Voyantic

Application note:

Measuring an NFC reader's magnetic field strength and creating the NFC reader profile for Tagformance HF

07/2020

1 Introduction

NFC reader's power profile is not only about reader power in mW or dBm. Also, the geometry of the reader antenna and tag antenna affects how well the antennas are connected.

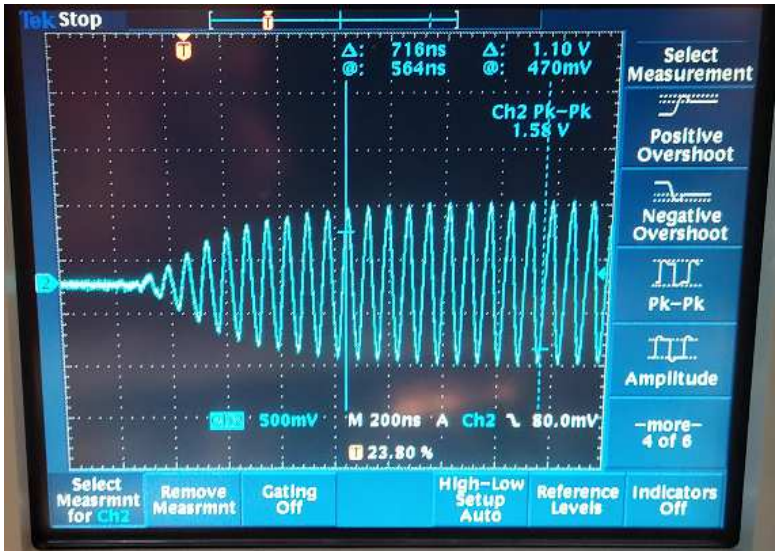
This paper describes a method for comparing NFC readers' magnetic field strengths, and for creating a reader profile to be used with Tagformance HF read range calculation.

2 Measuring the field strength

1. Create an open single loop coil
   - ideally, the coil size should match roughly the area size of the tag that is read with the reader, the measured magnetic field strength is the average field strength across the measurement coil. Higher geometrical accuracy is achieved with a smaller coil
   - The most common calibration coil is 72 mm x 42 mm = 3024 mm^2. This is larger than many commonly used NFC antennas nowadays.
   - A typical oscilloscope input impedance is about 1 MΩ parallel to 12 pF, this is high enough not to influence the results.
   - Wires to the coil should be twisted around each other, or a coaxial cable should be used for preventing any accidental loops distorting the measurement. Also, the cables should be kept as short as possible for minimizing cable losses.

2. Set the NFC reader to transmit
   - If you characterize an antenna only, connect the antenna to a signal generator transmitting at 13,56 MHz, record also the input power used.
3. Measure peak to peak voltage during reader transmissions using the open loop coil.
   - Note that because of the geometry of the antennas, the voltage level depends on the distance of the coil from the reader, position of the coil relative to the reader antennas center point, and any angle between the coil and reader antenna.
   - Unless specifically needed, measure the voltage having the coil facing the reader antenna, and center points of the antennas aligned. Measure at different distances.

Picture 1. Measurement setup with open loop. Coil is 30 mm x 30 mm square (A= 900 mm^2 = 0,00009 m^2)



Picture 2: measurement result showing 1.58 V peak to peak voltage (U_{PP})

Picture 3: measurement at different distance using 5 mm thick spacer foams

4. Convert the peak-to-peak voltage (UPP) to magnetic field strength (H_{RMS})
   - HRMS = UPP * $\frac{1}{2\pi f * \mu_R \mu_0 * A * 2\sqrt{2}}$ = UPP * 0,0033022 * $\frac{1}{A}$ = UPP * 3302,2 * $\frac{1}{A_{mm}}$

     where
     f = frequency used [MHz] (typically 13'560'000 Hz)
     μ_R = ~1 [Vs/Am] (for non-ferritic materials)
     μ_0 = magnetic field constant = 4π*10-7 [Vs/Am]
     A = Area of the single loop coil [m^2]
     A_{mm} = Area of the single loop coil [mm^2]

In the example test

- *U_{PP} = 1,58 V*
- *A = 0,00009 m^2 (30 mm x 30 mm)*
- *A_{mm} = 90 mm^2*
- *f=13560000 Hz (13,56 MHz)*
- *μ_R = 1*

➔ *H_{RMS} = ~58 A/m*

Picture 4: Example calculation with 30 mm x 30 mm loop and measured 1,58 V U_{PP}

