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PN7160 dynamic load modulation amplitude guide

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Application note

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Document information

Information	Content
Keywords	NFCC, NFC, DLMA, PN7160
Abstract	This document provides information about PN7160 dynamic load modulation amplitude (LMA) feature.

Revision history

Rev	Date	Description
1.1	20210913	Security status changed into "Company public", no content change
1.0	20210825	Initial version

1 Introduction

The PN7160 includes a specific feature called “dynamic LMA control” which makes it possible to adapt the load modulation amplitude to the received field strength.

With this capability, the device can generate an optimized signal in card mode and provide better performances by improving:

- communication distances
- interoperability with readers

This document is about to explain the PN7160 DLMA principle and the methodology to configure it.

2 PN7160 DLMA principle

2.1 TX settings lookup table

This methodology is based on a 40 entries TX settings lookup table. This table is called “universal table” and is fixed by PN7160 FW. Each entry (sequence) refers to a unique combination of TX setting (TXLDO output voltage, TX drop, number of drivers, BPSK available) which generates an estimated TX output voltage.

Ratio between two consecutive TX values is equal to 1/1.1. This shape corresponds to an ISO passive card answer. Some TX setting sequences are duplicated to consider TXLDO maximum voltage availability. The figure below illustrates calculated TX output voltages versus lookup table entries:

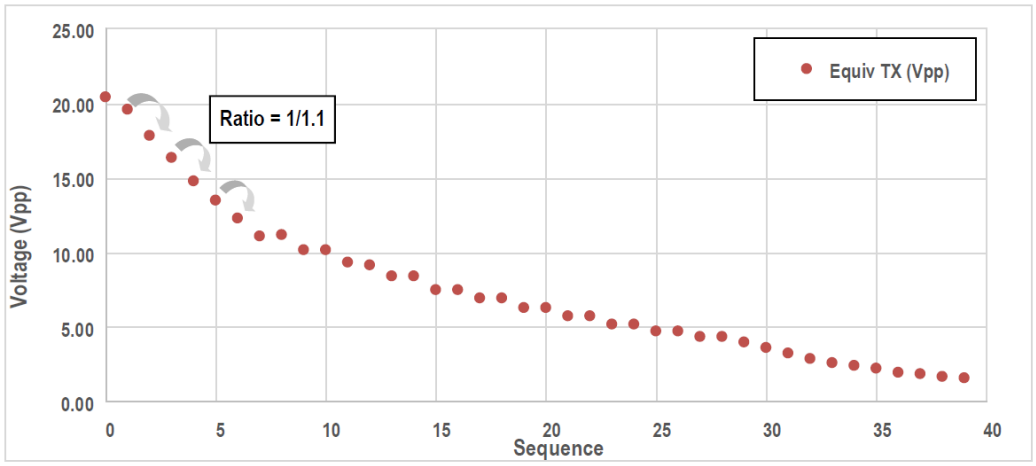

Figure 1. TX settings lookup table

Pay attention that TX output voltage does not mean antenna voltage. Matching network and antenna will apply a gain to the TX output to create the measured LMA, this gain is by default unknown by FW.

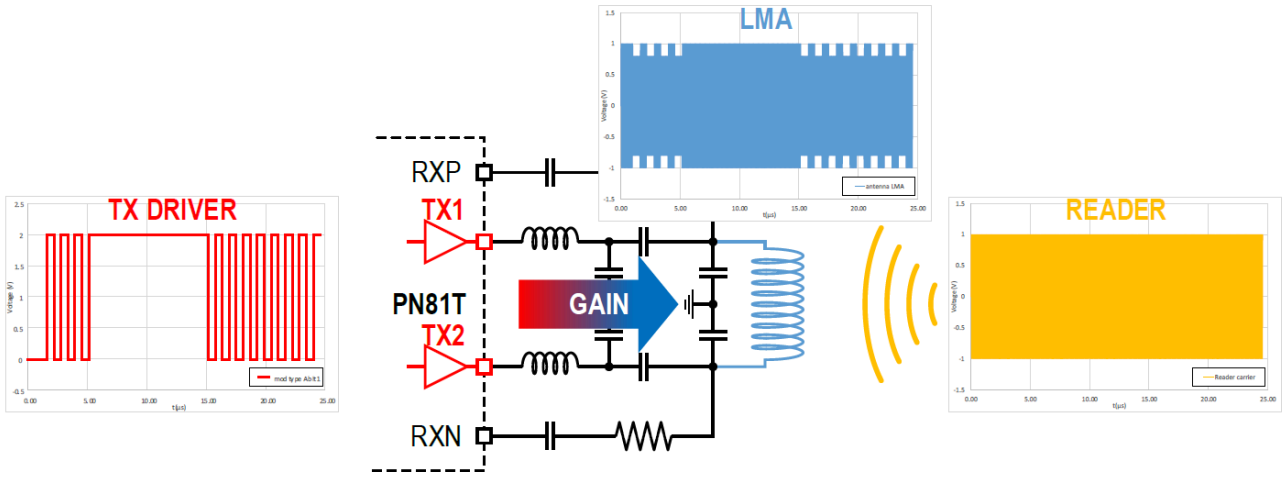

Figure 2. Matching network and antenna gain

Antenna gain should be set using the parameter ***DLMA_LMA_TX_SHIFT_AB(F)***. This parameter is calculated using the ratio between the target LMA @ 0A/m and the measured LMA @1.5A/m. Complete formula is available below:

$$\text{LMA/TX (target (@0A/m))} = \frac{\text{LMA target (mVpp)}}{\text{Equiv TX Voltage (Vpp)}}$$

$$\text{LMA/TX(measured (@1.5A/m))} = \frac{\text{LMA measured (mVpp)}}{\text{Equiv TX Voltage (Vpp)}}$$

$$\text{DLMA\_LMA\_TX\_SHIFT\_AB(F)} = \frac{\log\left(\frac{\text{LMA/TX measured (@1.5A/m)}}{\text{LMA/TX target (@0A/m)}}\right)}{\log(1.1)}$$

Figure 3. Antenna and matching network gain calculation

2.2 RSSI scaling

External field strength measurement is done using interpolated RSSI which is a combination of AGC and ADC measurements. Even if RSSI coefficients are trimmed during PN7160 IC production, RSSI global function spreads. Production equipment limits (±12%), and antenna matching networks external components (±10%) are the main reason of this discrepancy. RSSI expected slope is 75/(A/m). If the measured RSSI slope differs, a correction parameter is available: ***DLMA_RSSI_H_SCALE_AB(F)***.

