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Nuvoton Technology Corporation Japan

NFC TAG Antenna Design Guide

Version 1.20

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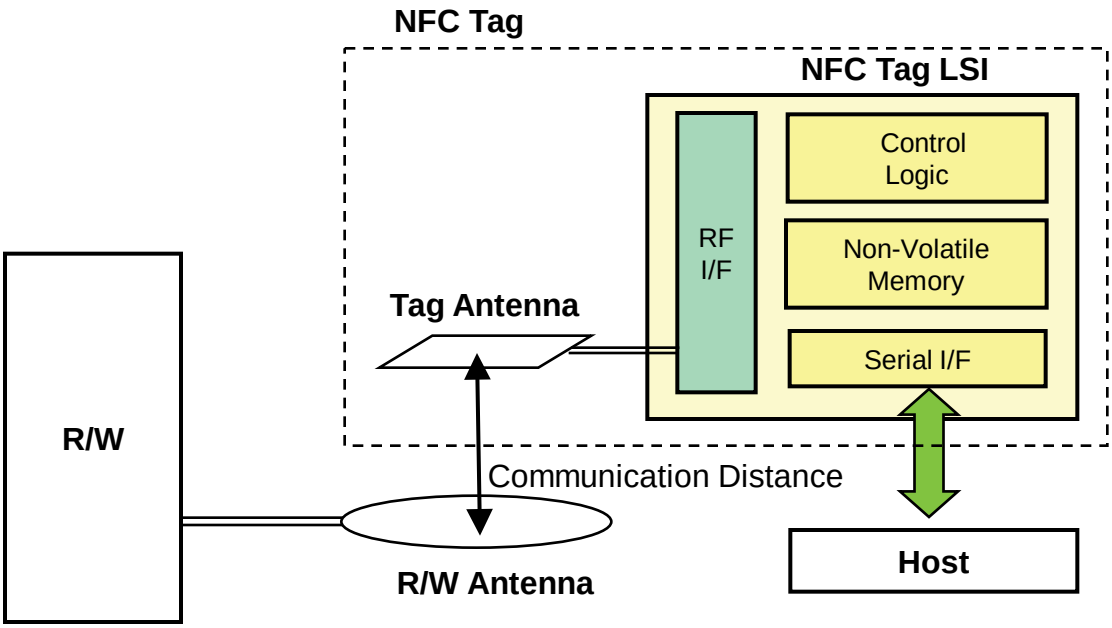
Contents

1. Introduction

1.1 Purpose of this Guide

This guide provides how to design the antenna to be connected to the NFC tag LSI.

Figure 1 shows an outline of the system using an NFC (Near Field Communication) tag.



Carrier Frequency: 13.56 MHz

R/W	: Reader/Writer (smartphone, etc.)
Host	: Host
RF I/F	: RF interface
Control Logic	: Control logic
Serial I/F	: Serial interface

Figure 1 Schematic NFC Tag Communication System

2. Designing the Antenna

2.1 Antenna Design Flow

Design the antenna for tag following the flow below.

[STEP 1] Determining the size of antenna
Determine the allowable antenna size, based on the specifications of NFC tag applications.

[STEP 2] Determining the specifications of antenna
Determine the specifications of antenna (number of turns, track width, spacing), based on the measurement results in Table 1.

[STEP 3] Setting up the antenna board
Set up the antenna board, based on the specifications determined in STEPs 1 and 2.

[STEP 4] Determining the resonant capacitor value
Determine the value of resonant capacitor mounted on antenna board.

[STEP 5] Checking the operation of NFC tag
Mount the NFC tag LSI on the antenna board and measure the following items to verify normal operation.
(1) Communication distance
(2) Voltage of antenna pin

2.2 Determining the Size of Antenna [STEP 1]

Determine the allowable antenna size, based on the specifications of NFC tag applications.

Refer to the measurement results (Table 1) of communication distance from our NFC tag LSI.

2.3 Determining the Specifications of Antenna [STEP 2]

The parameters for antenna specifications used in this guide are defined in Figure 2 Antenna Coil Outline Drawing.

Based on the measurement results (Table 1) of communication distance from our NFC tag LSI, determine the specifications of antenna (number of turns, track width, spacing).

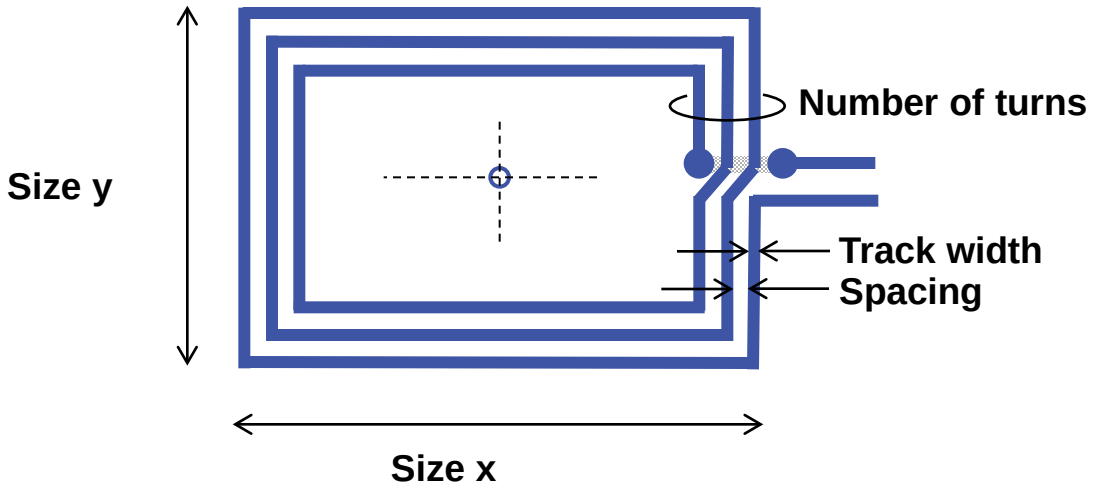


Figure 2 Antenna Coil Outline Drawing

2.3.1 Measurement Results of Communication Distance

Table 1 shows the measurement results of communication distance between smartphone and our prototype NFC tag.

