting 915 MHz	0915BM15A0001	0896BM15A0001 without ext LC + C	0896BM15A0001 with LC + C	FCC Limit
<b>C0</b>	10.4	11.4	11.2	
<b>C3</b>	9.3	10.7	10.4	
<b>8E</b>	0.4	0.8	0.8	
<b>50</b>	-	-0.1	0.0	
<b>1830 MHz</b>				
<b>C0</b>	-50	-26	-28	-20 dBc
<b>C3</b>	-55	-30	-33	-20 dBc
<b>8E</b>	-52	-46	-43	-41.2
<b>50</b>	-	<b>-36</b>	<b>-37</b>	-41.2
<b>2745 MHz</b>				
<b>C0</b>	-54	<b>-40</b>	-49	-41.2
<b>C3</b>	-55	<b>-41</b>	-50	-41.2
<b>8E</b>	-62	-53	-56	-41.2
<b>50</b>	-	-53	-56	-41.2
<b>3660 MHz</b>				
<b>C0</b>	<b>-39</b>	<b>-30</b>	-50	-41.2
<b>C3</b>	-43	<b>-34</b>	-52	-41.2
<b>8E</b>	-49	<b>-38</b>	-54	-41.2
<b>50</b>	-	<b>-41</b>	-55	-41.2
<b>4575 MHz</b>				
<b>C0</b>	-47	-44	-52	-41.2
<b>C3</b>	-45	-45	-53	-41.2
<b>8E</b>	-56	-54	-55	-41.2
<b>50</b>	-	-54	-55	-41.2
<b>5490 MHz</b>				
<b>C0</b>	<b>-40</b>	-44	-52	-41.2
<b>C3</b>	-46	-47	-52	-41.2
<b>8E</b>	-50	-47	-52	-41.2
<b>50</b>	-	-50	-52	-41.2
<b>6405 MHz</b>				
<b>C0</b>	-54	-51	-51	-20 dBc
<b>C3</b>	-52	-51	-51	-20 dBc
<b>8E</b>	-70	-51	-51	-41.2
<b>50</b>	-	-51	-51	-41.2

## Design Note DN025

7320 MHz	0915BM15A0001	0896BM15A0001 without ext LC + C	0896BM15A0001 with LC + C	FCC Limit
C0	-47	-49	-53	-41.2
C3	-54	-52	-54	-41.2
8E	-56	-52	-54	-41.2
50	-	-54	-55	-41.2
<b>8235 MHz</b>				
C0	-63	-53	-53	-41.2
C3	-65	-53	-52	-41.2
8E	-73	-54	-54	-41.2
50	-	-54	-54	-41.2
<b>746 MHz</b>	-61	<b>-54</b>	<b>-54</b>	-57

**Table 6. Output Power and Conducted Harmonic Values Obtained**

All values are in dBm unless stated. The values shown in red exceed the regulatory requirements. Limit values shown in Table 6. Output Power and Conducted Harmonic Values Obtained are taken from the ETSI EN 300 220 regulations for 868 MHz and FCC 15.247 for 915 MHz.

- For 0dBm and  $\leq 10$  dBm applications, the conducted harmonic attenuation is good for FCC and ETSI applications.
- For 10dBm+ applications, the conducted harmonic attenuation is borderline for the 4th and 6th harmonics for FCC applications; since majority of application have an integrated antenna this is not seen as an issue.
- Larger insertion loss compared to previous matched balun part for 868/915 MHz; this is acceptable since the external LC filter and DC block is now built into the new part.
- The new part will be also ideal for application that require conducted measurements since the fc-169 MHz notch has been included, exhibiting a BPF behaviour; ideal for 0 dBm and  $\leq 10$  dBm.

## 4 Conclusion

As an alternative to the traditional discrete reference designs as shown in Figure 2 and Figure 3; the JTI 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 12 components in the RF section compared to the JTI solution of 2 to 4 components depending on the usage of the LC filter.

For compact designs; the new matched Filter baluns at 433 MHz [6.2] or 868 MHz [6.3] or 915 MHz [6.4] from Johanson is recommended. The RF section component count is reduced to a single component.

