AN14236

NTAG X DNA - Antenna design guide

Rev. 1.0 — 27 May 2025 **Application note**

Document information

Information	Content
Keywords	Contactless, NTAG X DNA, ISO/IEC 14443, resonance, coil, inlay, antenna, card coil design
Abstract	This document provides guidance for engineers designing magnetic loop antenna coils for NTAG X DNA.

1 Introduction

NTAG X DNA can be powered by a magnetic field generated by the PCD. To get the magnetic flux cut by the PICC, it also requires a loop antenna.

This document provides guidance for engineers designing such a magnetic loop antenna coil for NTAG X DNA.

The detailed loop antenna design is explained in ref.[1]. Although such antennas are relatively straightforward in principle and look very similar when comparing various contactless smartcards, experience proves that their parameters do have a noticeable impact on performance.

Note: *In this document, the term "NTAG X DNA card" refers to a NTAG X DNA IC-based contactless card.*

1.1 How to use this document

This document is covers the hints and notes specific to NTAG X DNA. All the basics and design details are explained in ref.[1]. Use ref.[1] as the base document and apply the notes mentioned in this documents where applicable.

2 Card coil design notes for NTAG X DNA

There are different classes of antennas widely used in contactless applications for the NTAG X DNA PICC. The design of PICC coils differs for the antenna classic in use. Different application requirements can also lead to differences in antenna design.

The most important parameters for card coil design are:

- coil area
- coil quality factor
- the resonance frequency of the transponder under loaded conditions

2.1 Different classes of antenna according to ISO/IEC 14443-1

In Figure 1, different antenna sizes according to ISO/IEC 14443-1 ref.[3] are shown.