Table 1-1 Measurement Results of Communication Distance

Shape of antenna				Antenna inductance [μ H]	Resonant capacitor [pF]	Communication distance [mm]			
						Without external DC supply		With external DC supply	
Size [mm^2]	Track width [mm]	Spacing [mm]	Number of turns [turn]			FeliCa	Type B	FeliCa	Type B
72 x 42	0.5	0.5	1	0.242	551	52	42	60	55
			2	0.734	164	55	47	62	60
			3	1.442	77	52	46	59	60
			4	2.259	42	49	45	56	59
			5	3.171	24	47	43	53	58

(Note 1) Nexus S (manufactured by Samsung) is used as smartphone.

(Note 2) Resonant frequency is calibrated to 13.56 MHz.

(Note 3) These data are the results measured using our prototype NFC tag and do not guarantee the communication distance from your NFC tag.

Table 1-2 Measurement Results of Communication Distance

Shape of antenna				Antenna inductance [μ H]	Resonant capacitor [pF]	Communication distance [mm]			
						Without external DC supply		With external DC supply	
Size [mm²]	Track width [mm]	Spacing [mm]	Number of turns [turn]			FeliCa	Type B	FeliCa	Type B
40 × 30	0.1	0.1	1	0.182	742	28	26	36	36
			2	0.603	211	38	34	46	44
			4	1.992	54	40	36	47	48
		0.3	2	0.560	229	39	35	47	45
			4	1.726	63	41	37	48	49
	0.3	0.1	2	0.497	260	46	39	53	50
			4	1.721	63	41	37	48	50
		0.3	1	0.153	882	38	33	45	43
			2	0.470	275	47	39	54	50
			3	0.908	134	46	41	53	52
			4	1.430	78	45	40	51	52
			5	2.031	50	43	39	50	51
	0.5	0.5	1	0.138	979	42	36	49	46
			2	0.405	321	49	41	56	52
			3	0.753	164	49	42	55	53
			4	1.149	101	47	42	54	53
			5	1.582	72	44	41	48	50

(Note 1) Nexus S (manufactured by Samsung) is used as smartphone.

(Note 2) Resonant frequency is calibrated to 13.56 MHz.

(Note 3) These data are the results measured using our prototype NFC tag and do not guarantee the communication distance from your NFC tag.

Table 1-3 Measurement Results of Communication Distance

Shape of antenna				Antenna inductance [μ H]	Resonant capacitor [pF]	Communication distance [mm]			
						Without external DC supply		With external DC supply	
Size [mm^2]	Track width [mm]	Spacing [mm]	Number of turns [turn]			FeliCa	Type B	FeliCa	Type B
25 × 20	0.3	0.3	1	0.093	1463	18	17	25	25
			2	0.268	496	38	32	44	41
			4	0.777	161	39	34	45	44
			5	1.073	112	38	34	43	43

(Note 1) Nexus S (manufactured by Samsung) is used as smartphone.

(Note 2) Resonant frequency is calibrated to 13.56 MHz.

(Note 3) These data are the results measured using our prototype NFC tag and do not guarantee the communication distance from your NFC tag.

Table 1-4 Measurement Results of Communication Distance

Shape of antenna				Antenna inductance [μ H]	Resonant capacitor [pF]	Communication distance [mm]			
						Without external DC supply		With external DC supply	
Size [mm^2]	Track width [mm]	Spacing [mm]	Number of turns [turn]			FeliCa	Type B	FeliCa	Type B
12 × 10	0.1	0.1	8	1.251	95	23	20	28	28
			12	2.084	51	22	19	26	28
			16	2.787	34	20	18	24	26

(Note 1) Nexus S (manufactured by Samsung) is used as smartphone.

(Note 2) Resonant frequency is calibrated to 13.56 MHz.

(Note 3) These data are the results measured using our prototype NFC tag and do not guarantee the communication distance from your NFC tag.

Table 1-5 Measurement Results of Communication Distance Between GALAXY Nexus and our prototype NFC Tag

Shape of antenna				Antenna inductance [μ H]	Resonant capacitor [pF]	Communication distance [mm]			
						Without external DC supply		With external DC supply	
Size [mm^2]	Track width [mm]	Spacing [mm]	Number of turns [turn]			FeliCa	Type B	FeliCa	Type B
72 × 42	0.5	0.5	2	0.734	164	55	47	61	60
40 × 30	0.5	0.5	2	0.405	321	48	40	53	51
25 × 20	0.3	0.3	4	0.777	161	37	32	42	42
12 × 10	0.1	0.1	8	1.251	95	20	17	24	25

(Note 1) GALAXY Nexus (manufactured by Samsung) is used as smartphone.

(Note 2) Resonant frequency is calibrated to 13.56 MHz.

(Note 3) These data are the results measured using our prototype NFC tag and do not guarantee the communication distance from your NFC tag.

