Application Report

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RF430CL330H Practical Antenna Design Guide

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ABSTRACT

The Texas Instruments RF430CL330H Dynamic NFC Interface Transponder is a NFC Forum Type 4B Tag Platform operating at 13.56 MHz (HF band). The device provides the flexibility to be used in combination with various antennas to meet the application performance requirements.

The scope of this document is to provide a short practical guide on the basic antenna design approach.

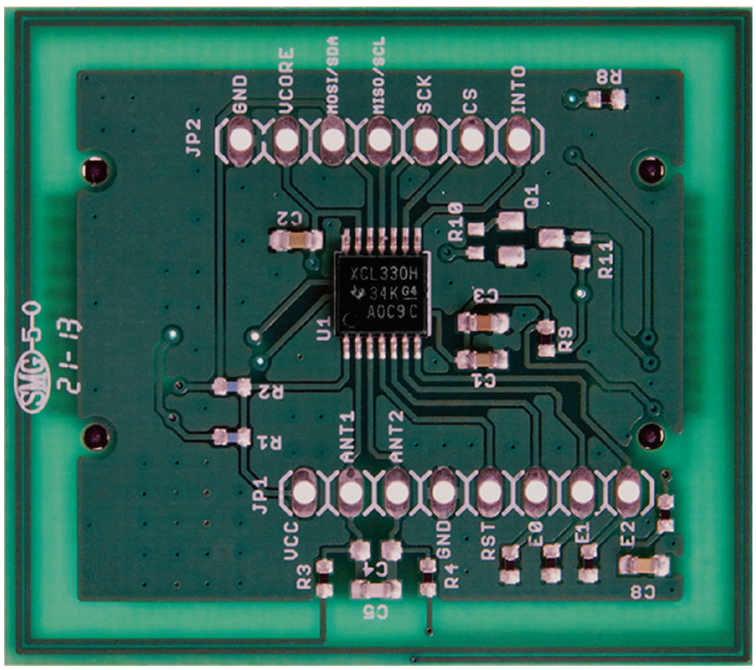

Figure 1. RF430CL330HTB Board

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1 RF430CL330H Dynamic NFC Interface Transponder

1.1 IC Overview

The Texas Instruments Dynamic NFC Interface Transponder RF430CL330H is an NFC Tag Type 4 device that combines a wireless NFC interface and a wired serial peripheral interface (SPI) or inter-integrated circuit (I2C) interface to connect the device to a host. The NDEF message in the SRAM can be written and read from the integrated SPI or I2C serial communication interface (for example, via a microcontroller) and can also be accessed and updated wirelessly via the integrated ISO14443B-compliant RF interface. The RF Interface supports data rates up to 848 kbps. The device allows for applications including, but not limited to, NFC connection handover for an alternative carrier like Bluetooth®, Bluetooth Low Energy (BLE), and Wi-Fi® as an easy and intuitive pairing process or authentication process with only a tap. As a general use NFC interface, the RF430CL330H enables end-equipment to communicate with the fast growing infrastructure of NFC-enabled smart phones, tablets, and notebooks.

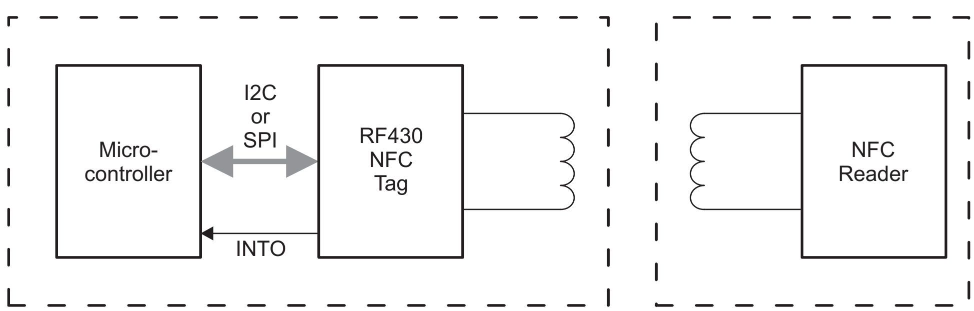


Figure 2. Typical Application

Bluetooth is a registered trademark of Bluetooth SIG, Inc.
Wi-Fi is a registered trademark of Wi-Fi Alliance.