This parameter is calculated using a ratio between reference and measured RSSI at H=1A/m. As RSSI function is more linear at high field strength than at low field strength, a measurement is done at H=5A/m and result is divided by 5:

$$DLMA\_RSSI\_H\_SCALE\_AB(F) = round\left(\frac{RSSI\ reference\ (@1A/m)}{RSSI\ measured\ (@5A/m)/5} \times 128\right)$$

Figure 4. RSSI scaling factor calculation

Figure below illustrates RSSI correction:

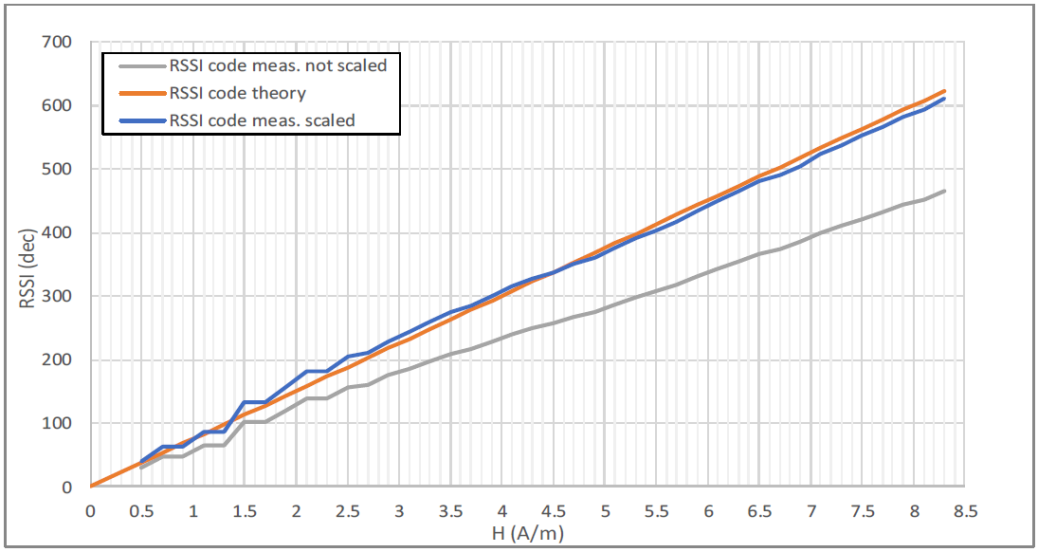

Figure 5. RSSI correction

2.3 DLMA options

To create a correspondence between internal measure of field strength (RSSI) and TX lookup table, an internal algorithm is used by FW. TX choice in the lookup table depends on:

- Interpolated RSSI value
- **DLMA_LIMIT_TXLDO_AB(F)** TXLDO maximum available output voltage (from 3 V to 5.25 V). This parameter is set by register. Rmk: TX output voltage is directly proportional to TXLDO output voltage. Then high LMA are not achievable with low TXLDO output voltage.
- **DLMA_ENA_SINGLE_TX_AB(F)** number of TX drivers (mode 1&2) is set by register. It allows usage of one or two TX drivers when enable and forbid single driver when disable. Rmk: this option is suitable to achieve low LMA.
- **DLMA_ENA_BPSK_AB(F)** BPSK modulation (mode 3) set by register gives the possibility to enable or disable BPSK modulation (roughly multiply by a factor of two TX output voltage). Rmk: this option is suitable to achieve high LMA.

Below the relation between RSSI and TX output voltage with previous options enabled/ disabled:

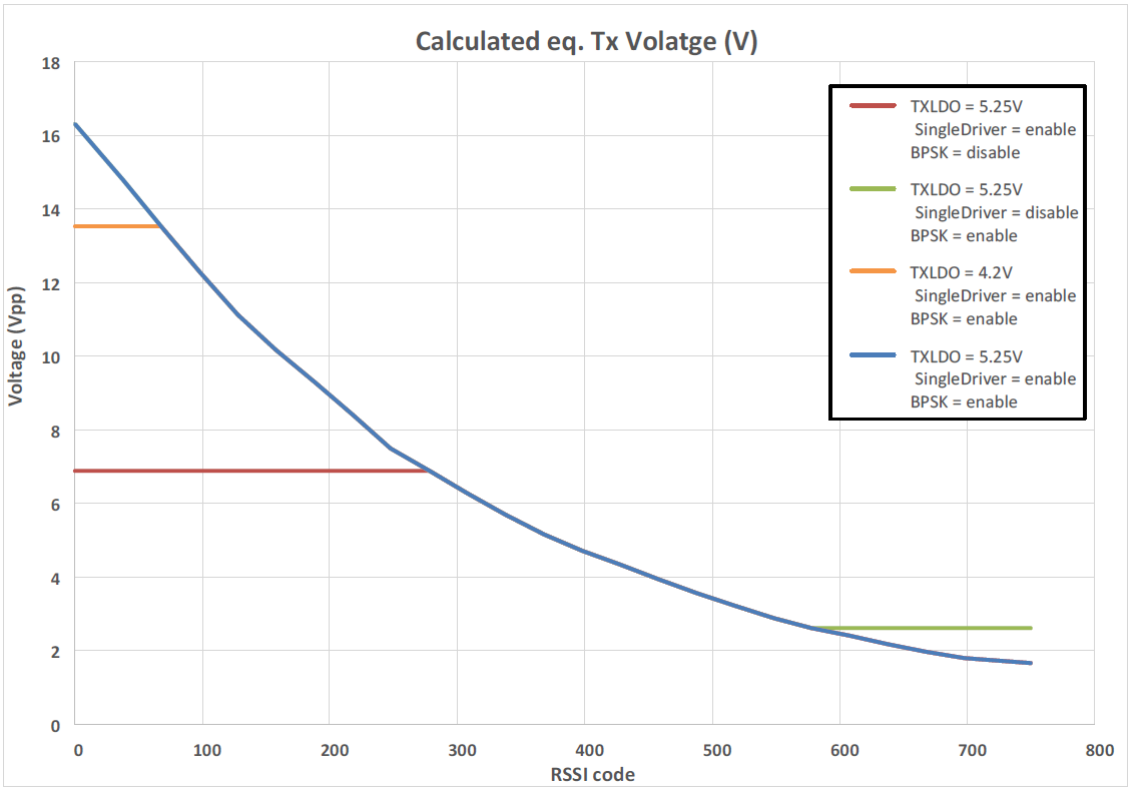

Figure 6. PN7160 DLMA options

2.4 DLMA parameters

PN7160 DLMA is configured via 3 parameters (see [1] for more details):

- **DLMA_CTRL**: enable/disable DLMA and options definition
- **DLMA_RSSI**: define RSSI threshold values
- **DLMA_TX**: to define TX settings lookup table

3 PN7160 DLMA configuration table

An EXCEL file, delivered as part of the PN7160 DLMA configuration package (see [3]), is offered to help setting DLMA configuration.