For best performance; the discrete wire-wound inductor solution [10] is recommended and for the lowest cost; the integrated ValueLine reference design is recommended.

For applications that require conducted emissions approval (application with an external RF connector); the 433 MHz [6.2] or 868 MHz [6.3] or 915 MHz [6.4] matched filter baluns are more beneficial since the notch filter has been designed into the filter. Since these baluns incorporate the additional notch filter, extra filtering and DC blocking capacitor this has caused a slightly higher insertion loss than the 868/915 MHz balun solution [6.1].

Table 7 summarizes the various reference designs available for CC110x and CC111x.

	<b>Integrated Inductor ValueLine</b>	<b>Wire-wound Discrete</b>	<b>JTI 868/915 MHz</b>	<b>JTI 433 MHz or 868 MHz or 915 MHz</b>
<b>Performance</b>	Middle	Highest	Middle	Middle
<b>Typical output Power for Maximum Power setting</b>	11.0 dBm	12.0 dBm	11.0 dBm	10.5 dBm
<b>Size</b>	Largest	Middle	Middle	Smallest
<b>RF Component Count (no notch filter)</b>	6	12	2 to 4	1
<b>RF Component Count (with notch filter)</b>	7	14	4 to 6	1

**Table 7. Summary Overview of Reference Designs Available**

## 5 References

- [1] CC1101 Data Sheet ([cc1101.pdf](#))
- [2] AN058 Antenna Measurement with Network Analyzer ([swra161.pdf](#))
- [3] AN050 Using the CC1101 in the European 868MHz SRD Band ([swra146.pdf](#))
- [4] [JTI Data Sheets](#)
- [5] Contact information: <http://www.johansontechnology.com/en/contact.html>
- [6] CC1101 JTI Balun 868/915 MHz Ref. Design Rev1.0 ([swrc112.zip](#))
- [7] DN016 Compact 868/915 MHz Antenna Design ([swra160.pdf](#))
- [8] CC1101EM 868/915 MHz Reference Design ([swrr045.zip](#))
- [9] CC1101EM 315/433 MHz Reference Design ([swrr046.zip](#))
- [10] AN001 SRD Regulations for License Free Transceiver Operation ([swra090.pdf](#))
- [11] DN017 CC11xx 868/915 MHz RF Matching (Rev. A) ([swra168.pdf](#))

## 6 Appendices

### 6.1 Appendix A - 0896BM15A0001 Datasheet

## High Frequency Ceramic Solutions

**868/915 MHz Impedance Matched/Balun/LPF Integrated Component for T.I.**      **P/N 0896BM15A0001**  
**CC110X, CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430**

Detail Specification: 09/09/2011

Page 1 of 3

#### General Specifications

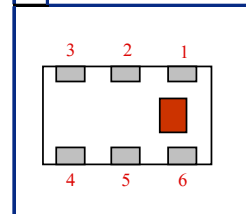
<b>Part Number</b>	0896BM15A0001
<b>Frequency (MHz)</b>	863 - 928 MHz
<b>Unbalanced Impedance</b>	50 Ω
<b>Differential Balanced Impedance</b>	Impedance-Matched to T.I. CC110X, CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430 Chipsets
<b>Insertion Loss</b>	1.5 dB max.
<b>Return Loss</b>	9.5 dB min.
<b>Attenuation (min.)</b>	25 @ 1726 - 1856MHz
	35 min.@ 2589 - 2784MHz
	35 min.@ 3452 - 3712MHz
	35 min.@ 4315 - 4640MHz

<b>Phase Difference</b>	180° ± 10
<b>Amplitude Difference</b>	1.5 dB max.
<b>Operating Temperature</b>	-40 to +85°C
<b>Power Rating</b>	1W max.
<b>Storage Conditions</b>	+5 to +35°C, Humidity 45 - 75%RH
<b>Storage Period</b>	18 months max sealed, 1 week max after opened*
<b>Reel quantity</b>	4000 pcs
<b>Moisture Sensitivity Level</b>	1

\*For more info go to [www.johansontechnology.com/silverleads](http://www.johansontechnology.com/silverleads)