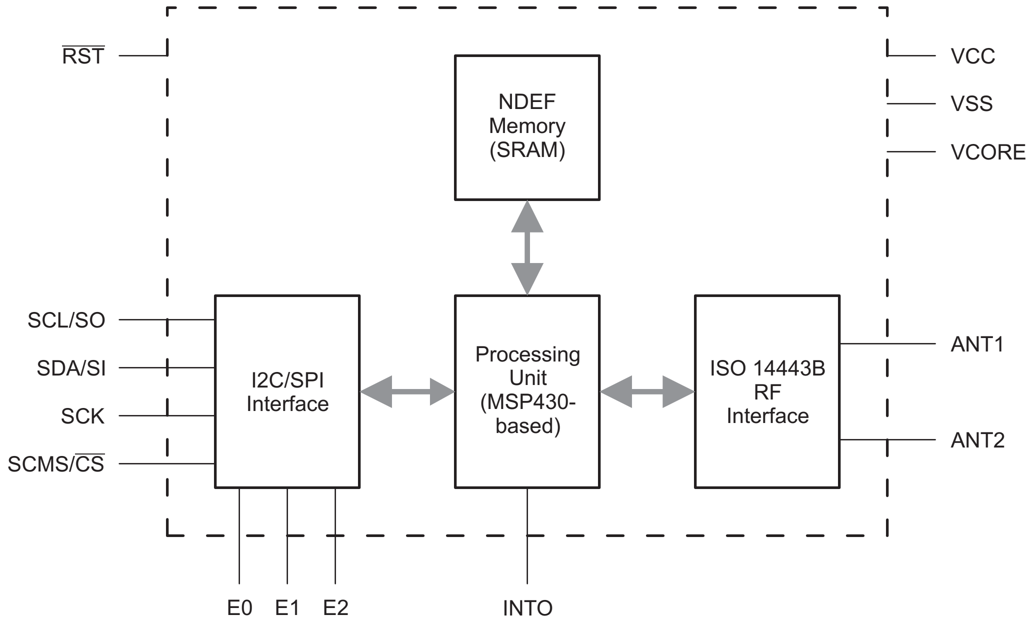


Figure 3. Functional Block Diagram

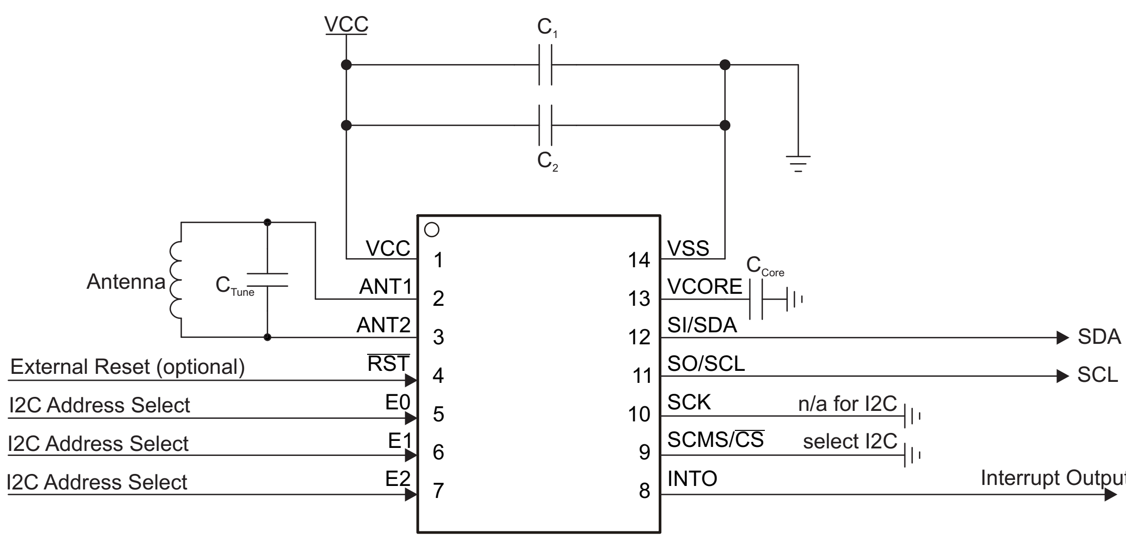


Figure 4. Typical Circuit for I2C

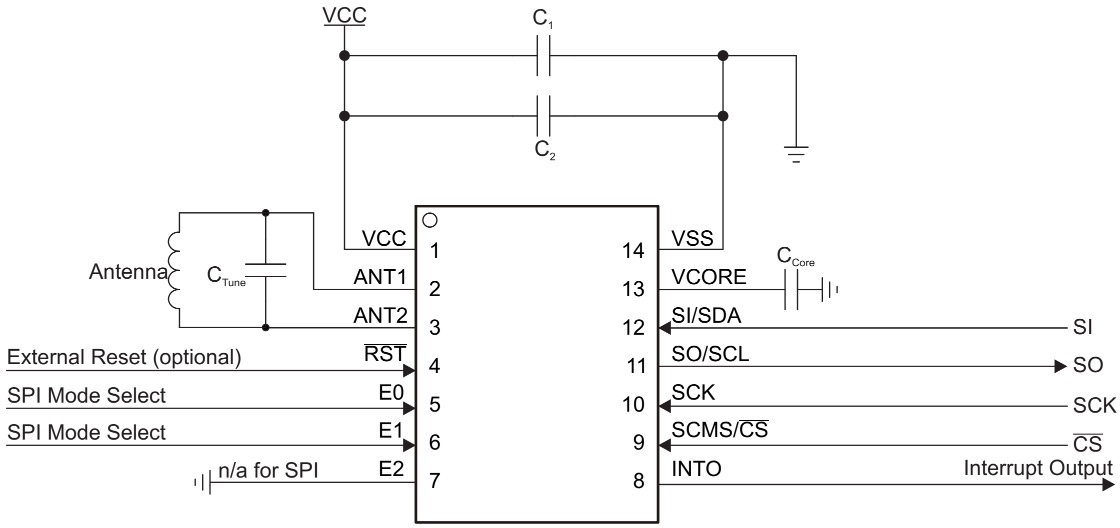


Figure 5. Typical Circuit for SPI

For details on the device, see the RF430CL330H product folder.

2 RF Interface

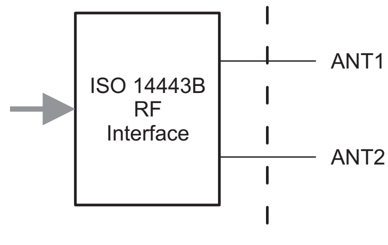


Figure 6. RF Interface Module

The RF Communication Interface is based on the ISO14443B specification. It supports data rates 106 kbps, 212 kbps, 424 kbps, and 848 kbps. The device is compliant with the NFC Tag Type 4B (T4BT) platform.

The antenna connection is the interface from the RF Module to the outside world. There are two pins connected to the external antenna: ANT1 and ANT2 (pin 2 and 3).

The antenna dimensions and parameters depend on the application requirements: communication distance, available space, antenna technology, and so forth.

The on-chip resonance capacitor has a typical value of 35 pF with a tolerance of ±10%.

A resonance circuit is generated using the external antenna and the on-chip resonance capacitor. An additional external resonance capacitor can be added to allow an antenna inductance variation for lower inductance antenna coils. The resonance frequency is calculated using the formula in Equation 1:

$$f_{res} = \frac{1}{2 * \pi * \sqrt{L * C}} \tag{1}$$

A Resonance capacitor C=C_internal+C_external
L: Antenna Inductance
fres: Resonance Frequency

For more information, see the *RF430CL330H Dynamic NFC Interface Transponder Data Sheet* (SLAS916).

3 RF430CL330HTB Target Board

The RF430CL330HTB is an evaluation platform for the RF430CL330H (NFC Type 4B Tag) device. Additional information on the target board can be found in the *RF430CL330H Target Board User's Guide* (SLOU373).

