AN002
Optimising CC400/CC900/CC1000 for low LO leakage

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Keywords

- *Minimising LO leakage*
- *RX spurious emission*
- *PCB reference designs*
- *EN 300 220 requirements*
- *Type approval*
- *Power decoupling*

Introduction

The ETSI standard for license-free short range devices (SRDs) in the 433/868 MHz bands, EN 300 220, sets the requirement to receiver spurious emission to <–57 dBm. FCC (USA) has similar, but somewhat less strict regulations. This application note deals with LO leakage in detail. This includes findings from making numerous of reference designs. Chipcon has reference designs for all our transceivers. LO leakage is the single most important reason for users of the CC400/900/1000 to **copy** these layouts/BOM **to the smallest detail.** The requirement for an LO leakage of –57dBm is met for all our reference designs.

Overview

In order to optimise a CC400/CC900/CC1000 design and layout for low spurious emission there are three critical factors. The first is the VCO amplitude set by the VCO current, the second is the "air" coupling from the VCO tank to the output matching network and the third is the coupling through the different internal power supplies (example: VCO to LNA power supply).

The VCO current can be controlled and reduced to a minimum level for appropriate operation. For CC400/900 the current is controlled by a 3-bit word in register location C[11:9]. Maximum current is achieved for C11:9=[000], minimum current is given by C11:9=[111]. The VCO current is less important for CC1000 with respect to LO leakage (use the SmartRF Studio default)

The coupling between the VCO tank and the matching network at the output is dominated by the inductive coupling between the VCO tank inductor, and the TX and RX match inductors. It is important to minimise this coupling in order to reduce the spurious emission. This is done by the using the optimal inductors with the optimal orientation in combination with the optimal layout (see below).

The coupling through the power supplies (VCO power to the LNA power) can be reduced with a correct decoupling of the VCO power to GND. It is important to realise that the decoupling frequency is high (RF) when choosing the value of the capacitor and the PCB placement. The value of this decoupling capacitor could be as low as 12 pF for 868 MHz and 33 pF for 433 MHz. Inductor types and orientation will also effect the LO leakage coupling to the different power sets. Use the inductors suggested by Chipcon, at least as a starting point, and use the same orientation!

Reducing LO leakage for CC400/CC900

CC400 and CC900 are somewhat equal, however they do not have the same pin-out. The most important difference with respect to LO leakage is the different power pins for the VCO and the LNA/PA.

Table 1 Different VDD pins for CC400/CC900

	PIN NUMBER CC400	PIN NUMBER CC900
VCO_VDD	8	9
LNA_PA_VDD	7	8
VCO_GND	10	11 (also GND for the prescaler)
LNA_PA_GND	4	4 and 5

Reducing the VCO-to-matching network coupling (CC400/CC900)

The CC400/900 Demonstration Board is equipped with inductors manufactured by Murata, type LQW2BH/LQN21A Series (AirCore-Wound type). These are wounded in the vertical direction (same way as you would wind a coil around your thumb with the thumb sticking upwards). Rotating these coils 180 degrees, results in a phase inversion of the radiated field.

It has been found through testing that for this layout and this particular type of inductors the optimum orientation is as shown Figure 1 in below. Note the orientation of the inductor, illustrated by on which side of the inductor the wire is terminated. L91 is the VCO inductor, while L61 and L51 is part of the output/input network. Note that L91 also influences the coupling to the different power supplies.

Shielding the VCO tank circuit will reduce the LO leakage by about 3 dB. The shielding will also reduce noise (for example GSM) coupling into the VCO, so shielding is highly recommended (CC400/CC900).

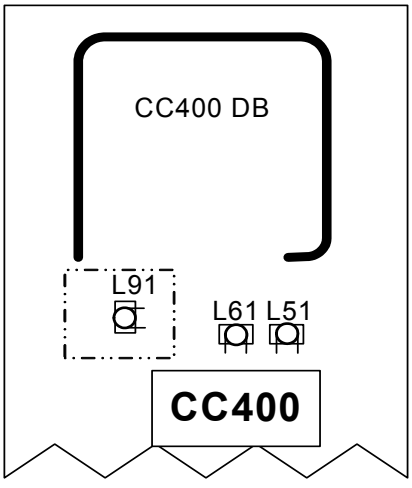

Figure 1

Adjusting the VCO current (CC400 and CC900)

The VCO current is controlled by a 3-bit word located in register bits C[11:9]. Maximum current is achieved for [000], and minimum current for [111].

In TX mode the [000] setting is suggested used (if low phase noise is important, a lower current setting should be investigated). In RX mode the current can be reduced in order to reduce the amplitude in the VCO tank and hence the leakage. Using the CC400DB, Demonstration Board the current is set to [100] for optimum performance, giving adequate LO suppression and current margin, this also gives the best sensitivity. For your design: Verify that the VCO starts up for temperature and VDD extremes. Note that lower VCO current than 100 is not recommended and might prevent the VCO from starting up in worst-case conditions. For inductors with lower Q than the LQW2BH/LQN21A Series (not recommended), a higher VCO current might be needed.

Decoupling of the individual VDD power supplies (CC400/CC900)

The most important pin to decouple is the VCO power supply pin, see table 1 (CC400 and CC900 are different). The optimised decoupling capacitor value is depending on the frequency and is rather small compared to “normal” decoupling capacitor values. The reason for this is that the total pin/pcb/via inductance and the decoupling capacitor forms a series resonant circuit that will give a very low impedance path to ground when it resonates at the RF frequency of interest. For the CC400 reference design (CC400DB, Demonstration Board), this capacitor is C24 = 33pF (RF = 433 MHz). For the CC900 reference design (CC900DB Demonstration Board), this capacitor is C25 = 12pF (RF = 868 MHz).

Note that the decoupling capacitor should be placed as closed as possible to the chip to keep the wires as short as possible. If possible, more than one via should be used to reduce the lead inductanse.

Reducing LO leakage for CC1000

All the coupling mechanism mentioned above is also valid for CC1000. If the suggested KOA inductor is used, the LO leakage is well below the –57dBm requirement (for Europe). The KOA inductor is a thin film high Q chip inductor (0805) on a ceramic substrate. Note that the orientation is VERY important for the KOA inductor, the LO leakage will increase by 20-30dB if the orientation is “wrong”. See the CC1000 Plug and Play module for a reference design.

Reference Designs (Layout/BOM)

For CC400 : CC400DB, Demonstration Board
For CC900 : CC900DB, Demonstration Board
For CC1000 : CC1000PP, Plug and Play module

Note that the CC1000 Development Kit includes 2 CC1000PP Plug and Play modules.
See www.chipcon.com for Gerber and BOM.

Conclusion

Sufficient LO suppression (<-57dBm) can be achieved for all Chipcon transceivers, copy the reference designs !

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