#### Terminal Configuration

No.	Function
1	Unbalanced Port
2	GND
3	Balanced Port
4	Balanced Port
5	GND
6	GND



#### Mechanical Dimensions

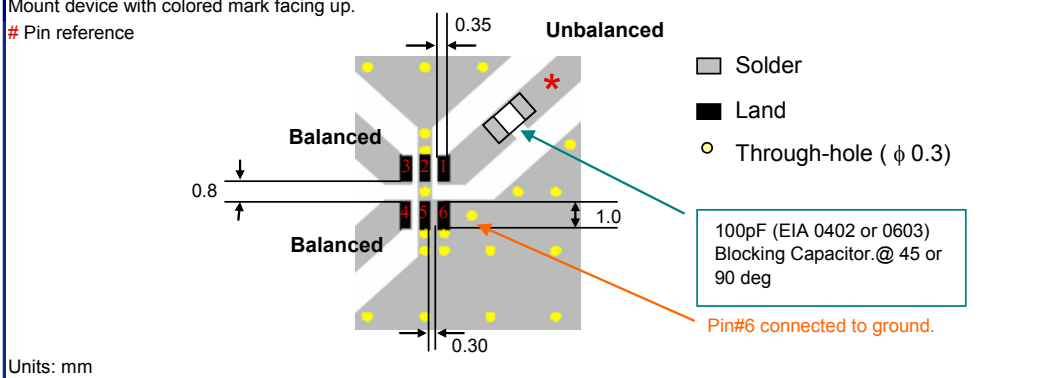
	In	mm
L	0.079 ± 0.004	2.00 ± 0.10
W	0.049 ± 0.004	1.25 ± 0.10
T	0.028 ± 0.004	0.70 ± 0.10
a	0.012 ± 0.004	0.30 ± 0.10
b	0.008 ± 0.004	0.20 ± 0.10
c	0.012 ± 0.004/-0.008	0.30 +0.1/-0.20
g	0.014 ± 0.004	0.35 ± 0.10
p	0.026 ± 0.002	0.65 ± 0.05

#### Mounting Considerations

\* Line width should be designed to match 50 Ω characteristic impedance, depending on PCB material and thickness.

Mount device with colored mark facing up.

# Pin reference



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## 6.2 Appendix B - 0433BM15A0001 Datasheet

### High Frequency Ceramic Solutions

**433 MHz Impedance Matched/Balun/LPF Integrated Component for T.I. CC110X, CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430** P/N 0433BM15A0001  
 Detail Specification: 09/09/2011 Page 1 of 3

#### General Specifications

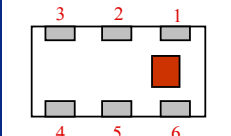
<b>Part Number</b>	0433BM15A0001	<b>Insertion Loss</b>	1.9 dB max
<b>Frequency (MHz)</b>	430 - 435	<b>Return Loss</b>	9.5 dB min.
<b>Unbalanced Impedance</b>	50 Ω	<b>Phase Difference</b>	180° ± 10
<b>Balanced Impedance</b>	Impedance-Matched to T.I. CC110X, CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430 Chipsets	<b>Amplitude Difference</b>	1.5 dB
<b>Attenuation (dB)</b>	34 min. @ 2Fo	<b>Input Power</b>	1W max.
	35 min. @ 3Fo	<b>Reel Quantity</b>	4,000
	35 min. @ 4Fo	<b>Operating Temperature</b>	-40 to +85°C
	35 min. @ 5Fo	<b>Storage Temperature Range</b>	+5 ~ +35 °C, Humidity 45~75%RH, 18 months. 1 week max after opened*

\*For more info go to [www.johansontechnology.com/silverleads](http://www.johansontechnology.com/silverleads)

<b>P/N</b>	<b>Packaging Style</b>	Bulk	Suffix = S	Eg. 0433BM15A0001S
		T & R	Suffix = E	Eg. 0433BM15A0001E
<b>Suffix</b>	<b>Termination Style</b>	AgPt	Suffix = None	Eg. 0433BM15A0001(E or S)
	<b>Evaluation Board</b>	0433BM15A0001-EBSMA		