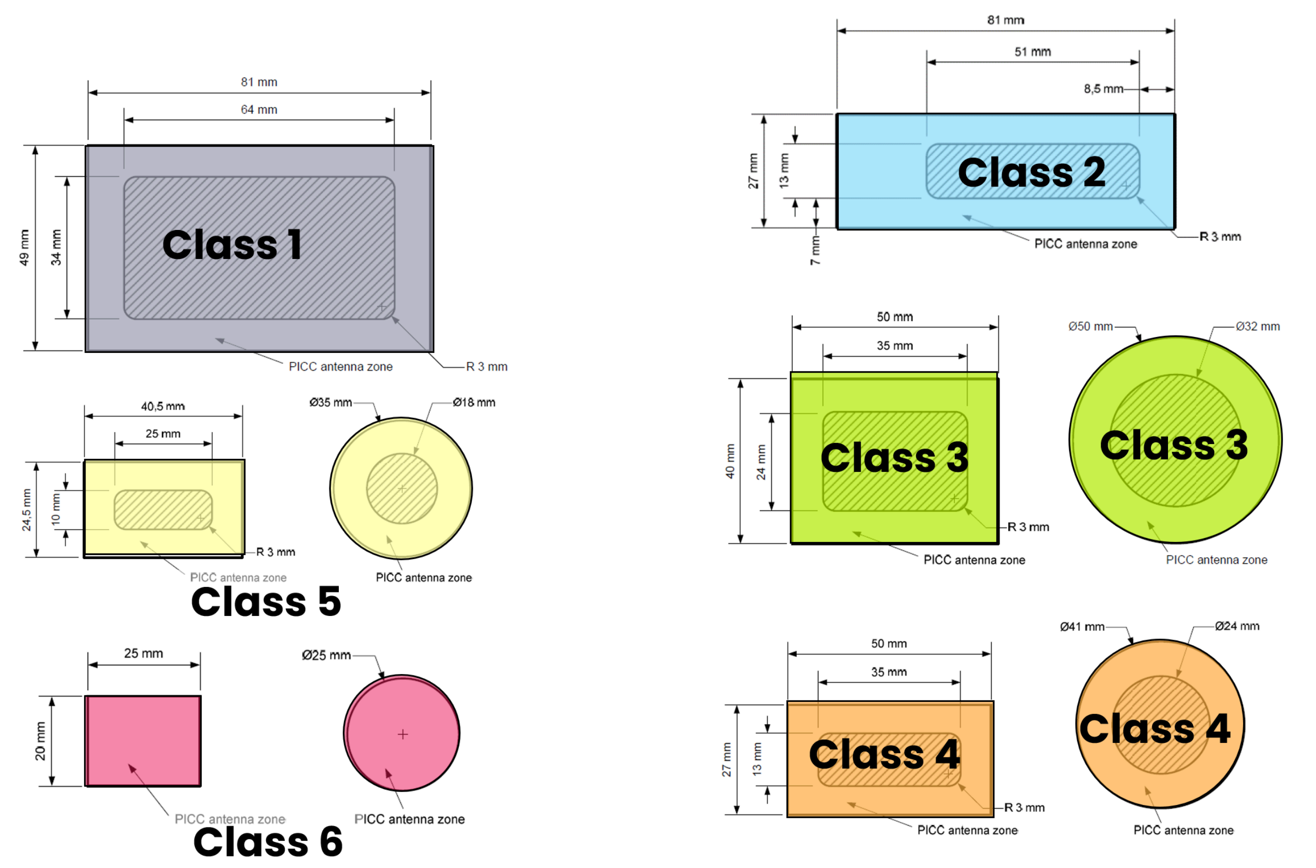


Figure 1. Different coil antenna sizes according to ISO/IEC 14443-1

2.2 Card coil area

Make the card coil area as large as possible. Bending corners are better than sharp corners.

2.3 Coil Q-factor

To get optimum performance and to cover manufacturing tolerances, for NTAG X DNA, the recommended coil Q values are provided in Table 1.

2.3.1 Measurement of coil Q-factor

There are different ways to measure the Q-factor of the coil, which may lead to different results. Follow the instructions in ref.[1] or contact your NXP technical support for more information.

2.4 Definition for “loaded” and “unloaded” conditions

“***loaded conditions***”, or just “loaded”, means that the NTAG X DNA IC gets enough power to be able to fully operate.

“***unloaded conditions***”, or just “unloaded”, means that the NTAG X DNA IC does not get enough power in order to even start to operate.

2.5 Loaded resonance frequency of the transponder

The loaded resonance frequency of the transponder is the resulting resonance frequency, if the IC is operated under loaded conditions.

In general, the appropriate resonance frequency of the transponder depends on the card ICs and applications. To get optimum performance and to cover manufacturing tolerances, the recommended loaded resonance frequency for NTAG X DNA is given in Table 1.