3.1 DLMA_CTRL parameter

'DLMA_CTRL Settings' sheet is used to define configuration options (single/dual driver, BPSK, TXLDO max output). It is also the place where measurements of RSSI @ 5A/m, LMA and internal index @ 1.5A/m are reported. These measurements are used to calculate TX shifting and RSSI scaling factors for type A&B and F.

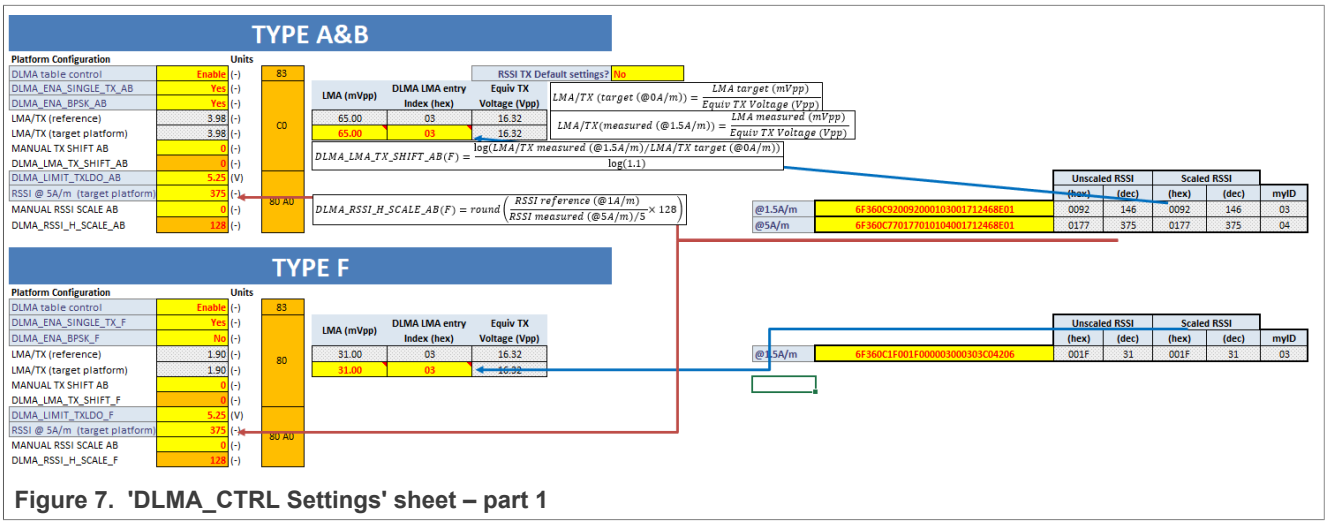

Figure 7. 'DLMA_CTRL Settings' sheet – part 1

A second part of the sheet is dedicated to phase compensation mechanisms. Phase compensation (AGC, TX, ATE) controls for type F, type A&B are included in DLMA_CTRL register:

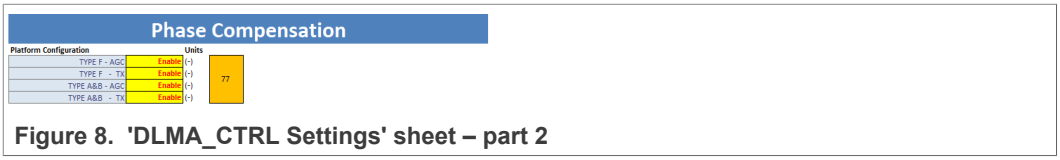

Figure 8. 'DLMA_CTRL Settings' sheet – part 2

Remark: Only highlighted cells can be modified.

3.2 DLMA_RSSI parameter

'DLMA RSSI Settings' sheet is used to define target LMA @ 0A/m and to define the field strength thresholds. Type A&B and Type F definitions are independent. Another column is dedicated to arbitrary phase definition. This phase offset is included in a range of -127° to +127°.

TYPE A+B

	Dialed Input			
DLMA Table ID Power/Phase Control Table	Field strength (A/m) (input)	Target (Type A+B) (pre-defined)	Abritrary Phase Comp. (±127° | step 1°) (input)	NCI LUT cmd
0	0	65		
1	0.7	59.1	0	35 00 00
2	1	53.7	0	4B 00 00
3	1.5	48.8	0	71 00 00
4	1.5	44.4	0	71 00 00
5	2	40.4	0	96 00 00
6	2.5	36.7	0	BC 00 00
7	2.5	33.4	0	BC 00 00
8	3	30.3	0	E1 00 00
9	3.5	27.6	0	07 01 00
10	3.5	25.1	0	07 01 00
11	4	22.8	0	2C 01 00
12	4	20.7	0	2C 01 00
13	4.5	18.8	0	52 01 00
14	4.5	17.1	0	52 01 00
15	5	15.6	0	77 01 00
16	5	14.1	0	77 01 00
17	6	12.9	0	C2 01 00
18	6	11.7	0	C2 01 00
19	7	10.6	0	0D 02 00
20	7	9.7	0	0D 02 00
21	8	8.8	0	58 02 00
22	8	8.0	0	58 02 00
23	10	7.3	0	EE 02 00
24	10	6.6	0	EE 02 00

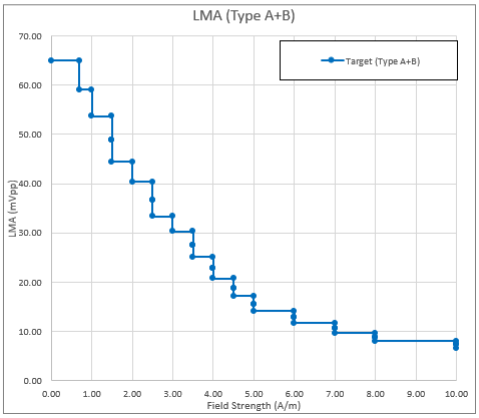

Figure 9. 'DLMA RSSI Settings' sheet - Type A&B

TYPE F

	Dialed Input			
DLMA Table ID Power/Phase Control Table	Field strength (A/m) (input)	Target (Type F) (pre-defined)	Abritrary Phase Comp. (±127° | step 1°) (input)	NCI LUT cmd
0	0	31		
1	2.5	28.2	0	BC 00 00
2	2.5	25.6	0	BC 00 00
3	2.5	23.3	0	BC 00 00
4	2.5	21.2	0	BC 00 00
5	3	19.2	0	E1 00 00
6	3	17.5	0	E1 00 00
7	4	15.9	0	2C 01 00
8	4	14.5	0	2C 01 00
9	4	13.1	0	2C 01 00
10	4	12.0	0	2C 01 00
11	4	10.9	0	2C 01 00
12	20	9.9	0	DC 05 00
13	20	9.0	0	DC 05 00
14	20	8.2	0	DC 05 00
15	20	7.4	0	DC 05 00
16	20	6.7	0	DC 05 00
17	20	6.1	0	DC 05 00
18	20	5.6	0	DC 05 00
19	20	5.1	0	DC 05 00
20	20	4.6	0	DC 05 00
21	20	4.2	0	DC 05 00
22	20	3.8	0	DC 05 00
23	20	3.5	0	DC 05 00
24	20	3.1	0	DC 05 00