Table 1-5 Measurement Results of Communication Distance Between ELUGA and our prototype NFC Tag

Shape of antenna				Antenna inductance [μ H]	Resonant capacitor [pF]	Communication distance [mm]			
						Without external DC supply		With external DC supply	
Size [mm^2]	Track width [mm]	Spacing [mm]	Number of turns [turn]			FeliCa	Type B	FeliCa	Type B
72 × 42	0.5	0.5	2	0.734	164	40	34	45	41
40 × 30	0.5	0.5	2	0.405	321	38	31	42	35
25 × 20	0.3	0.3	4	0.777	161	28	24	31	29
12 × 10	0.1	0.1	8	1.251	95	17	16	19	20

(Note 1) ELUGA (manufactured by Panasonic) is used as smartphone.

(Note 2) Resonant frequency is calibrated to 13.56 MHz.

(Note 3) These data are the results measured using our prototype NFC tag and do not guarantee the communication distance from your NFC tag.

2.4 Setting up the Antenna Board [STEP 3]

Based on Figure 3 Recommended Circuit Diagram, set up the antenna board.

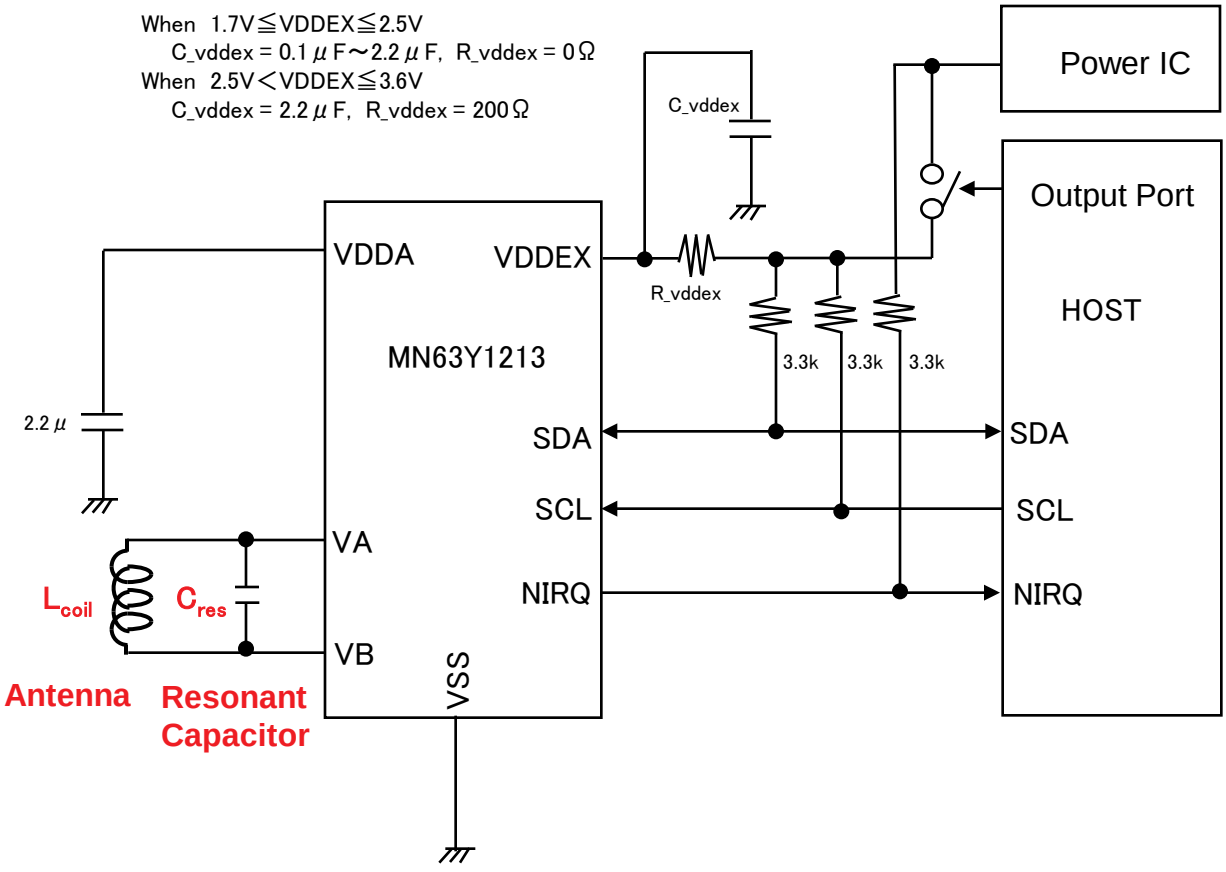
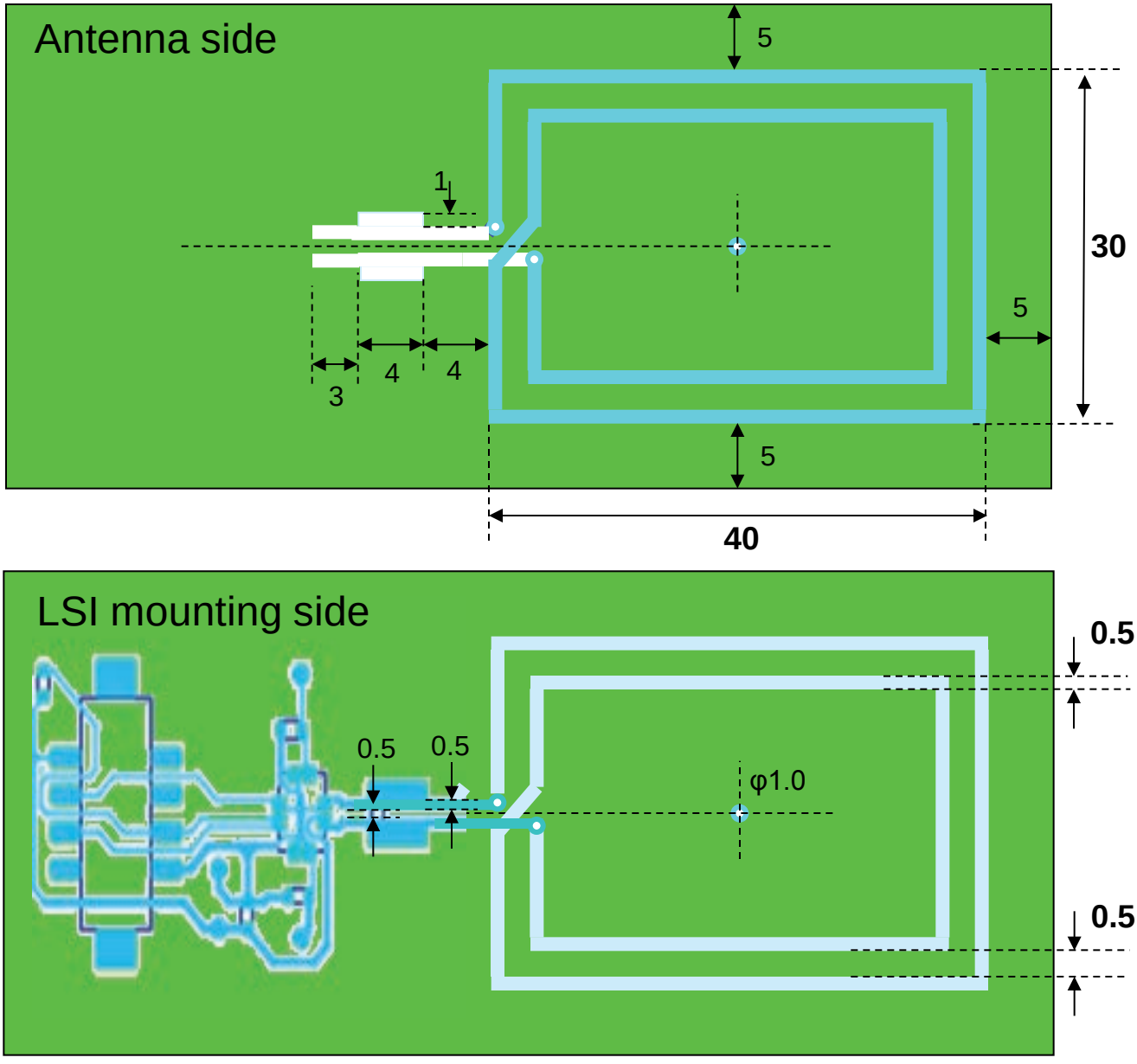