2.5.1 Measurement of loaded resonance frequency of the transponder

There are different ways to measure the resonance frequency of the transponder, which may end up with different results. Follow the instructions in ref.[1] or contact your NXP technical support for more information.

2.6 NXP recommendation for PICC coil design

Table 1 summarizes the recommendations for PICC coil design.

17 pF chip version:

- NTAG X DNA works properly between 14.5 MHz - 16 MHz loaded f_R. However, for optimization of speed at a 1.5 A/m field strength, a **loaded f_R of 14.5 MHz - 15 MHz is most ideal and recommended**.
- For maximum operating distance, the loaded f_R is ideally close to 14.5 MHz.
- A loaded f_R too close at 13.56 MHz (e.g 14 MHz) might have an impact on detuning of the reader antenna and might cause reading issues on some reader models.

50 pF chip version:

- NTAG X DNA works best between 13.9 MHz - 14.4 MHz loaded f_R.

Table 1. PICC coil design recommendation

Antenna class	Recommended chip of NTAG X DNA	Recommended loaded transponder resonance frequency (f_R)	Recommended Coil Q	Comments
Class 1	17 pF	14.5 MHz < f_R < 16 MHz	> 30	Transponder optimum loaded resonance frequency for stacked 2 cards operation is close to 15 MHz.
Class 2, 3, 4, 5, 6	50 pF	13.9 MHz < f_R < 14.4 MHz	> 40	For 106 kbit/s and single card application. The optimum loaded resonance frequency is slightly above 13.9 MHz.