3 Creating the NFC reader profile

5. Fill in the magnetic field strength values to table in a .txt file
    - modify the A/m values to mA/m

distance [mm]	mA/m		U_{PP}		1/90 mm^2
0	132088		3,6	3302,2	0,011111111
5	83655,73		2,28	3302,2	0,011111111
10	44763,16		1,22	3302,2	0,011111111
15	29646,42		0,808	3302,2	0,011111111
20	17464,97		0,476	3302,2	0,011111111
25	11741,16		0,32	3302,2	0,011111111
30	8952,631		0,244	3302,2	0,011111111
35	6604,4		0,18	3302,2	0,011111111
40	4843,227		0,132	3302,2	0,011111111
45	3962,64		0,108	3302,2	0,011111111
50	3228,818		0,088	3302,2	0,011111111
55	2641,76		0,072	3302,2	0,011111111
60	1761,173		0,048	3302,2	0,011111111

Picture 5: Clip from a table used to calculate the mA/m values from measured U_{PP}

Fill in the values to the profile file

- The name of the file is the name shown in the Tagformance SW menu, typically referring to the reader. The first 2 rows and columns should be as in the picture below. Typically only 13.56 MHz measurement is valid for smart readers. antennas can be characterized accorss multiple frequencies.
- format of the table is as below, extending to frequencies and distances that are of interest

10	dBm	Frequency	MHz					
		10	10,1	10,2	10,3	10,4	10,5	
Distance	0	0,670918	0,674654	0,696589	0,70792	0,724633	0,734371	0,
cm	0,5	0,628843	0,632345	0,652904	0,663524	0,679189	0,688317	0,7
	1	0,533014	0,535982	0,553408	0,56241	0,575688	0,583425	0,
	1,5	0,429166	0,431556	0,445587	0,452835	0,463526	0,469755	0,4
	2	0,339244	0,341133	0,352224	0,357953	0,366404	0,371328	0,3
	2,5	0,267722	0,269213	0,277966	0,282487	0,289156	0,293042	0,2
	3	0,212601	0,213785	0,220735	0,224326	0,229622	0,232708	0,2
	3,5	0,170481	0,171431	0,177004	0,179884	0,18413	0,186605	0,1
	4	0,138232	0,139002	0,143521	0,145855	0,149299	0,151305	0,1
	4,5	0,113364	0,113995	0,117702	0,119616	0,12244	0,124086	0,1

Picture 6: Clip of an antenna profile file with a "10dBm" reader

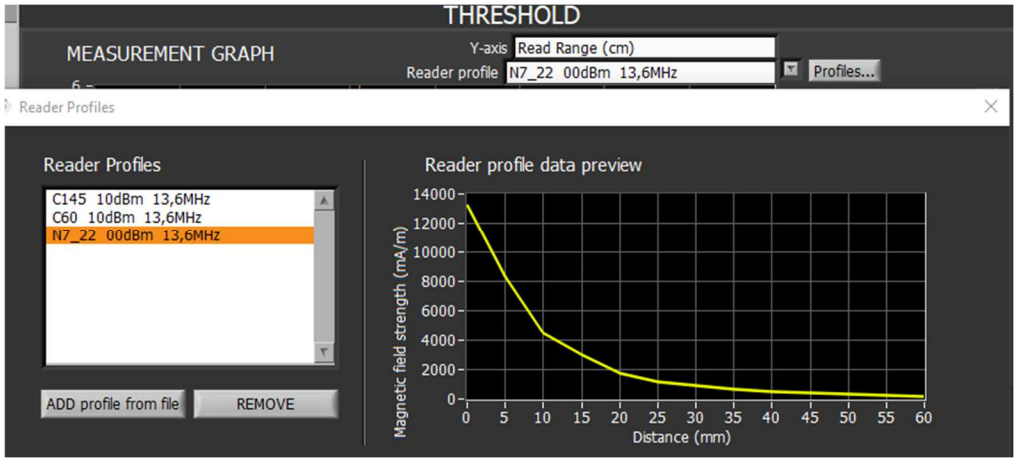
Reader_profile_Nokia7_2.txt - Notepad

File Edit Format View Help

```
N7_22  00dBm  13,6MHz   10
0,000000        13208,800000
5,000000        8365,573000
10,000000       4476,316000
15,000000       2964,642000
20,000000       1746,497000
25,000000       1174,116000
30,000000       895,263100
35,000000       660,440000
40,000000       484,322700
45,000000       396,264000
50,000000       322,881800
55,000000       264,176000
60,000000       176,117300
```