The Target Board allows the developers to design and test their systems and become familiar with the NFC T4T Type B protocol.

The Target Board is connected to a microcontroller board. The current board is designed to fit to a variety of TI microcontroller platforms (for example, MSP-EXP430FR5739, http://www.ti.com/tool/msp-exp430fr5739), and can be directly connected via the RF1 and RF2 headers.

For test purposes, an “on-board” antenna is available on the Target Board. This antenna is connected to the RF430CL330H IC pins, ANT1 and ANT2, through the two 0 Ω resistors, R3 and R4. The resistors are used to disconnect the on-board antenna, if a different external antenna is connected.

3.1 RF430CL330HTB Schematic

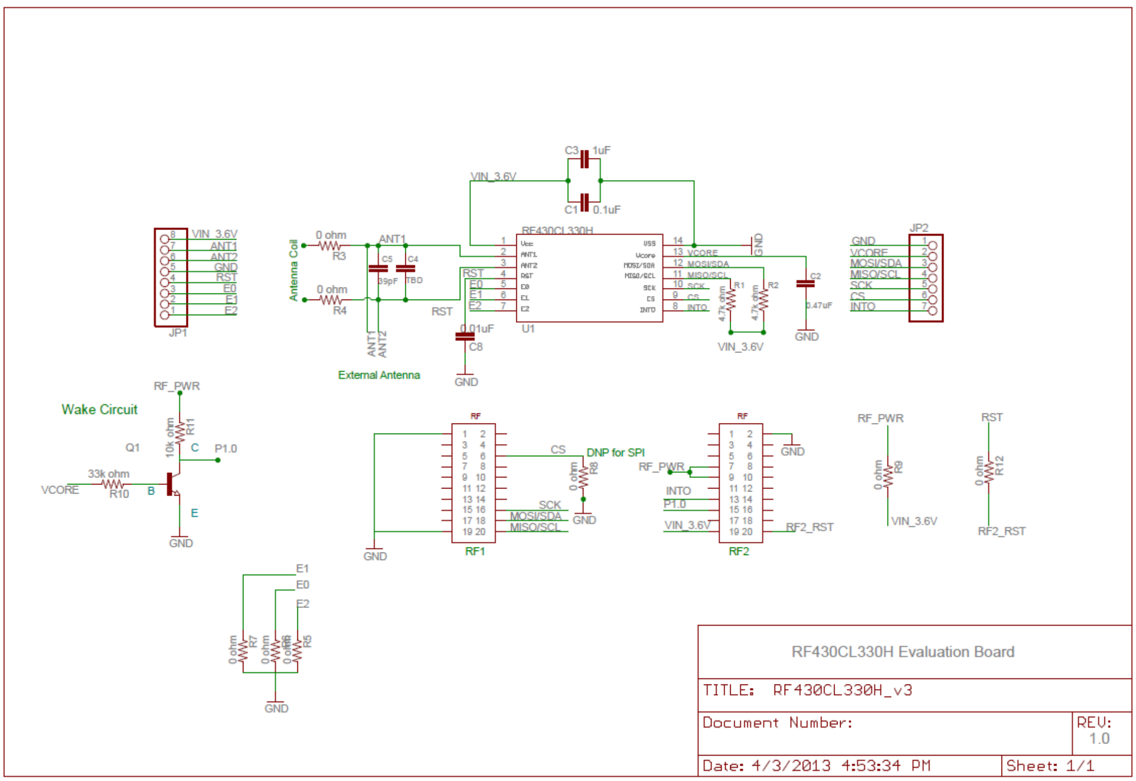
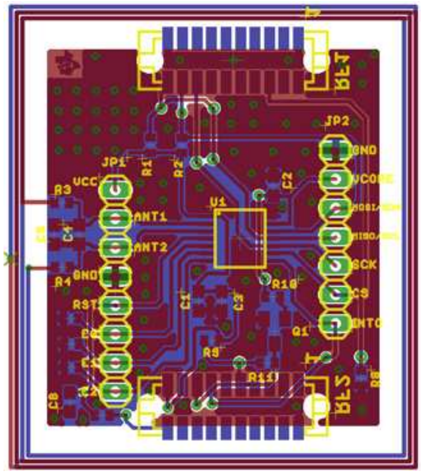