Those recommended quality factor values for the Coil are important to ensure good power transfer and to increase the so-called power range of the transponder. Those recommended values will also remain valid for higher bit rates than 106 kbit/s (up to 848 kbit/s).

For CLASS 1 antennas (17 pF IC version), a minimum Coil Q-Factor = 30 is recommended. The resulting transponder Q-factor under “unloaded” conditions is similar to this value. Once the IC starts to operate, the transponder (loaded) Q-Factor is decreasing and this is leading to a loaded Q-Factor in the range of Q = 8-9. This value is a good compromise in the middle of the Range Q = 6-15, which results in a good performance for all data transfer rates (from 106 kbit/s to 848 kbit/s).

All those considerations are also valid for CLASS 2 to CLASS 6 antennas (50 pF IC version), the only difference is that a minimum Coil Q-Factor = 40 is recommended.

Refer to Section 2.9.1 in this document for further reference on this topic.

Note: *Increasing the communication bit rate may reduce the communication distance especially for the small antennas (smaller than class 1).*

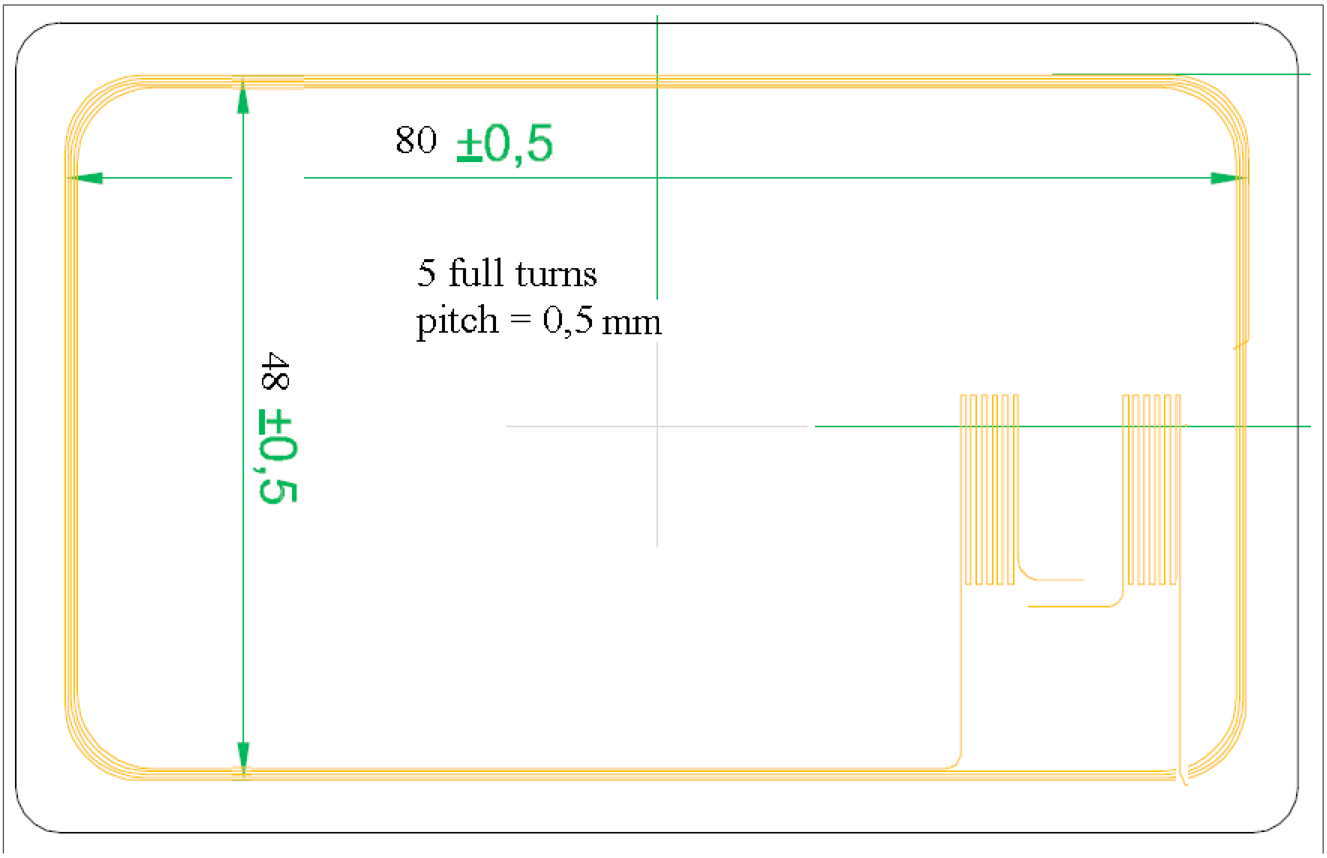
2.7 Practical design hints and recommendations for the 17 pF chip version