Figure 3 Recommended Circuit Diagram

(Note 1) Use a resonant capacitor with a withstand voltage of at least 50 V.
(Note 2) The value of resonant capacitor should be adjusted as needed, so we recommend a pattern design that allows multiple capacitors to be mounted.

2.4.1 Reference Example of Antenna Board

Figure 4 shows a reference example of antenna board.



Double-sided glass epoxy board (FR-4)
Thickness of board: 1.0 mm
Thickness of track: 60 mm (Copper)

Figure 4 Reference Example of Antenna Board

2.5 Determining Resonant Capacitor Value [STEP 4]

Determine the value of resonant capacitor following the flow below.

[STEP 4-1] Measuring the antenna equivalent circuit parameters
Measure the antenna equivalent circuit parameters using an impedance analyzer or other equipment.

[STEP 4-2] Calculating the resonant capacitor value
With the parameters measured in [STEP 4-1], calculate the value of resonant capacitor to set the resonant frequency to 13.56 MHz.

[STEP 4-3] Determining a proper resonant capacitor value
Mount a resonant capacitor with a value calculated in [STEP 4-2] and the NFC tag LSI on the antenna board, and measure the resonant frequency. Adjust the capacitor value so that the measured frequency is 13.56 MHz.

2.5.1 Measuring Antenna Equivalent Circuit Parameters [STEP 4-1]

Figure 5 shows how to measure the antenna equivalent circuit parameters. Here, the parameters represent L_{coil}, R_{coil}, and C_{coil}.

