8. Appendix

8.1 Antenna design

8.1.1 Antenna inductance

The following two sub-chapters 8.1.2 and 8.1.3 show required formulas to estimate the antenna inductance in free air.

Note: Sophisticated simulation software is required to calculate the antennas parameters to estimate antenna values in environments containing metal (such as shielding planes or batteries in devices).

8.1.2 Circular antennas

Fig 39 shows the profile a typical circular antenna.

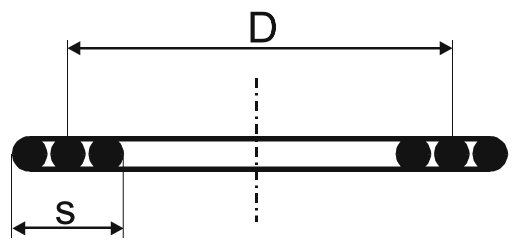

Fig 39. Circular antenna

The inductance can be estimated using the following formula:

$$L_a[nH] = \frac{24.6 \cdot N_a^{\,2} \cdot D[cm]}{1 + 2.75 \cdot \frac{s[cm]}{D[cm]}} \qquad (22)$$

D Average antenna diameter

s Antenna width

N_a Number of turns

8.1.3 Rectangular antennas

Fig 40 shows a typical rectangular antenna.

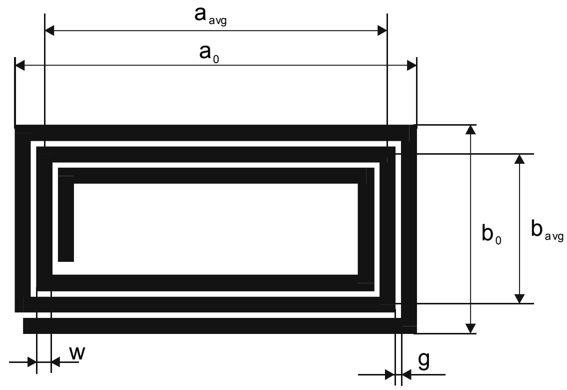

Fig 40. Rectangular antenna

Variables:

a_o, b_o	Overall dimensions of the coil
a_{avg}, b_{avg}	Average dimensions of the coil
t	Track thickness
w	Track width
g	Gap between tracks
N_a	Number of turns
d	Equivalent diameter of the track

The inductance can be calculated by:

$$L_a = \frac{\mu_0}{\pi} \cdot \left[x_1 + x_2 - x_3 + x_4\right] \cdot N_a{}^{1.8} \quad (23)$$

With:

$$d = \frac{2 \cdot (t + w)}{\pi}$$

$$a_{avg} = a_o - N_a \cdot (g + w) \qquad b_{avg} = b_o - N_a \cdot (g + w)$$

$$x_1 = a_{avg} \cdot \ln\left[\frac{2 \cdot a_{avg} \cdot b_{avg}}{d \cdot \left(a_{avg} + \sqrt{a_{avg}{}^2 + b_{avg}{}^2}\right)}\right] \qquad x_2 = b_{avg} \cdot \ln\left[\frac{2 \cdot a_{avg} \cdot b_{avg}}{d \cdot \left(b_{avg} + \sqrt{a_{avg}{}^2 + b_{avg}{}^2}\right)}\right]$$

$$x_3 = 2 \cdot \left[a_{avg} + b_{avg} - \sqrt{a_{avg}^{\ 2} + b_{avg}^{\ 2}} \right] \qquad x_4 = \frac{a_{avg} + b_{avg}}{4}$$

8.1.4 Number of turns

Depending on the antenna size, the number of turns has to be chosen in a way to achieve an antenna inductance between 300 nH and 3 µH.

The parasitic capacitance should be kept as low as possible to achieve a self-resonance frequency > 35 MHz.

A typical the number of turns will be in the range

N_a=1 – 6,

which is suitable for various applications and antenna sizes.

Due to the coupling coefficient, a low number of turns are preferred. The lower the numbers of turns, the lower is the influence of coupled devices (e.g. 2nd NFC device, Card, Reader) to the 1st device. This also means that the detuning effect on the 1st device is minimized when reducing the distance between the two devices. The overall performance loss due to low number of turns is negligible.

8.1.5 Antenna symmetry

The symmetry in antenna design is absolutely necessary with respect to tuning and EMC behavior (see Fig 41). Otherwise common mode currents are generated due to parasitic capacitances from the antenna to ground. These currents can cause emissions that hurt the EMV regulations

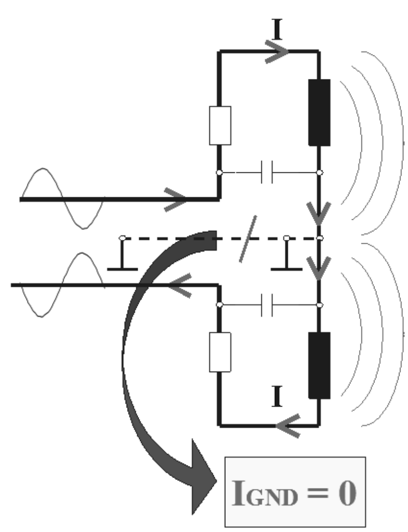

Fig 41. Ground current compensation

The following Fig 42 shows an example of a symmetric 4-turn antenna design. It can be seen that the center tap of the antenna is connected to ground. Basically, we do not recommend grounding the center tap, but leaving it floating. This has the advantage of a