Picture 7: reader profile of Nokia 7.2 Smart phone

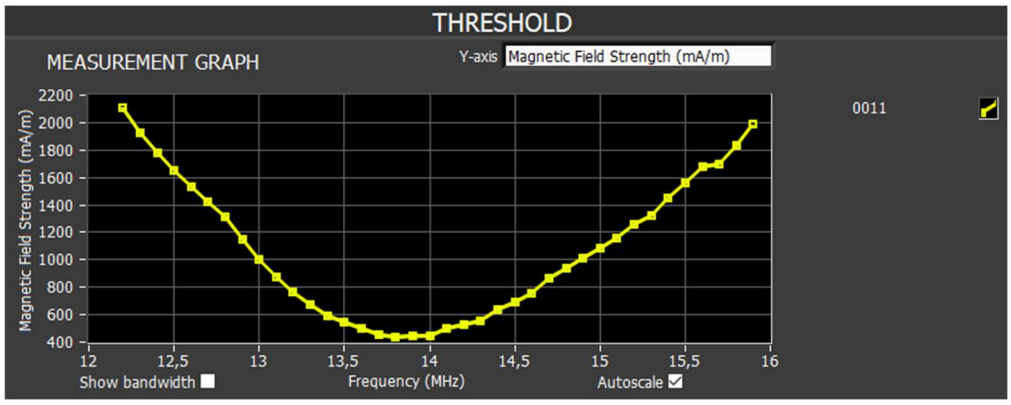
6. Take the profile file into use
   - Save the new file to the Tagformance HF data folder.
   - open the profile with Thershold test, Read range Axis and Add profile from file



Picture 8: Tagformance HF reader profile window

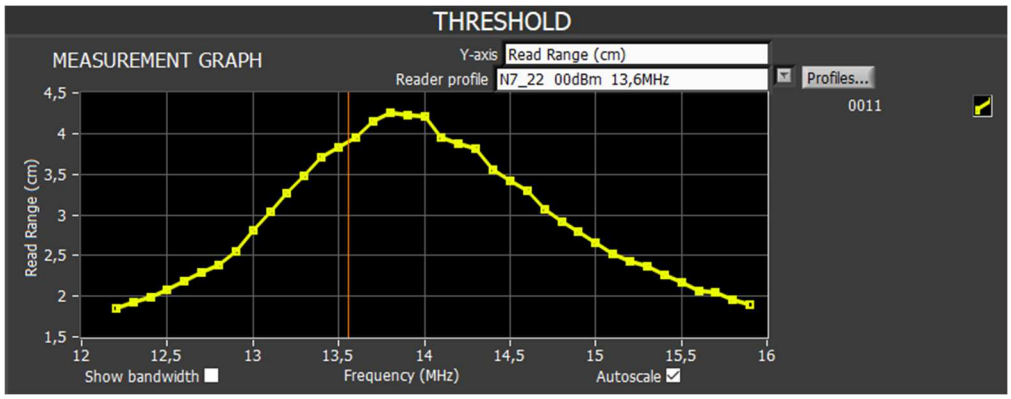
4 NFC reader's field strength and tag sensitivity

- When an NFC tag is characterized with Tagformance HF system, one of the results is threshold magnetic field strength



Picture 9: Tagformance HF threshold sweep in magnetic field strength view

- The tag wakes up and responds when the reader's magnetic field strength exceeds the tags threshold magnetic field strength.
- The threshold curve can also be viewed as read range using the selected reader profile



Picture 10: Tagformance HF threshold sweep in read range view. expected read range at reader frequency (orange line, 13,56 MHz) is just below 40 mm.

For evaluating the methodology three characterized tags were compared with measurements made with the profiled smartphone.

Picture 11: Measuring read range using spacer foams.

Comparison of the results is in below table.

	Measured with		
	tag and phone	Tag measured with Tagformance HF using the phone's profile	Difference
Sample 1	38 mm	39 mm	2,6 %
Sample 2 (bigger than profiling coil)	51 mm	57 mm	10,5 %
Sample 3 (smaller than profiling coil)	37 mm	39 mm	5,1 %

Table 1. Comparison of read ranges measured directly with smartphone and tag; and by using tag and reader characteristics. Both methods have their own error sources.

The main benefit of the method is that after profiling the reading device once – or possibly twice for different size tags. It is enough to just test each tag model once. After testing a tag, the results are instantly available for each reading device. There is no need to test each tag+reader combination.

The limitation is the uncertainty related to tag sizes. If the inlay size (area of the loop) varies significantly, more than 1 profile may be needed. When the magnetic field strength is measured, the result shows in practice the average field strength across the measurement coil area. The field strength is not uniform at all distances. If the tag size would be significantly different from the measurement coil size the average field strength across the measurement coil would not represent average field strength across different size tag areas.

5 References:

Tagformance Pro user manual.

M. Gebhart, S. Birnstingl, J. Bruckbauer and E. Merlin. Properties of a Test Bench to Verify Standard Compliance of Proximity Transponders.

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