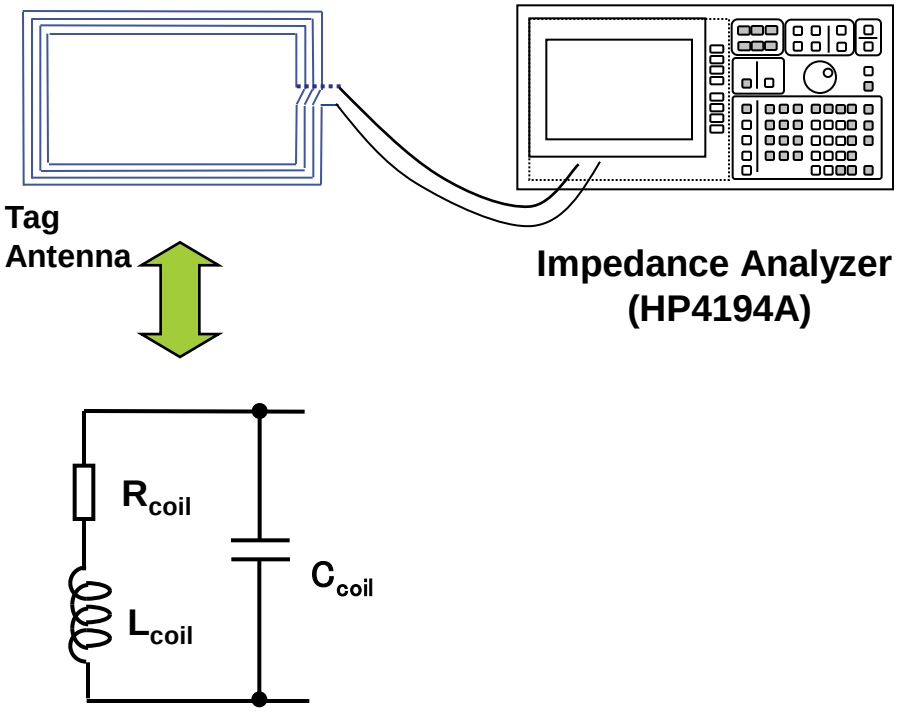


Figure 5 How to Measure the Antenna Equivalent Circuit Parameters

< Measurement example for HP4194A >
(1) Set the impedance analyzer's start and stop frequencies to 13 MHz and 14 MHz, respectively.
(2) Make a single measurement in |Z| -θ mode.
(3) Push the "MoreMenu > Equivalent Circuit" button to select the same equivalent circuit as the figure above.
(4) Push the "Calculate" button to obtain L_{coil}, R_{coil}, and C_{coil} values.
(5) When C_{coil} is small, and cannot measure by this method definitely, as C_{coil} = 0pF, make a measurement in L_s-R_s mode.

Antenna equivalent circuit parameters can also be calculated utilizing an electromagnetic simulator.

2.5.2 Calculating Resonant Capacitor Value [STEP 4-2]

Based on equation (1) derived from the NFC tag equivalent circuit shown in Figure 6, calculate the resonant capacitor value.

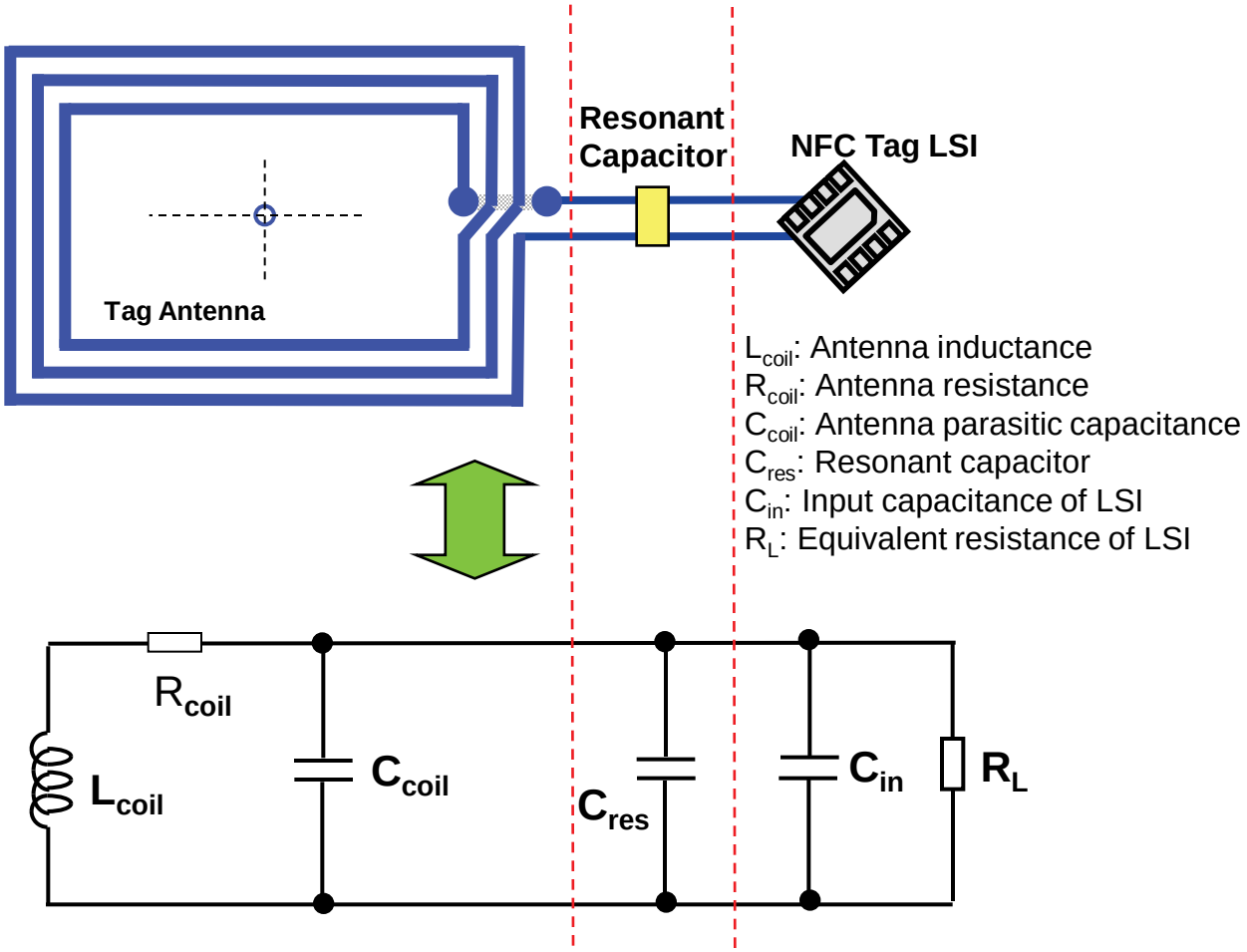


Figure 6 Equivalent Circuit of NFC Tag

In the equivalent circuit of Figure 6, the resonant frequency (f_r) is given by equation (1).

$$f_r = \frac{1}{2 \cdot \pi \cdot \sqrt{L_{coil} \cdot (C_{coil} + C_{res} + C_{in})}} \quad \text{... Equation (1)}$$

2.5.2.1 Calculation Example of Resonant Capacitor Value

Calculate the resonant capacitor value (C_{res}) by substituting the antenna equivalent circuit parameter values into equation (1).