Figure 7. RF430CL330HTB Reference Schematic

3.2 RF430CL330HTB PCB Layout



A Design files are located at the following link:
http://www.ti.com/lit/zip/slor112

Figure 8. RF430CL330HTB Reference PCB Layout

3.3 External Antenna Connection

On the RF430CL330HTB, it is possible to disconnect the "on-board" antenna and connect an external antenna. The modifications to the board are as follows:

1. Remove R3 and R4 (blue).
2. Connect the external antenna at JP1 Pin 6 ANT1 and Pin 7 ANT2 (yellow).
3. Use the C4 and C5 capacitors to adjust the new antenna to resonance frequency (red).

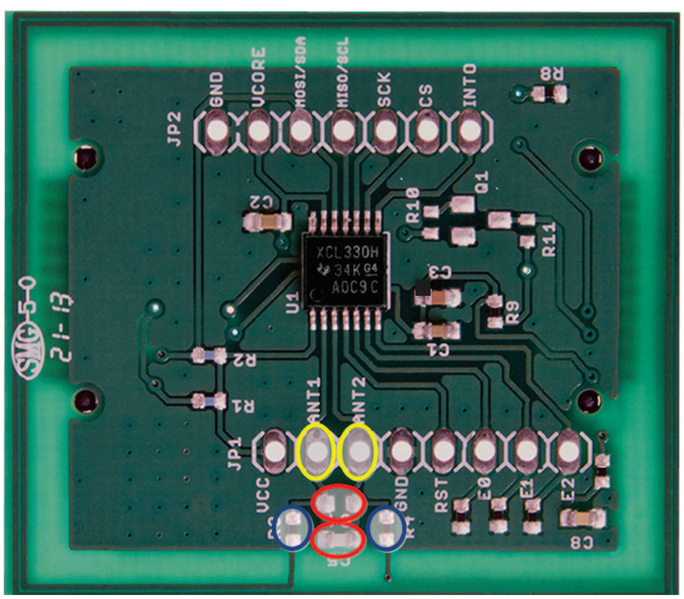


Figure 9. Target Board Modifications

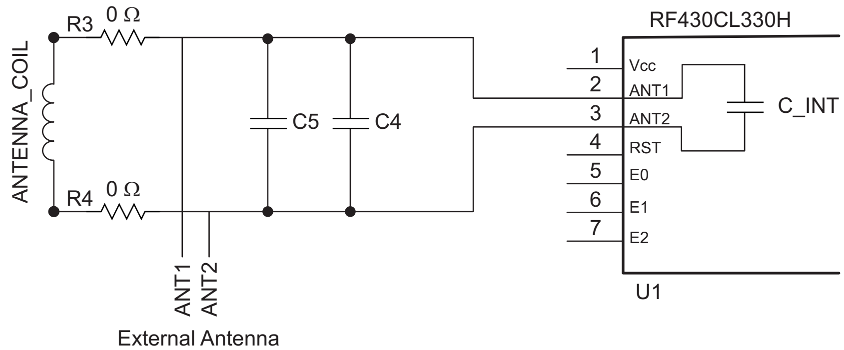


Figure 10. Target Board Antenna Connection

4 Internal Resonance Capacitor

An on-chip resonance capacitor (C_{int}) has been implemented. The C_{int} is connected parallel to the JP1 Pin 6 and Pin 7 to create a resonant circuit with the antenna.

Table 1. Internal Resonance Capacitor

C_{int} = 35 pF ±10% On-Chip Resonance Capacitor (C_{int})		
Min	**Typ**	**Max**
31.5 pF	35 pF	38.5 pF

5 Antenna

The antenna is connected at JP1 Pin 6 and Pin 7 on the RF430CL330HTB (Pin 2 and Pin 3 on the device) being parallel to the internal resonance capacitor C_{int} to generate the resonance circuit.