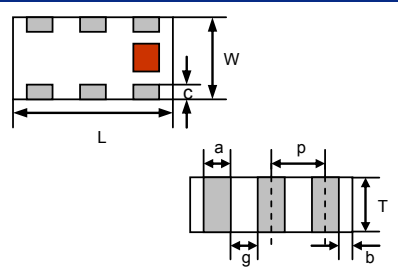
#### Terminal Configuration

No.	Function
1	Unbalanced Port
2	GND
3	Balanced Port**
4	Balanced Port**
5	GND
6	GND



#### Mechanical Dimensions

	In	mm
<b>L</b>	0.079 ± 0.004	2.00 ± 0.10
<b>W</b>	0.049 ± 0.004	1.25 ± 0.10
<b>T</b>	0.028 ± 0.004	0.70 ± 0.10
<b>a</b>	0.012 ± 0.004	0.30 ± 0.10
<b>b</b>	0.008 ± 0.004	0.20 ± 0.10
<b>c</b>	0.012 +.004/-0.008	0.30 +0.1/-0.2
<b>g</b>	0.014 ± 0.004	0.35 ± 0.10
<b>p</b>	0.026 ± 0.002	0.65 ± 0.05



\*\*Balanced ports are DC-Blocked from pins 1-2-5-6, capacitor is embedded. No need for external DC-Blocking cap at GND pins or unbalanced port.

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## 6.3 Appendix C - 0868BM15C0001 Datasheet

# High Frequency Ceramic Solutions

**868MHz Impedance Matched/Balun/BPF Integrated Component for T.I. CC110X, P/N 0868BM15C0001**  
**CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430**  
 Detail Specification: 09/09/2011 Page 1 of 3

### General Specifications

<b>Part Number</b>	0868BM15C0001	<b>Insertion Loss</b>	2.1 dB max.
<b>Operating Frequency</b>	863 - 873 (MHz)	<b>Return Loss</b>	9.5 dB min.
<b>Unbalanced Impedance</b>	50 Ω	<b>Phase Difference</b>	180° ± 15
<b>Balanced Impedance</b>	Impedance-Matched to T.I. CC110X, CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430 Chipsets	<b>Amplitude Difference</b>	1.5 dB max.
<b>Attenuation*</b>	10 dB min. @ 699MHz	<b>Input Power</b>	1W max.
	30 dB min. @ 1736MHz	<b>Reel Quantity</b>	4,000
	30 dB min. @ 2604MHz	<b>Operating Temperature</b>	-40 to +85°C
	35 dB min. @ 3472MHz	<b>Storage Temperature Range</b>	+5 ~ +35 °C, Humidity 45~75%RH, 18 months. 1 week max after opened**
	30 dB min. @ 4340MHz		

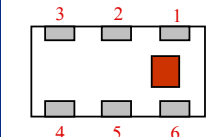
\* Band Pass Filtering

\*\*For more info go to [www.johansontechnology.com/silverleads](http://www.johansontechnology.com/silverleads)

<b>P/N</b>	<b>Packaging Style</b>	Bulk	Suffix = S	Eg. 0868BM15C0001S
		T & R	Suffix = E	Eg. 0868BM15C0001E
<b>Suffix</b>	<b>Termination Style</b>	AgPt	Suffix = None	Eg. 0868BM15C0001(E or S)
	<b>Evaluation Board</b>	0868BM15C0001-EBSMA		

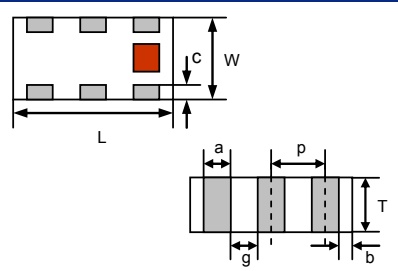
### Terminal Configuration

No.	Function
1	Unbalanced Port
2	GND
3	Balanced Port***
4	Balanced Port***
5	GND
6	GND



### Mechanical Dimensions

	In	mm
<b>L</b>	0.079 ± 0.004	2.00 ± 0.10
<b>W</b>	0.049 ± 0.004	1.25 ± 0.10
<b>T</b>	0.028 ± 0.004	0.70 ± 0.10
<b>a</b>	0.012 ± 0.004	0.30 ± 0.10
<b>b</b>	0.008 ± 0.004	0.20 ± 0.10
<b>c</b>	0.012 +.004/-.008	0.30 +0.1/-0.2
<b>g</b>	0.014 ± 0.004	0.35 ± 0.10
<b>p</b>	0.026 ± 0.002	0.65 ± 0.05



\*\*\*Balanced ports are DC-Blocked from pins 1-2-5-6, capacitor is embedded. No need for external DC-Blocking cap at GND pins or unbalanced port.