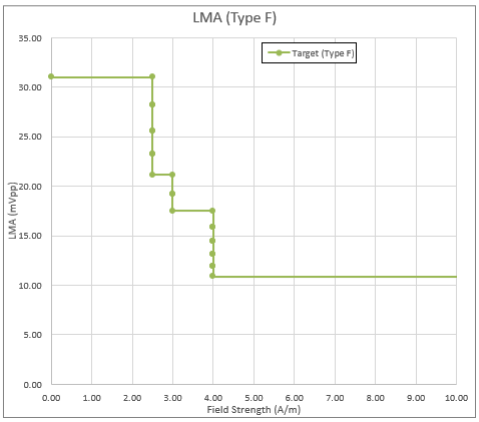

Figure 10. 'DLMA RSSI Settings' sheet - Type F

3.3 DLMA_TX parameter

This sheet is more informative one, as the TX lookup table is fixed and cannot be modified.

$$= (1 + BPSK) \times Drivers\ Numbers \times \left(TXLDO(V) + \frac{TX\ drop(mV)}{1000}\right) \times \frac{Res.Carrier}{100}$$

Seq.	ID	Equiv TX (Vpp)	Equiv TX One Driver (Vpp)	TxLDO (V)	TX_AMP (mV)	Num Drivers	BPSK Active	Modulation index config	Modulation Index	Res. Carrier	Phase (°)
0	0	20.40	5.10	5.25	-150	2	1	[00]: Res.Carrier=100, ModIndex=0	00	100	-1.2
1	1	19.60	4.90	5.25	-250	2	1	[01]: Res.Carrier=98, ModIndex=1.01	01	98	0.3
2	2	17.86	4.47	5.25	-500	2	1	[03]: Res.Carrier=94, ModIndex=3.09	03	94	1.4
3	3	16.32	4.08	4.5	-250	2	1	[02]: Res.Carrier=96, ModIndex=2.04	02	96	-0.2
4	4	14.79	3.70	4.5	-250	2	1	[06]: Res.Carrier=87, ModIndex=6.95	06	87	0.4
5	5	13.52	3.38	3.6	-150	2	1	[01]: Res.Carrier=98, ModIndex=1.01	01	98	-3.6
6	6	12.28	3.07	3.6	-150	2	1	[05]: Res.Carrier=89, ModIndex=5.82	05	89	-2.7
7	7	11.12	2.78	3.6	-250	2	1	[10]: Res.Carrier=83, ModIndex=9.29	10	83	-2.8
8	7	11.17	2.79	3	-150	2	1	[01]: Res.Carrier=98, ModIndex=1.01	01	98	1.5
9	8	10.17	2.54	3.6	-500	2	1	[11]: Res.Carrier=82, ModIndex=9.89	11	82	-3.2
10	8	10.15	2.54	3	-150	2	1	[05]: Res.Carrier=89, ModIndex=5.82	05	89	-4.0
11	9	9.30	2.33	3.6	-500	2	1	[18]: Res.Carrier=75, ModIndex=14.29	18	75	-3.7
12	9	9.10	2.28	3	-500	2	1	[04]: Res.Carrier=91, ModIndex=4.71	04	91	-6.2
13	10	8.42	2.11	3.6	-1000	2	1	[12]: Res.Carrier=81, ModIndex=10.5	12	81	-4.4
14	10	8.40	2.10	3	-500	2	1	[09]: Res.Carrier=84, ModIndex=8.7	09	84	-6.6
15	11	7.49	1.87	3.6	-1000	2	1	[20]: Res.Carrier=72, ModIndex=16.29	20	72	-5.5
16	11	7.50	1.88	3	-500	2	1	[18]: Res.Carrier=75, ModIndex=14.29	18	75	-7.1
17	12	6.90	3.45	3.6	-150	2	0	[00]: Res.Carrier=100, ModIndex=0	00	100	-4.0
18	12	6.96	1.74	3	-1000	2	1	[06]: Res.Carrier=87, ModIndex=6.95	06	87	-7.7
19	13	6.28	3.14	3.6	-150	2	0	[04]: Res.Carrier=91, ModIndex=4.71	04	91	-2.8
20	13	6.32	1.58	3	-1000	2	1	[14]: Res.Carrier=79, ModIndex=11.73	14	79	-9.2
21	14	5.70	2.85	3.6	-250	2	0	[08]: Res.Carrier=85, ModIndex=8.11	08	85	-2.8
22	14	5.70	2.85	3	-150	2	0	[00]: Res.Carrier=100, ModIndex=0	00	100	3.4
23	15	5.16	2.58	3.6	-250	2	0	[16]: Res.Carrier=77, ModIndex=12.99	16	77	-3.1
24	15	5.19	2.59	3	-150	2	0	[04]: Res.Carrier=91, ModIndex=4.71	04	91	-3.1
25	16	4.71	2.36	3.6	-500	2	0	[17]: Res.Carrier=76, ModIndex=12.99	17	76	-3.6
26	16	4.73	2.37	3	-150	2	0	[10]: Res.Carrier=83, ModIndex=9.29	10	83	-5.7
27	17	4.34	2.17	3.6	-500	2	0	[21]: Res.Carrier=70, ModIndex=17.65	21	70	-4.2
28	17	4.33	2.17	3	-150	2	0	[17]: Res.Carrier=76, ModIndex=12.99	17	76	-6.5
29	18	3.95	1.98	3	-500	2	0	[14]: Res.Carrier=79, ModIndex=11.73	14	79	-6.8
30	19	3.56	1.78	3	-1000	2	0	[05]: Res.Carrier=89, ModIndex=5.82	05	89	-7.4
31	20	3.24	1.62	3	-1000	2	0	[12]: Res.Carrier=81, ModIndex=10.5	12	81	-8.7
32	21	2.88	1.44	3	-1000	2	0	[20]: Res.Carrier=72, ModIndex=16.29	20	72	-11.5
33	22	2.60	1.30	3	-1000	2	0	[23]: Res.Carrier=65, ModIndex=21.29	23	65	-15.0
34	23	2.40	2.40	3	-500	1	0	[02]: Res.Carrier=96, ModIndex=2.04	02	96	-5.4
35	24	2.18	2.18	3	-500	1	0	[06]: Res.Carrier=87, ModIndex=6.95	06	87	-6.5
36	25	1.98	1.98	3	-500	1	0	[14]: Res.Carrier=79, ModIndex=11.73	14	79	-6.8
37	26	1.80	1.80	3	-500	1	0	[20]: Res.Carrier=72, ModIndex=16.29	20	72	-7.3
38	27	1.66	1.66	3	-1000	1	0	[10]: Res.Carrier=83, ModIndex=9.29	10	83	-8.3
39	28	1.54	1.54	3	-1000	1	0	[16]: Res.Carrier=77, ModIndex=12.99	16	77	-9.7