Depending on the antenna inductance, an additional external resonance capacitor parallel to C_{int} can be used. If no external capacitor is used, and assuming a given f_{res} (f_{res}~ 13.7 MHz), the C_{int} tolerances have to be considered for the calculation of the antenna inductance.

NOTE: In this calculation, the antenna tolerances are not considered. Normally these are in the range of ±2%.

Table 2. Antenna Inductance (f_{res} ~13.7MHz)

Antenna Inductance ($_{fres}$~ 13.7MHz)		
Min	**Typ**	**Max**
3.57 µH (@ C_{int} = 38.5 pF)	3.85 µH (@ $_{Cint}$ = 35 pF)	4.28 µH (@ C_{int} = 31.5 pF)

6 Antenna Resonance Circuit

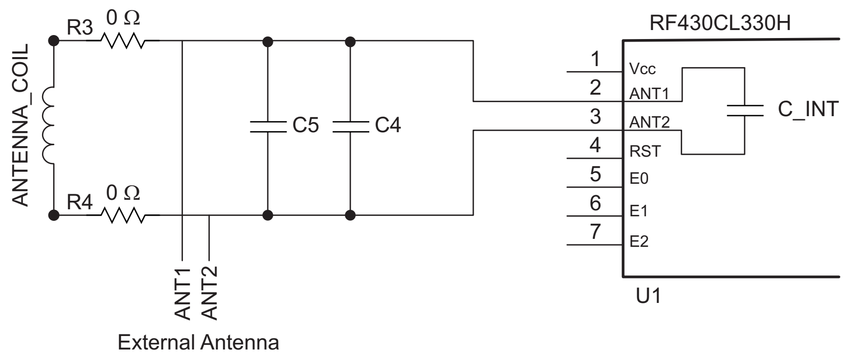


Figure 11. Target Board Antenna Connection

Figure 11 illustrates the basic input circuit of the RF430CL330H. The external antenna is connected at the JP1 pin, Pin 6 and Pin 7 on the RF430CL330HTB. The antenna (L) with the internal parallel capacitor (C_{int}) creates a resonant frequency.

If an external resonance capacitor is not used, the typical resonance capacitor is calculated:

$C_{res} = C_{int} = 35$ pF

Depending on the antenna inductance, an additional external resonance capacitor can be added at pads C4 and C5, which are connected in parallel to the internal C_{int}. The sum of the parallel capacitances is the value for the total resonance capacitance.

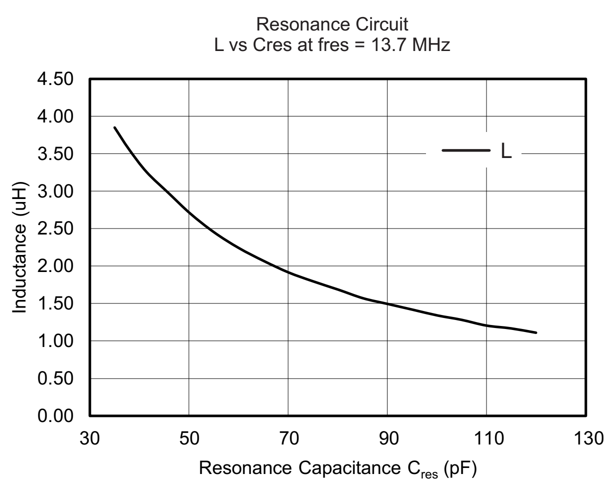
$C_{res} = C_{int} + C4 + C5 = 35pF + C4 + C5$

During the development phase, it is recommended to use an external adjustable capacitor for fine-tuning. This helps to eliminate component tolerance and board parasitic. For production, the value of the variable capacitor is measured and replaced by an external fixed capacitor with the same value (or combination of two capacitors).

Recommended operating resonance frequency ($_{fres}$) is about f_{res}~ 13.7 MHz for optimum performance. Resonance frequencies >13.7 MHz leads to performance reduction. Ensure that the resonant frequency, including all the tolerances, stays above 13.56 MHz.

Figure 12 shows the inductance and capacitor values to generate resonance at 13.7 MHz.