2.7.1 ID1-sized antennas

Within the confines of the application and the card manufacturing processes used, try to maximize the antenna size. The outermost turn of the antenna coil should be placed as close as possible to the edge of the card represented by an 81 x 49 mm rectangle. Class 1 antenna examples (with two different parameters) are shown in Figure 2.

Note: *International standards and industry specifications may restrict the choice of the maximum allowed antenna coil size.*

For ID1 size (class 1) antenna, the 17 pF chip version is recommended. For all other classes, the usage of the 50 pF version of the NTAG X DNA chip is recommended.



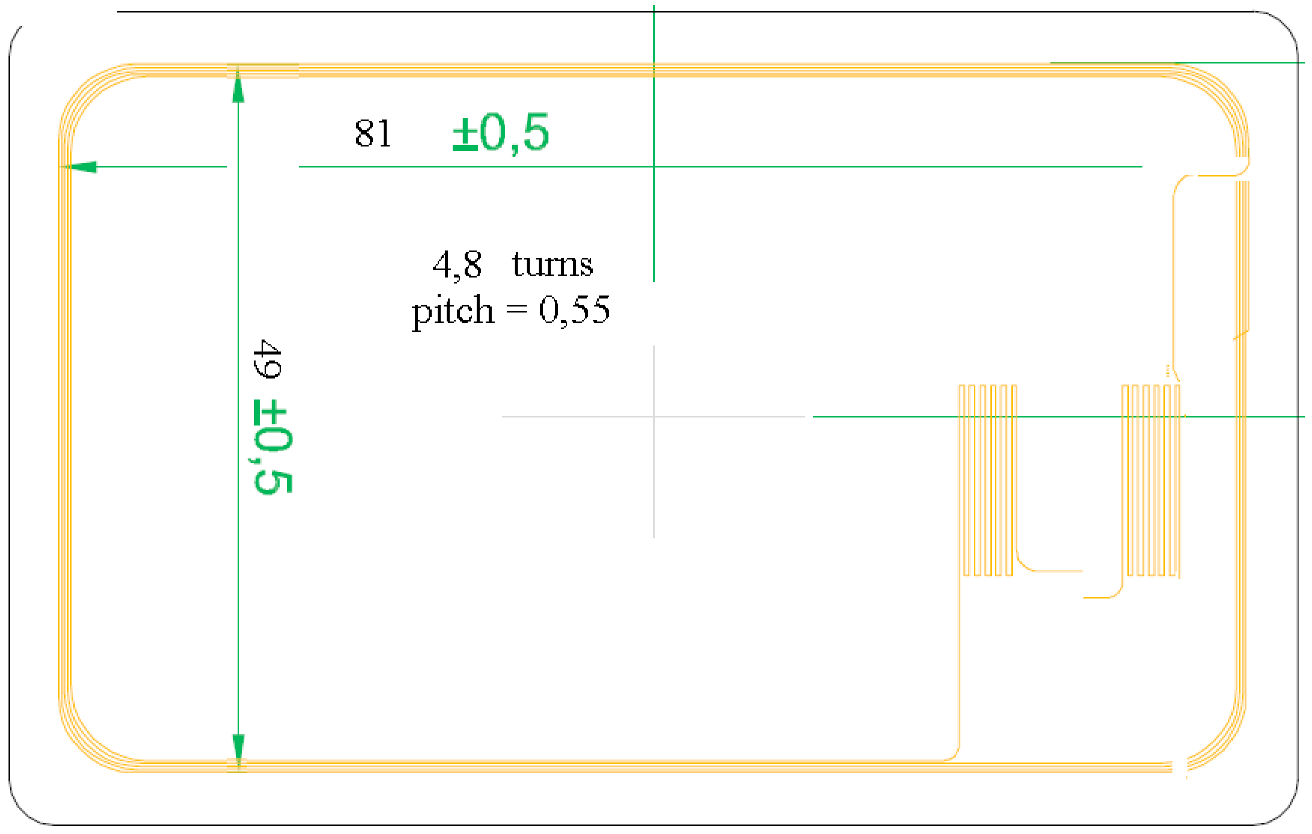


Figure 2. Class 1 antenna examples (with two different parameters)

Figure 3 shows further examples of typical parameters for different ID1-sized antenna designs. Besides geometrical coil parameters (orange colored area), also measured (blue colored area) and calculated (green colored area) electrical parameters are listed in comparison.

	Embedded Wire rectangular Antennas									
Dimensions	outline	mm	72,6 x 42		80,2 x 48	80 x 47,5	80 x 48	80,5 x 48		
	wire diam.	mm	0,112		0,112	0,112	0,112	0,112 ?		
	wire pitch	mm	0,14		0,45	0,45	0,45	0,3		
	turns		5		5	4,9	5	5		
measured	Ls @ 1MHz	µH	4,83		4,89	4,69	4,90	5,23		
	Rs Q 1 MHz	Ohm	2,05		2,29	2,22	2,24	2,37		
	fres	MHz	36,84		38,45	42,58	39,46	39,19		
	Rp @ fres	kOhm	55,00		69,00	90,00	90,00	55,00		
Calculated	Q @ fres		63,00		66,00	72,00	70,00			
	Cp	pF	3,87		3,51	2,98	3,32	3,16		
	Rs	Ohm	3,92		3,78	3,22	3,38	4,49		
	Q		105,03		110,11	124,00	123,70	99,16		

Figure 3. Typical parameters of different class 1 card antennas

2.8 Practical design hints and recommendations for the 50 pF chip version

For class 2 and up to class 6 antennas, it is recommended to use the 50 pF chip version.

2.8.1 ID ½ sized (class 2) antenna

Geometrical parameters of one possible class 2 size antenna design, as well as its location within the ID1 card area is shown in Figure 4.