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## 6.4 Appendix D - 0915BM15A0001 Datasheet

### High Frequency Ceramic Solutions

915MHz Impedance Matched/Balun/BPF Integrated Component for T.I. CC110X, P/N 0915BM15A0001  
 CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430

Detail Specification: 09/09/2011

Page 1 of 3

#### General Specifications

<b>Part Number</b>	0915BM15A0001	<b>Insertion Loss</b>	2.0 dB max
<b>Frequency (MHz)</b>	902 - 928	<b>Return Loss</b>	9.5 dB min.
<b>Unbalanced Impedance</b>	50 $\Omega$	<b>Phase Difference</b>	180° $\pm$ 15
<b>Balanced Impedance</b>	Impedance-Matched to T.I. CC110X, CC111X, CC113X and CC115X, CC110L, CC113L, CC115L and CC430 Chipsets	<b>Amplitude Difference</b>	1.5 dB
<b>Attenuation*</b>	5 min. @ 745MHz	<b>Input Power</b>	1W max.
	30 min. @ 1830MHz	<b>Reel Quantity</b>	4,000
	40 min. @ 2745MHz	<b>Operating Temperature</b>	-40 to +85°C
	45 min. @ 3660MHz	<b>Storage Temperature Range</b>	+5 ~ +35 °C, Humidity 45~75%RH, 18 months. 1 week max after opened**

\* Band Pass Filtering

\*\*For more info go to [www.johansontechnology.com/silverleads](http://www.johansontechnology.com/silverleads)

<b>P/N</b>	<b>Packaging Style</b>	Bulk	Suffix = S	Eg. 0915BM15A0001S
		T & R	Suffix = E	Eg. 0915BM15A0001E
<b>Suffix</b>	<b>Termination Style</b>	AgPt	Suffix = None	Eg. 0915BM15A0001(E or S)
	<b>Evaluation Board</b>	0915BM15A0001-EBSMA		

#### Mechanical Dimensions

	In	mm
<b>L</b>	0.079 $\pm$ 0.004	2.00 $\pm$ 0.10
<b>W</b>	0.049 $\pm$ 0.004	1.25 $\pm$ 0.10
<b>T</b>	0.028 $\pm$ 0.004	0.70 $\pm$ 0.10
<b>a</b>	0.012 $\pm$ 0.004	0.30 $\pm$ 0.10
<b>b</b>	0.008 $\pm$ 0.004	0.20 $\pm$ 0.10
<b>c</b>	0.012 +.004/-0.008	0.30 +0.1/-0.2
<b>g</b>	0.014 $\pm$ 0.004	0.35 $\pm$ 0.10
<b>p</b>	0.026 $\pm$ 0.002	0.65 $\pm$ 0.05

#### Terminal Configuration

No.	Function
1	Unbalanced Port
2	GND
3	Balanced Port***
4	Balanced Port***
5	GND
6	GND

\*\*\*Balanced ports are DC-Blocked from pins 1-2-5-6, capacitor is embedded. No need for external DC-Blocking cap at GND pins or unbalanced port.

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## 7 General Information

### 7.1 Document History

Revision	Date	Description/Changes
SWRA250A	2011.10.12	Updated to include single frequency matched balun filters.
SWRA250	2009.01.14	Initial release.

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### 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

Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
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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>
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Телефон: 8 (812) 309-75-97 (многоканальный)

Факс: 8 (812) 320-03-32

Электронная почта: [ocean@oceanchips.ru](mailto:ocean@oceanchips.ru)

Web: <http://oceanchips.ru/>

Адрес: 198099, г. Санкт-Петербург, ул. Калинина, д. 2, корп. 4, лит. А