The passive quality factor (Q) of the resonance circuit should be Q<50. In case of a higher Q, an external resistor parallel to C3 and C4 should be added. The value could be in the range of 10kΩ-20kΩ.



A Parasitic capacitance from the layout and the connections are not considered in this document.

Figure 12. Inductance vs. Resonance Capacitance Values

7 Antenna Q Factor

The Antenna Q factor can be calculated with the formula shown in Equation 2. For the RF430CL330H, typical Q values should range from ~30 – 40.

$$BW = f2 - f1$$

$$Q = \frac{f_{res}}{BW} \tag{2}$$

The resonant frequency and bandwidth should be captured using a spectrum analyzer with tracking generator (such as Agilent E440x). The test fixture should consist of a pickup coil connected to the input of the spectrum analyzer and a larger coil connected to the output of the spectrum analyzer tracking generator as shown in Figure 13.

The steps for the Spectrum analyzer Setup are as follows:

1. Connect the fixture to the analyzer (the red connector to the output of the tracking generator, the blue connector to the input channel).
2. Place a reference unit on top of the fixture.

NOTE: The Antenna should to be centered and flat. The temperature and humidity will impact frequency and Q of the antenna.

3. Enable the tracking generator output, centered to the expected transponder operating frequency (13.56 MHz) with a span of 2 MHz.
4. At about –60dBm reference level with a vertical scale of 1 dB/div, the resonance curve will be shown as illustrated in Figure 13 and Figure 14.
5. View the bandwidth by enabling the N dB 3 points through the peak search menu.
6. The quality factor is calculated by dividing the resonant frequency by the measured bandwidth. The example in Figure 14 shows a Q value of ~39.