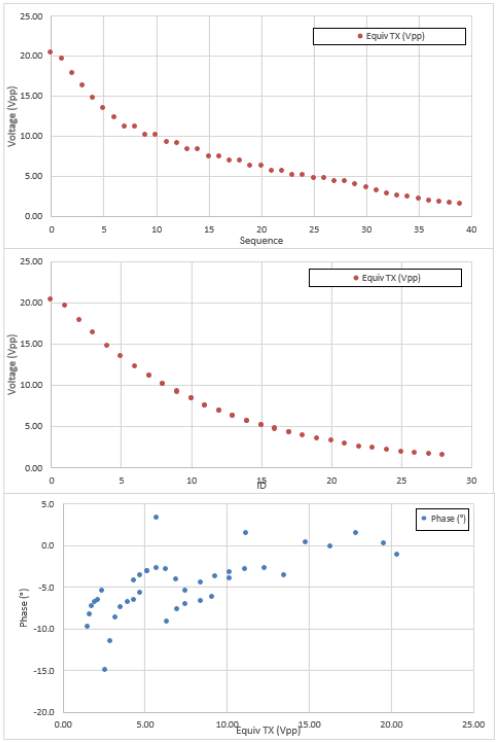

Figure 11. 'DLMA TX Setings' sheet

4 DLMA configuration procedure

Before starting any measurement/configuration please be sure that PN7160 setup is functional, that matching is done (see [2]) and sanity check have been done.

The DLMA configuration procedure requires then dedicated FW version been loaded into PN7160. This specific FW, as part of the PN7160 DLMA configuration package (see [3]), is indeed implementing customized notification required for the DLMA calibration Section 4.5.

The FW update procedure is further detailed in dedicated PN7160 documentation according to the target environment (Android, Linux or RTOS/NullOS).

Pay attention that this specific FW version MUST only be used for the DLMA configuration purpose since it does not include full PN7160 features validated.

4.1 Step0: RSSI Rext setting

PN7160 DLMA is based on field strength internal measurement in other words on RSSI feature. This function is trimmed in production with polynomial combination of ADC and AGC value. Another parameter is the value of RX path resistor (Rext):

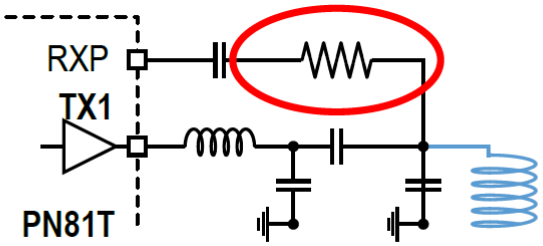

Figure 12. Rext resistor

Value of this external component is by definition unknown by NFCC system, so it must be set externally. This is done thanks to REXT_RSSI_CFG parameter split into 2 parts:

- Rext value referenced as wRextAGCCor (in Ohms)
- A coefficient used to compensate a bend in the transition from ADC region to AGC region referenced as wRextGainCor

See [1] for more details about REXT_RSSI_CFG parameter definition.

As guidance:

Table 1. REXT_RSSI_CFG parameter guidance

Rext	wRextGainCor		wRextAGCCor	
560Ω	1021	0x03FD	560	0x0230
1k0Ω	1027	0x0403	1000	0x03E8
1k3Ω	1050	0x041A	1300	0x0514
2k2Ω	1080	0x0438	2200	0x0898
3k3Ω	1090	0x0442	3300	0x0CE4
5k6Ω	1110	0x0456	5600	0x15E0

To verify if Rext register is correctly set, RSSI versus field strength must be measure and RSSI shape should be linear (no bend at ADC → AGC region) as presented below:

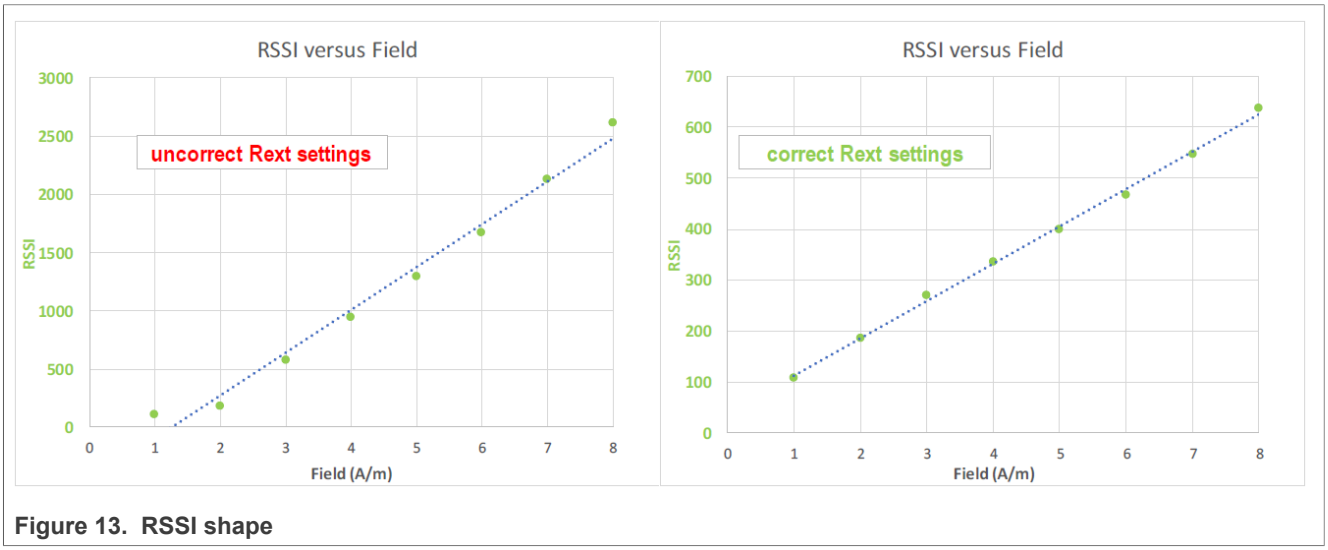

Figure 13. RSSI shape

4.2 Step1: DLMA RSSI threshold settings

Customer needs to define independently Type A&B and Type F target LMA versus field strength shape. To proceed, user will use 'DLMA_RSSI Settings' sheet. As a starting point two shapes are proposed. They can be adapted to user constraints.