This example (MN63Y1213) assumed it C_{in} = 15.5pF from item C9 of the product standard.

Substituting the antenna equivalent circuit parameters (L_{coil} = 1 μH, C_{coil} = 2 pF) and the resonant frequency (f_r = 13.56 MHz), gives

$$13.56\text{MHz} = \frac{1}{2 \cdot \pi \cdot \sqrt{1\mu\text{H} \cdot (2\text{pF} + C_{res} + 17.5\text{pF})}}$$

Hence, the resonant capacitor value C_{res} = 120 pF.

2.5.3 Determining Proper Resonant Capacitor Value [STEP 4-3]

Figure 7 shows how to measure the resonant frequency. While the resonant capacitor with a value calculated in [STEP 4-2] and the NFC tag LSI are mounted on the antenna board, measure the resonant frequency to determine the proper resonant frequency.

If the resonant frequency has not been 13.56 MHz, adjust the resonant capacitor value. If the frequency is high, increase the capacitor value; if low, decrease it.

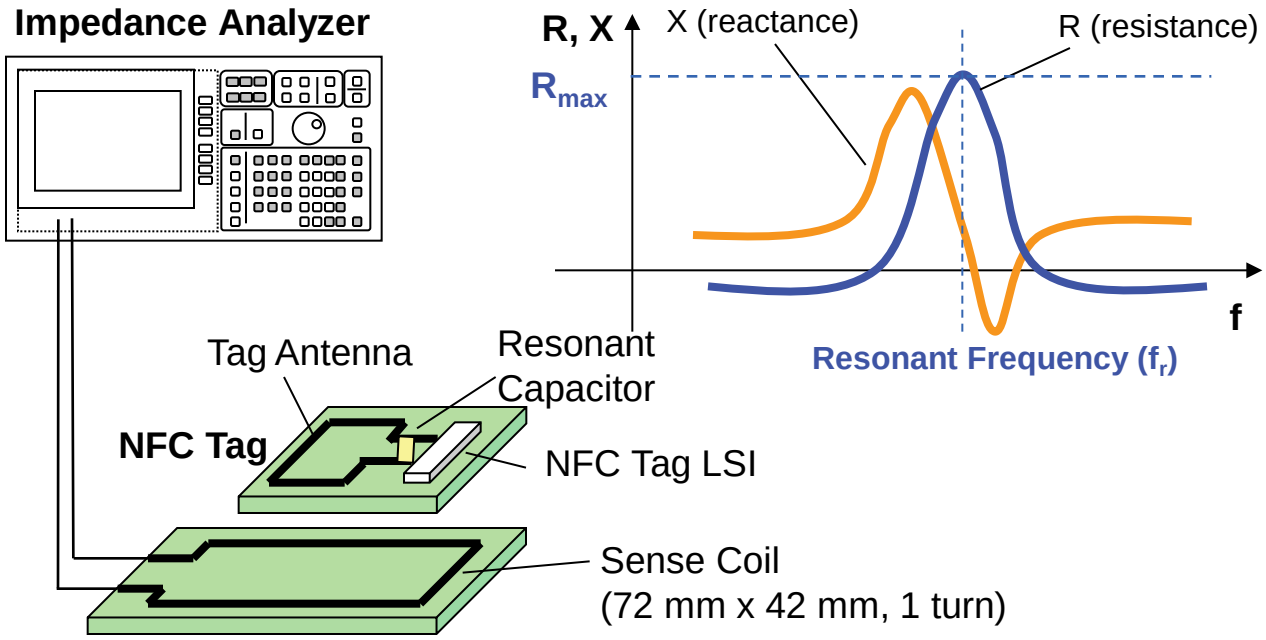


Figure 7 How to Measure the Resonant Frequency

< Measurement example >
(1) Perform the calibration with no sense coil connected in OPEN mode. In SHORT mode, do it with a sense coil connected.
(2) Do not apply a voltage to the NFC tag LSI's power supply (VDDEX) and GND (VSS).
(3) Set the start and stop frequencies of the impedance analyzer to 10 MHz and 15 MHz, respectively.
(4) Set to R-X mode.
(5) Measure the resonant frequency (f_r) at which the resistance R is maximum.

2.6 Checking the Operation of NFC Tag [STEP 5]

Mount the NFC tag LSI on the antenna board and measure the following items to verify normal operation.

(1) Communication distance
(2) Voltage of antenna pin

2.6.1 Measuring the Communication Distance

Based on the method for measuring the communication distance shown in Figure 8, measure the communication distance from smartphone.
Verify whether the result meets the specifications of your model.

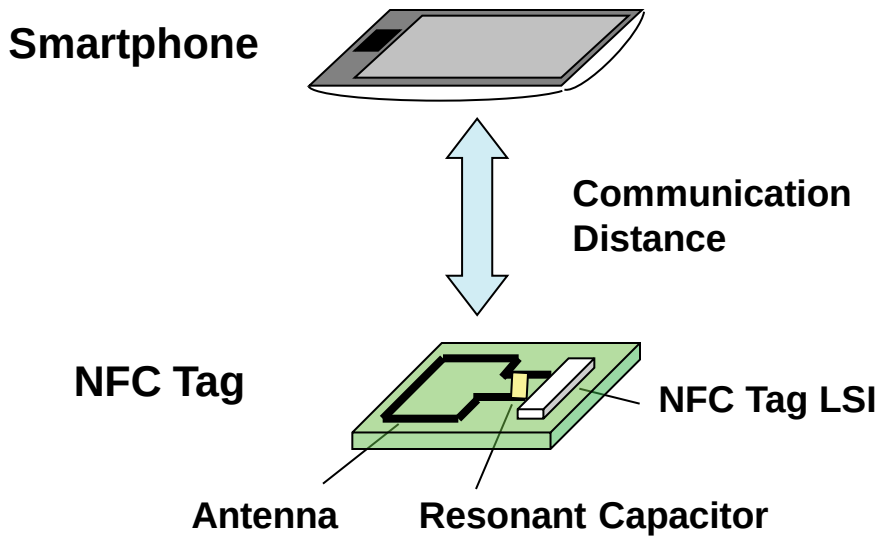


Figure 8 How to Measure the Communication Distance

< Measurement example >
(1) Move the NFC tag closer to a smartphone until NFC communication succeeds.
(2) Then, measure the distance from the smartphone.