$$Q = \frac{13.67\ MHz}{349.1\ kHz}$$
$$Q = 39.15 \tag{3}$$

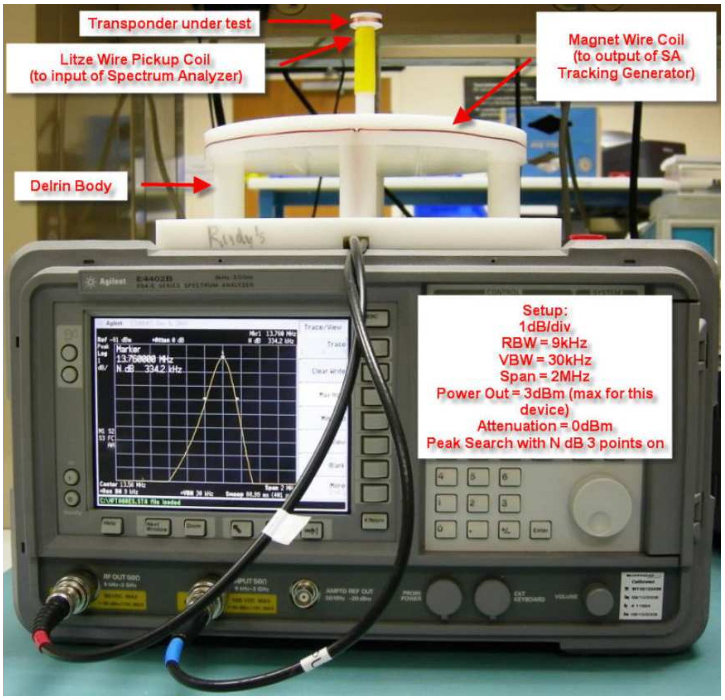


Figure 13. Frequency and Bandwidth Measurement Fixture

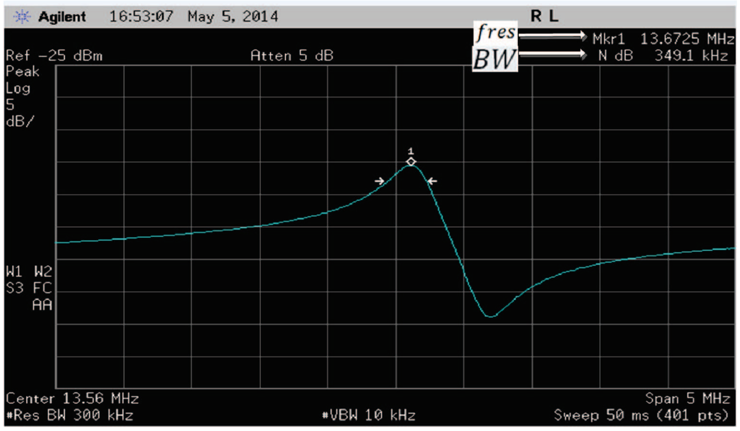


Figure 14. Antenna Q Measurement

8 Resonant Frequency Detuning

The resonant frequency (in combination with a stable quality factor) should be tuned for the best communication distance between reader and tag. Variation of the resonance frequency causes performance degradation.

The variations normally come from the tags' internal capacitor tolerances, antenna parameters, connections and external influences, such as metallic objects in close proximity.

Table 1 gives the internal resonance capacitor tolerances of the RF430CL330H IC. For practical reasons, it is recommended to compensate all the tolerances using an external capacitor connected between ANT1 and ANT2. During the development phase, an adjustable capacitor can be used to fine tune for the best communication distance. This capacitor can be replaced with a fixed value for the final product. It is difficult to compensate the resonance frequency variations caused by unpredictable external influences in advance as these are not known. In these cases, a special antenna design may be used to reduce the influences.

Figure 15 shows an example of influence of a detuned RF430CL330HTB over the communication distance using the TRF7970AEVM from TI: http://www.ti.com/tool/trf7970aevm.

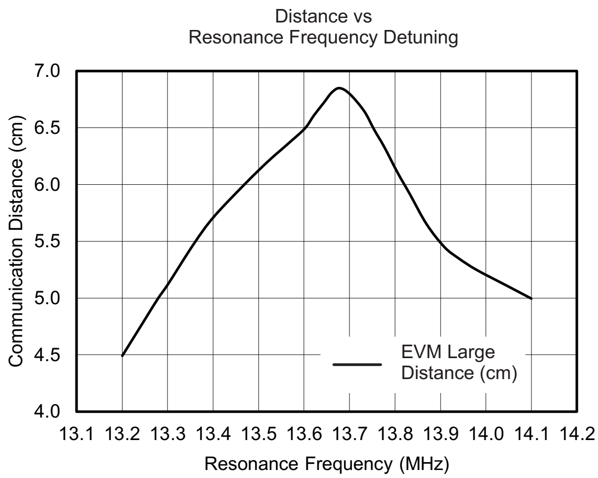


Figure 15. Read Range vs. Detuning

9 References

- RF430CL330H product folder: http://www.ti.com/tool/RF430CL330HTB
- *RF430CL330H Dynamic NFC Interface Transponder Data Sheet* (SLAS916)
- *RF430CL330H Target Board User's Guide* (SLOU373)
- Missouri University of Science and Technology Inductance Calculators: http://emclab.mst.edu/inductance/

Appendix A Antenna Inductance Calculation

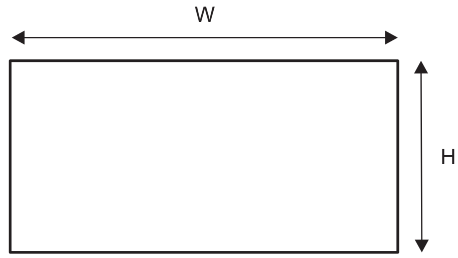


Figure 16. Antenna Coil Calculation

- N: number of turns
- w: width of the rectangle
- h: height of the rectangle
- a: wire radius
- μr: relative permeability of the medium

$$L_{rect} = \frac{N^2 \mu_0 \mu_r}{\pi}\left[-2(w+h)+2\sqrt{h^2+w^2}-h\ ln\left(\frac{h+\sqrt{h^2+w^2}}{w}\right)-w\ ln\left(\frac{w+\sqrt{h^2+w^2}}{h}\right)+h\ ln\frac{2h}{a}+w\ ln\left(\frac{2w}{a}\right)\right] \quad (4)$$

More information regarding the antenna calculation methods can be found online: http://emclab.mst.edu/inductance/.

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