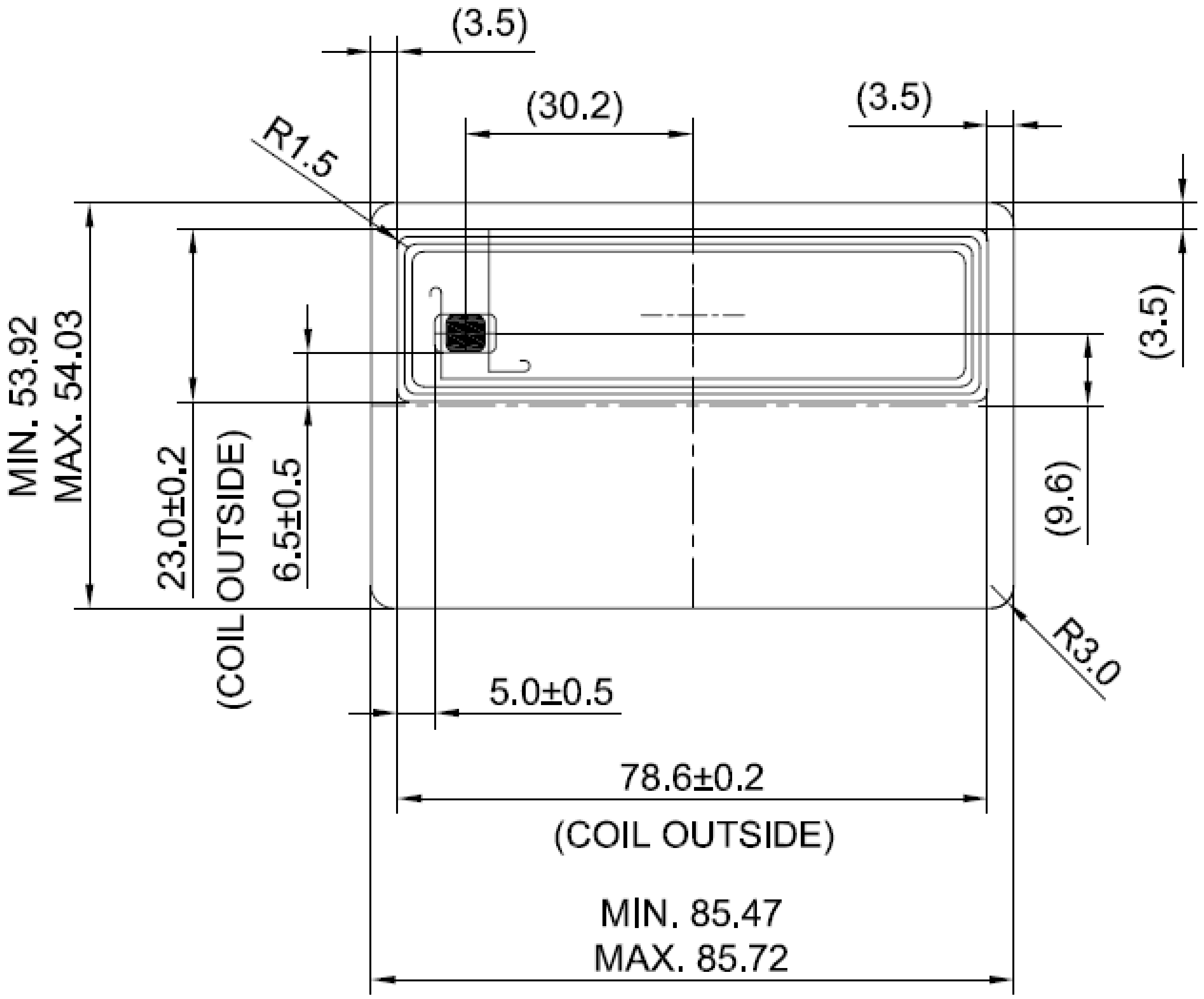


Figure 4. Class 2 antenna example

2.9 Antenna coil design considerations for unloaded and loaded conditions (17 pF IC)

2.9.1 Quality factor and bandwidth of the transponder

The quality factor of a transponder Q_T is an important parameter defined at air interface. The value of Q_T has to be properly chosen in order to guarantee sufficient performance for both power and data transmission.

The quality factor of the transponder results from the quality factor values of its' both components, the antenna (Q_A) and the chip (Q_C), and is dictated by the component with lower Q-factor, in this case by the Q_C. Taking into account that both chip electrical parameters (capacitance C_C and resistance R_C) are power-dependent, it is obvious that the Q_T also changes with power and frequency. This point is relevant when considering Q_T under "loaded" and "unloaded" conditions.

For a transponder resonant LCR circuit, Q_T can be determined in frequency domain. Q_T is related to the bandwidth, which can be measured from the resistance trace as shown in Figure 5 (see ref.[2]).