2.6.2 Checking the Voltage of Antenna Pin

Table 2 shows the measurement results of antenna pin voltage of our prototype NFC tag.

Based on Table 2, verify that the following product standards are satisfied: Parameters D10 (21 Vpp or less for VB-VSS pins)

Table 2 Measurement Results of Antenna Pin Voltage

Shape of antenna				H_{max} [A/m]	Voltage between VB and VSS pins [Vpp]
Size [mm²]	Track width [mm]	Spacing [mm]	Number of turns [turn]		
72 x 42	0.5	0.5	1	7.5	21.8
			2	7.5	17.1
			3	7.5	14.6
40 x 30	0.5	0.5	2	8.5	18.5
			3	8.5	15.3
			4	8.5	13.4
25 x 20	0.3	0.3	3	(8.5)	11.8
			4	(8.5)	10.4
			5	(8.5)	10.2
12 x 10	0.1	0.1	8	(8.5)	6.9
			12	(8.5)	6.7
			16	(8.5)	6.5

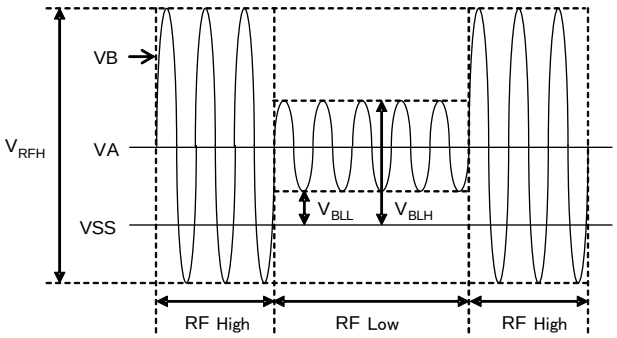


Figure 9 Voltage Waveform on VA and VB Pins

(Note 1) These data are the results measured using our prototype NFC tag and do not guarantee your NFC tag's antenna pin voltage.

(Note 2) If using a large-sized antenna, make sure that the antenna pin voltage does not exceed the values specified in parameters D10.

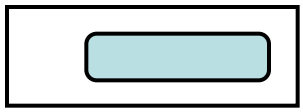
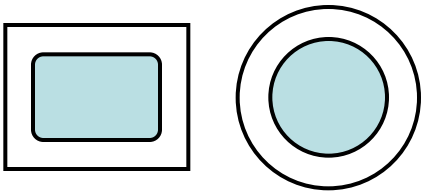
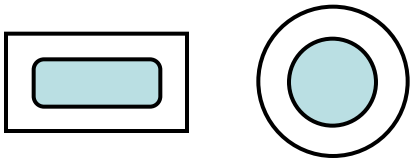
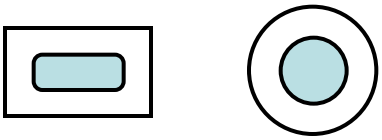
(Note 3) The maximum magnetic field strength of 25*20 and 12*10 size assume it 8.5A/m by limitation of the measuring equipment.

3. Reference

3.1 Antenna Class Based on ISO/IEC14443

Table 3 shows the antenna class based on ISO/IEC14443-1,2. Operating magnetic field intensity varies with antenna class.

Table 3 Antenna Class Based on ISO/IEC14443

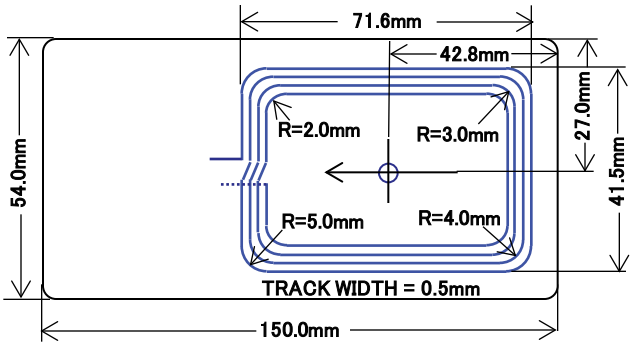
Classification by shape and outline dimensions [mm]			Shape Area where antenna coil is prohibited	Operating magnetic field intensity [A/m]
Class	Wide [mm]	Long [mm]		
Class 1	64-81	34-49		1.5 to 7.5
Class 2	51-81	13-27		1.5 to 8.5
Class 3	35-50	24-40		1.5 to 8.5
Class 4	35-50	13-27		2.0 to 12
Class 5	25-40.5	10-24.5		2.5 to 14
Class 6	25>	20>		4.5 to 18

3.2 Antenna Coil Specifications in NFC Forum

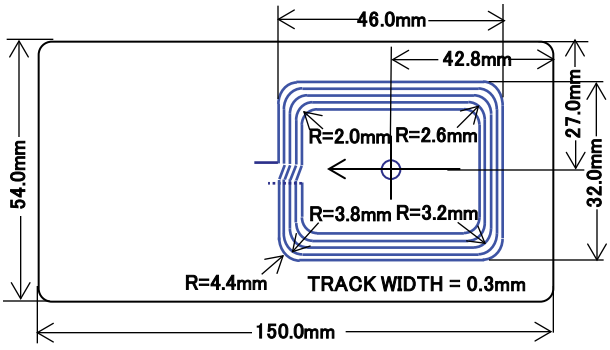
Figure 10 shows the antenna coil specifications reported in the NFC Forum on February 15, 2011.