To do this, customer needs to define independently Type A&B and Type F target LMA @ 0A/m and RSSI thresholds. As a reminder, only yellow highlighted cells can be changed.

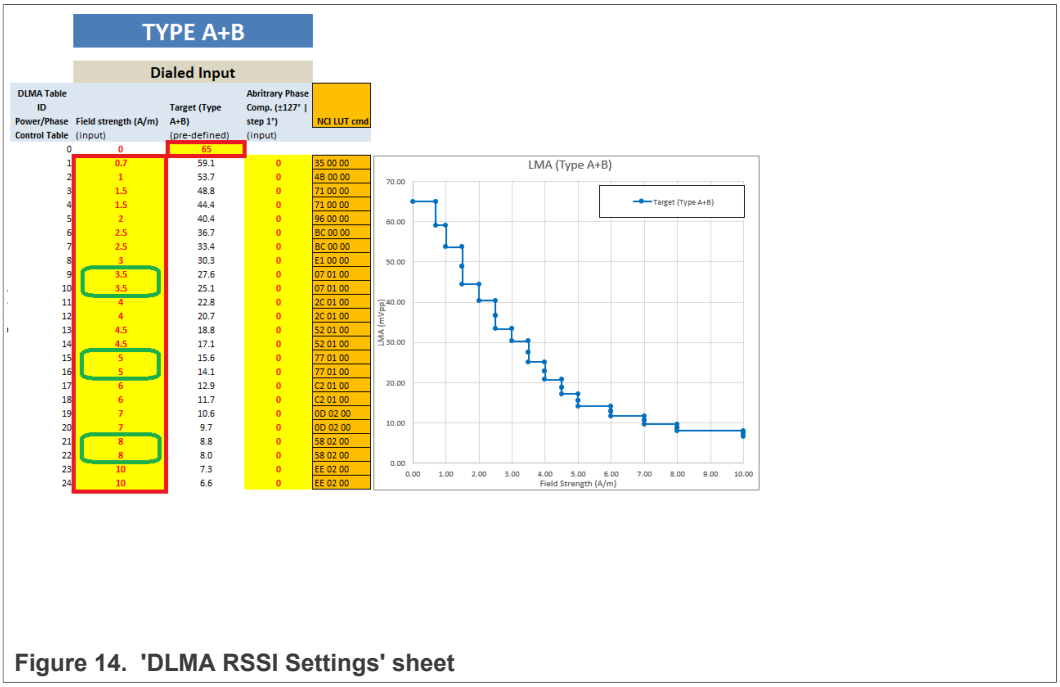

Figure 14. 'DLMA RSSI Settings' sheet

LMA function is a decreasing function (no possibility to increase). Ratio between two consecutive steps is 1.1. If a bigger ratio is needed, a step could be left, as shown in above case (surrounded in green).

4.3 Step2: DLMA option settings

Customer must define independently Type A&B and Type F target LMA PN7160 DLMA options:

- Enabling/disabling DLMA
- Allowing use of single driver possibility (enable: dual and single driver | disable: only dual)
- Allowing use of BPSK
- Defining TXLDO maximum allowed voltage depending on DC-DC use or not and Vup characteristics.

To proceed, user will use ‘DLMA_CTR Settings’ sheet.

4.4 Step3: DLMA default settings

Before performing DLMA calibration, default TX and RSSI DLMA_CTRL register value should be applied (meaning ***DLMA_LMA_TX_SHIFT*** = 0 and ***DLMA_RSSI_H_SCALE*** = 128). To make it easier a function has been implemented in the PN7160 DLMA configuration table. Answer “Yes” to the question: “RSSI TX Default settings?”. This will darken unnecessary cells and set default values, as presented below:

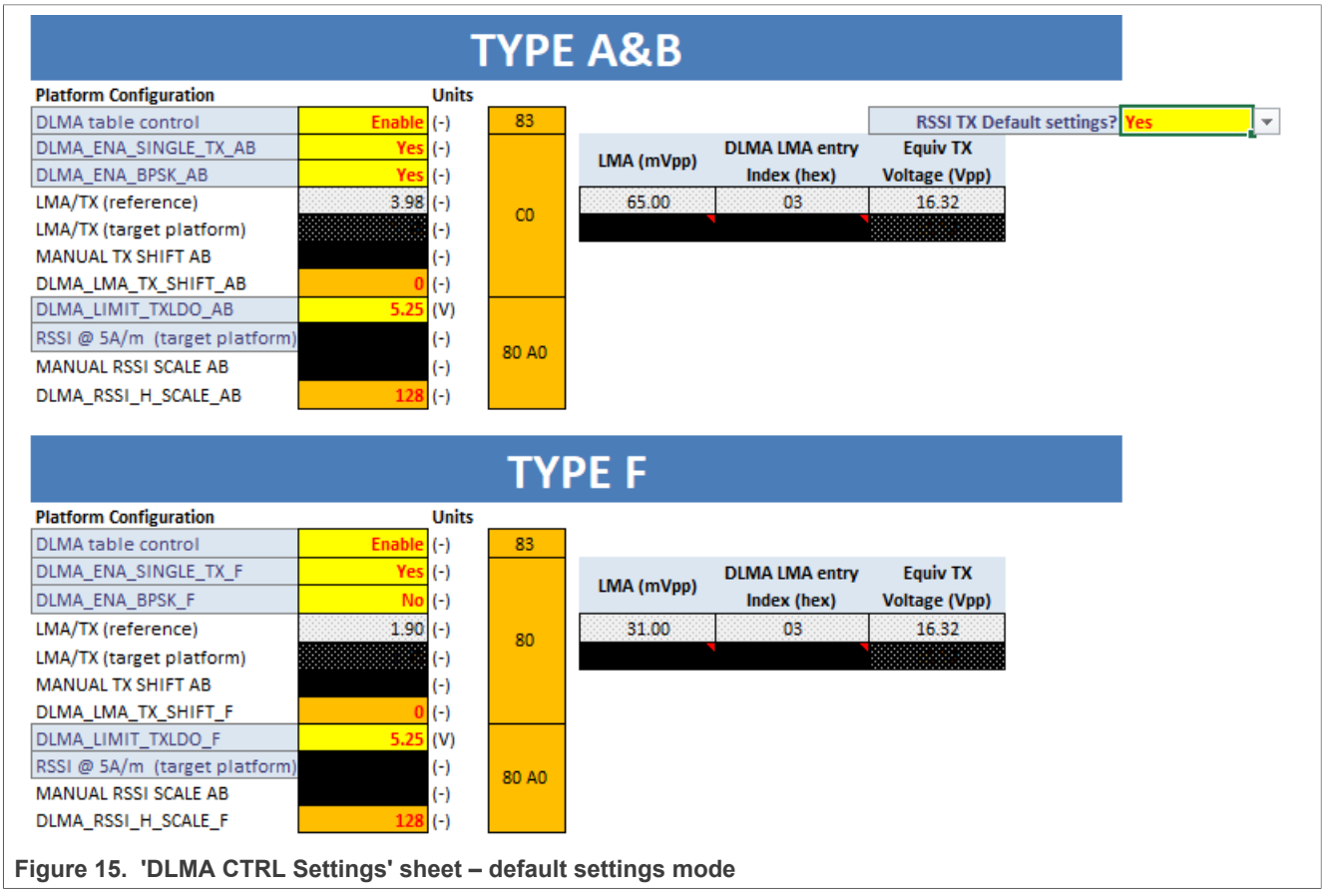

Figure 15. 'DLMA CTRL Settings' sheet – default settings mode

NCI command is then generated and must be applied to the PN7160 IC before starting calibration, please refer to ‘DLMA NCI CMD’ sheet:

DLMA_CTRL	20 02 10 01 A0 AF 0C 83 C0 80 A0 00 83 C0 80 A0 00 77 08
DLMA_RSSI	20 02 98 01 A0 34 94 23 04 18 35 00 00 4B 00 00 71 00 00 71 00 00 96 00 00 BC 00 00 BC 00 00 E1 00 00 07 01 00 07 01 00 2C
DLMA_TX	20 02 A4 01 A0 A9 A0 00 C1 00 0A 01 80 41 0A 02 81 83 0A 03 C0 42 06 04 80 46 06 05 C3 01 03 06 C2 05 03 07 C2 4A 03 07 8

Figure 16. 'DLMA NCI CMD' sheet – default settings command

4.5 Step4: DLMA calibration

This step consists in measuring PN7160 DLMA internal states and LMA for type A&B and type F when 1.5A/m and 5A/m field strength is applied. Following steps requires then an ISO bench to be performed. To measure calibration parameters, PN7160 DLMA “debug” mode need to be enabled. This "debug" mode, only available in PN7160 DLMA configuration-specific FW version, is controlled thanks to the following NCI commands:

```
// DLMA Debug mode enable: 20020601A01D028000
// DLMA Debug mode disable: 20020601A01D020000
// DLMA Debug read status: 20030301A01D
```

This option makes readable PN7160 internal states, meaning RSSI unscaled and index of the TX lookup table. To make customer measurement easier, a decoding function is available in the ‘DLMA CTR Settings’ sheet. Below is an example of adb log extract and decoding function:

```
09-10 15:50:12.545 NxpNciR : len = 15 < 6F360CA501A5010D10001510039103
```

		RSSI (hex)	RSSI (dec)	myID (hex)
@1.5A/m	6F360CA501A5010D10001510039103	01A5	421	10
@5A/m	6F360C770177010104001712468E01	0177	375	04

Figure 17. DLMA debug mode use

To perform measurements, PN7160 must be set in card mode.

Referring to chapter Section 2, the followings measurements are needed for type A&B and for type F:

- RSSI meas. @5 A/m
- LMA meas. @1.5 A/m
- ID meas. @1.5A/m

When it is done ‘DLMA CTRL Settings’ sheet entries should be filled. And most important thing is the answer to the question: “RSSI TX Default settings?” should be put back to “No”:

		Unscaled RSSI		Scaled RSSI		
		(hex)	(dec)	(hex)	(dec)	myID
@1.5A/m	6F360C9200920001030017124 68E01	0092	146	0092	146	03
@5A/m	6F360C7701770101040017124 68E01	0177	375	0177	375	04

		Unscaled RSSI		Scaled RSSI		
		(hex)	(dec)	(hex)	(dec)	myID
@1.5A/m	6F360C1F001F000003000303C04206	001F	31	001F	31	03

Figure 18. 'DLMA CTRL Settings' sheet – calibration mode

Calibration is now done, new parameters ***DLMA_LMA_TX_SHIFT***, ***DLMA_RSSI_H_SCALE*** must be applied to the PN7160 IC, please refer to 'DLMA NCI CMD' sheet:

DLMA_CTRL	20 02 10 01 A0 AF 0C 83 C0 7B A0 00 83 C0 80 A0 00 77 08

Figure 19. 'DLMA NCI CMD' sheet – calibrated command

4.6 Step5: DLMA final measurement

LMA versus field strength is performed again and experimentation should fit customer requirements:

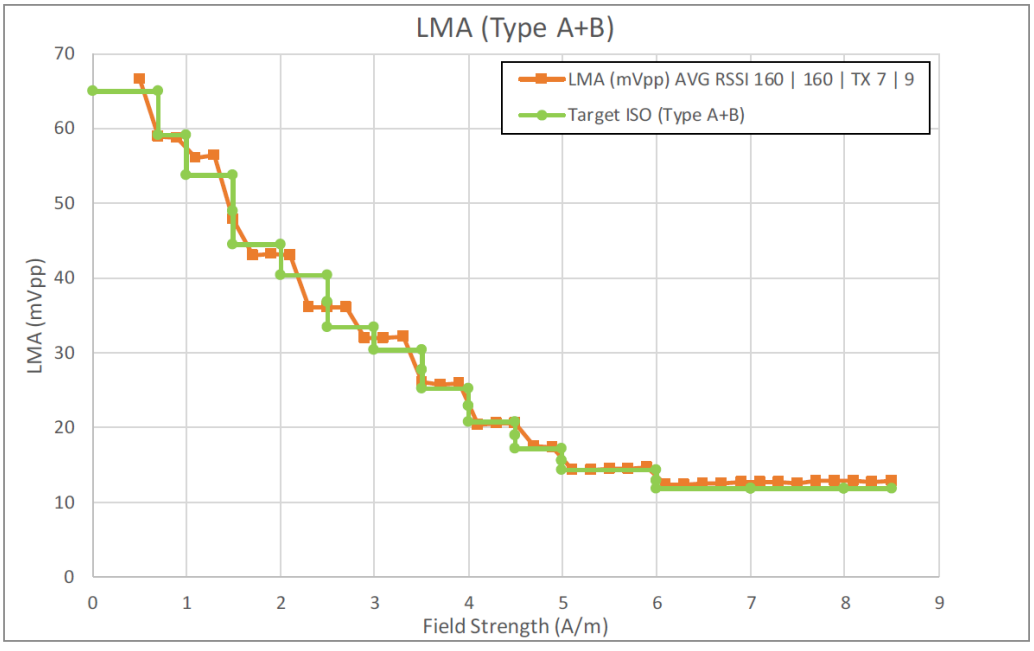

Figure 20. LMA and target versus field strength measurement for type A&B

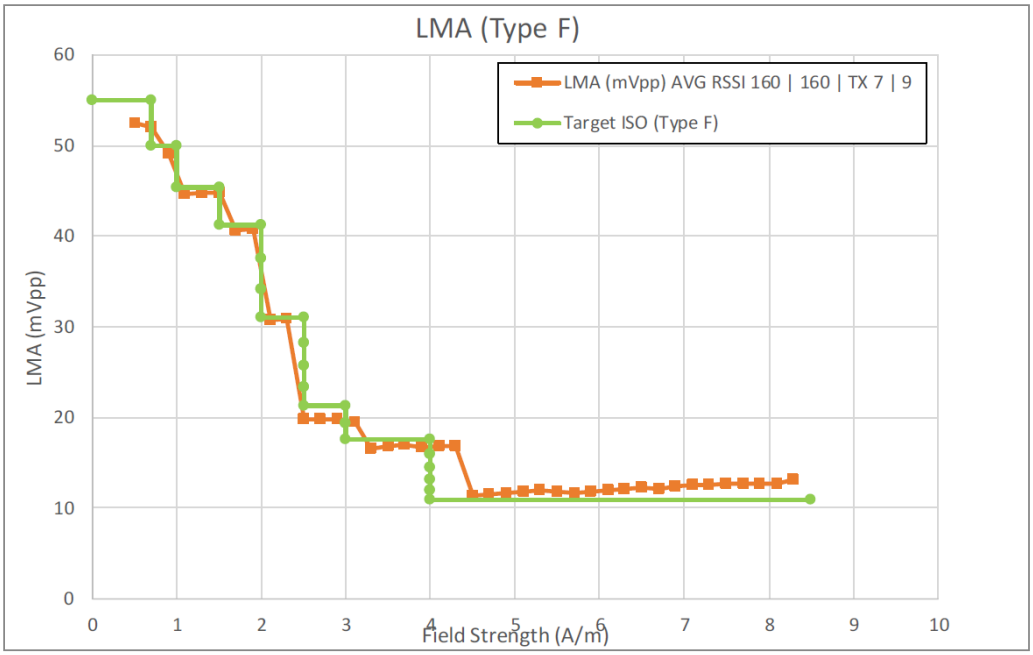

Figure 21. LMA and target versus field strength measurement for type F

RSSI versus field strength measurement are also performed to verify that RSSI fit theoretical curve (75/A.m^{-1}):

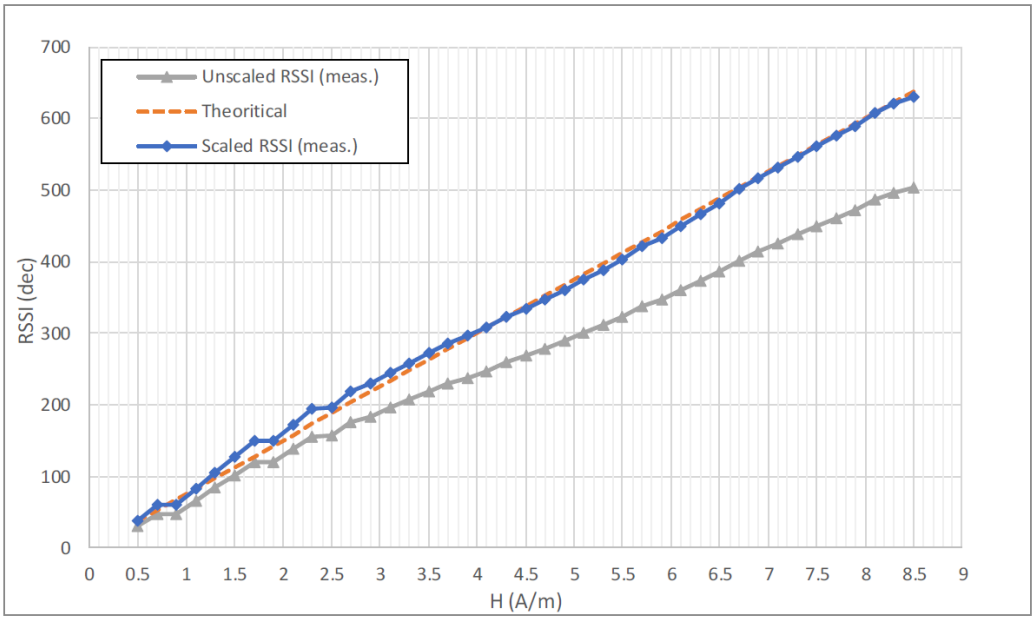

Figure 22. RSSI versus field strength measurement

5 Abbreviations

Table 2.

Abbr.	Meaning
A/m	Ampere per meter (magnetic field strength measurement unit)
AGC	Automated Gain Control
AN	Application Note
DLMA	Dynamic Load Modulation Amplitude
FW	FirmWare
Hmin / Hmax	Minimal and Maximum magnetic field strength
H-field	Magnetic field
IC	Integrated Circuit
ISO/IEC	International Standard Organization / International Electrotechnical Community
mA	milli Ampere
NFC	Near Field Communication
NFCC	NFC Controller (i.e. PN7160)
PCD	Proximity Coupling Device (Contactless reader)
PICC	Proximity Integrated Circuit Card (Contactless card)
RF	Radiofrequency
RSSI	Received Signal Strength Indication
V	Voltage
Vpp	Peak to peak voltage

6 References

[1] UM11495 - PN7160 user manual
[2] AN13219 - PN7160 Antenna design and matching guide
[3] SW6780 - PN7160 DLMA configuration package

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