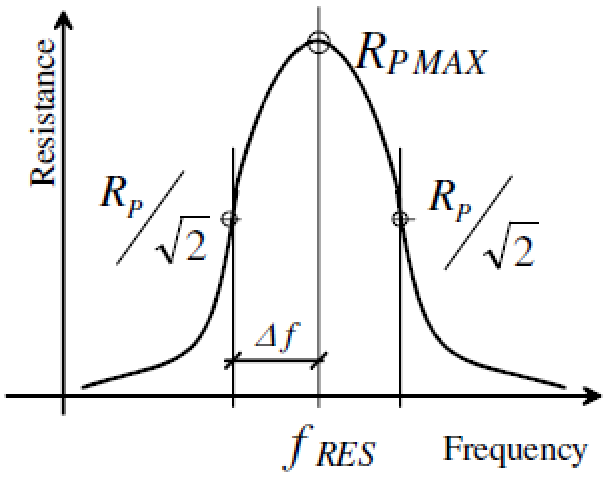


Figure 5. Resistance trace for determining the transponder bandwidth

Q_T can be calculated by using Equation 1, which connects three relevant parameters (quality factor Q_T, resonance frequency f_{res} and bandwidth B) with each other:

$$Q_T = \frac{f_{res}}{2\Delta f} = \frac{f_{res}}{B} \qquad (1)$$

Where f_{res} is a transponder resonance frequency and Δf is defined as in Figure 5.

Note: *This is only valid, if the broadband equivalent circuit representation really is a parallel resonant circuit.*

2.10 Required transponder bandwidth for (PICC ➔ PCD) data transfer

The demand for data transfer sets certain requirements on the transponder bandwidth *B*, which limits the transponder quality factor Q_T. The needed bandwidth is related to the modulation scheme, coding and data rates, used.

The highest data rate, which is defined in the standard, requires the largest transponder bandwidth.

Figure 6 demonstrates how this bandwidth can be calculated for 424 bit/s data rate.

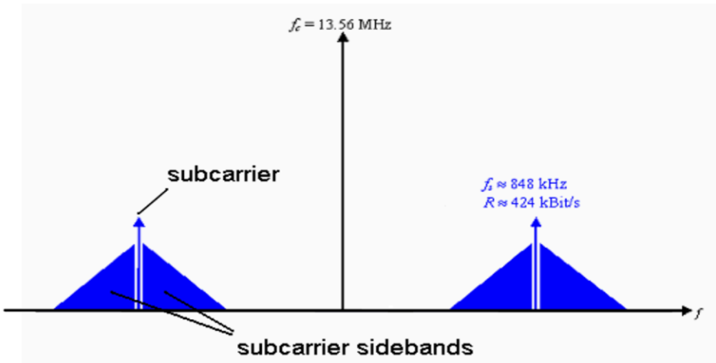


Figure 6. Theoretical needed PICC bandwidth for a data transfer at 424 kB/s

Other possible data rates and their relationship to their associated required bandwidth is given in Table 2.

Table 2. Theoretical PICC needed bandwidth for a data transfer with different data rates

Data rates [kbit/s]	B [MHz]
106	1.8
212	1.9
424	2.1
848	2.5

One important remark: If a transponder bandwidth is smaller, than theoretically required bandwidth, this does not automatically mean that the communication will not be possible. What will happen is that the sideband levels of the card answer will be more damped than 3 dB, (which was accepted for a bandwidth definition), but are still sufficient for successful communication.

Note: For higher antenna classes (class 2 to class 6): *With coil size reduction the inductance of the coil decreases. Additionally, there is a recommendation to utilize 50 pF IC version together with antennas smaller than class 1. This results in the increase of the transponder* Q_T *factor. It is recommended to control resulting* Q_T *or bandwidth B of the new designed small transponder, to enable successful communication for all desired data rates.*

3 Terms and abbreviations

Table 3. Abbreviations

Acronym	Description
CCDG	Card coil design guide
PCD	Proximity coupling device
PICC	Proximity IC card
f_R / fres	Resonance frequency

4 References

[1] Application note - AN11276 - NTAG Antenna Design Guide (link)

[2] M. Gebhart, Air Interface, Antennas and Signals in Contactless Near-Field Communication 2nd lecture in Selected Topics of Advanced Analog Chip Design, 439.224

[3] Standard - ISO/IEC 14443-1 - Identification cards - Contactless integrated circuit cards - Proximity cards - Part 1: Physical characteristics

5 Revision history

Table 4. Revision history

Revision	Release date	Description
AN14236 v.1.0	27 May 2025	• Initial version

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