NFC FORUM -NFC Analogue Specification- 2/15/2011					
	Wide [mm]	Long [mm]	Number of turns [turn]	Track width [mm]	Spacing [mm]
LISTENER-1	72.1	42	4	0.5	0.5
LISTENER-3	46.3	32.3	5	0.3	0.3
LISTENER-6	25	20	5	0.3	0.3

LISTENER-1



LISTENER-3



LISTENER-6

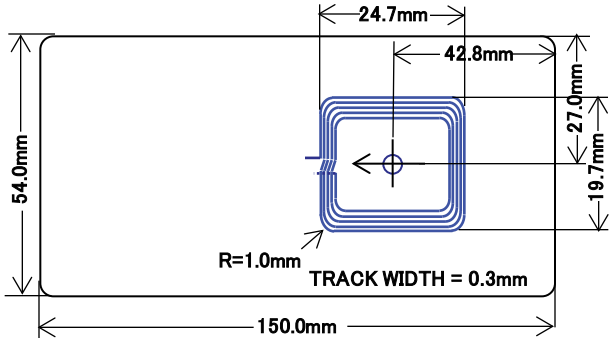


Figure 10 Antenna Coil Specifications in NFC Forum

3.3 How to Measure the Voltage of Antenna Pin

Set up the measurement environment as shown in Figure 11 to measure the voltage of antenna pin.

For more information on how to test an NFC tag, refer to ISO/IEC10373-6.

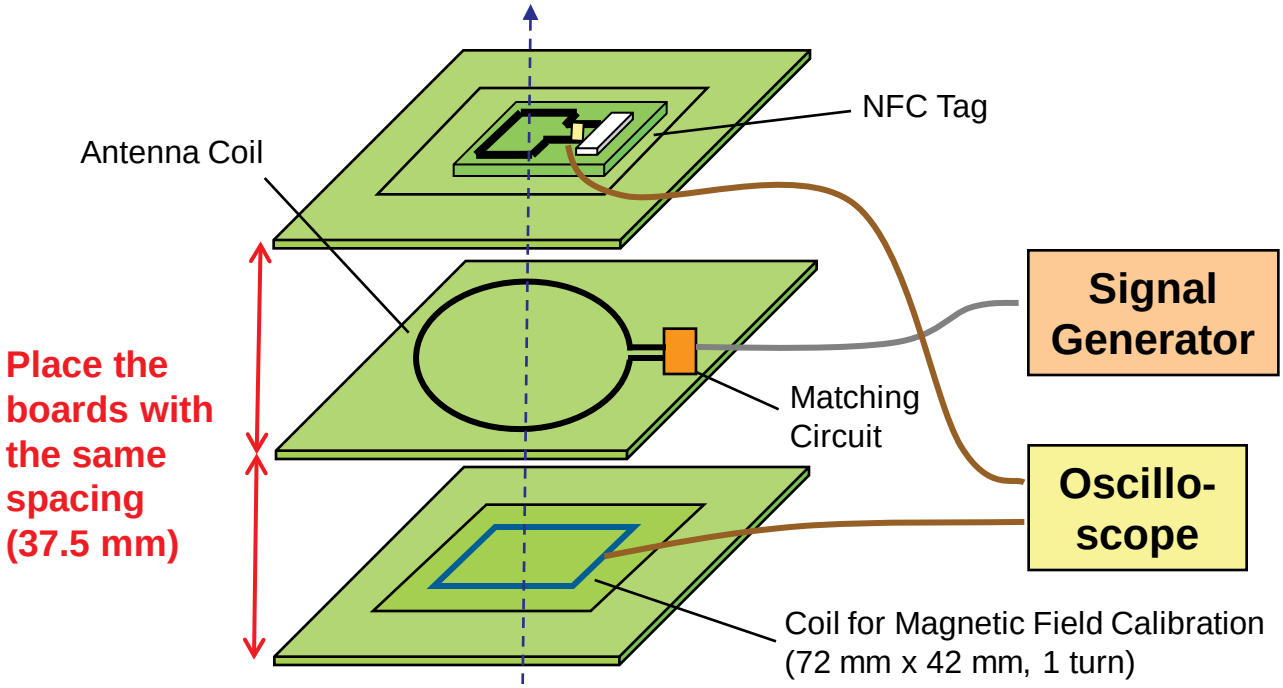


Figure 11 Schematic Measurement Environment for Antenna Pin Voltage

Based on the antenna class specification (3.1) of ISO/IEC14443, verify the maximum magnetic field strength (H_{max}) according to the antenna class. Some reader/writers may generate a magnetic field exceeding H_{max}. In this case, the value is H_{max} .

< Measurement example >
(1) Adjust the resonant capacitor value to set the resonant frequency to 13.56 MHz while the probe is connected to the node to be measured.
(2) Place the NFC tag on the center of the antenna.
(3) Change the output level of the signal generator to generate the maximum magnetic field strength (H_{max}) and measure the voltage between VB and VSS pins using an oscilloscope.

Revision History

No.	Date	Version	Comment
1	Oct. 30, 2012	1.00	Initial edition
2	Nov. 30, 2012	1.10	Added page 2. Added communication distance data in table 1. Modified antenna pin voltage data in table 2.
2	May 31, 2016	1.20	All pages: Change the example in MN63Y1213

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