HX68XX POWER TOOTHBRUSH NFC DETAILS

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1. Overview

- This Document describes the RF exposure Calculation for the Rechargeable Philips Power Toothbrush (Hx68xx_ Models) with NFC (13.56MHz)

2. Terminology & Abbreviations

Terminology & Abbreviations	Description/Definition
RF	Radio Frequency
NFC	Near Field Communication
IC	Integrated Circuit
RC	Resistor–Capacitor circuit
LC	Resonant circuit, Inductor and Capacitor circuit
EC	European Commission
Hz	Hertz
mA	Milli Ampere
mW	Milliwatt
N/A	Not Available
mm	Millimeter
msec	Milli seconds
MHz	Megahertz
v	Volts
ASK	Amplitude-shift keying
HF	High Frequency
PTB	Power toothbrush

3. References

Reference	Title / additional remarks
REF-1	st25r3912 data Sheet
FCC Part 1.1310	Radiofrequency radiation exposure limits
KDB 447498 D01	Radiofrequency radiation exemption limits

4. General Product Information

- The Philips PTB uses HF reader/ NFC transceiver (ST25R3912) IC for the NFC communication in the product.
- It's a portable stand-alone device and is battery operated.
- Nominal operating voltage ranges from 4.1v to 3.15v

5. Antenna Details:

Details	Description/Definition
Make	Philips Proprietary
Antenna Transmission Range	12mm Max
Antenna type(s)	loop/Coil Antenna
Antenna Topology	Single Ended
Antenna Connection Type	Integral

6. Modulation Scheme

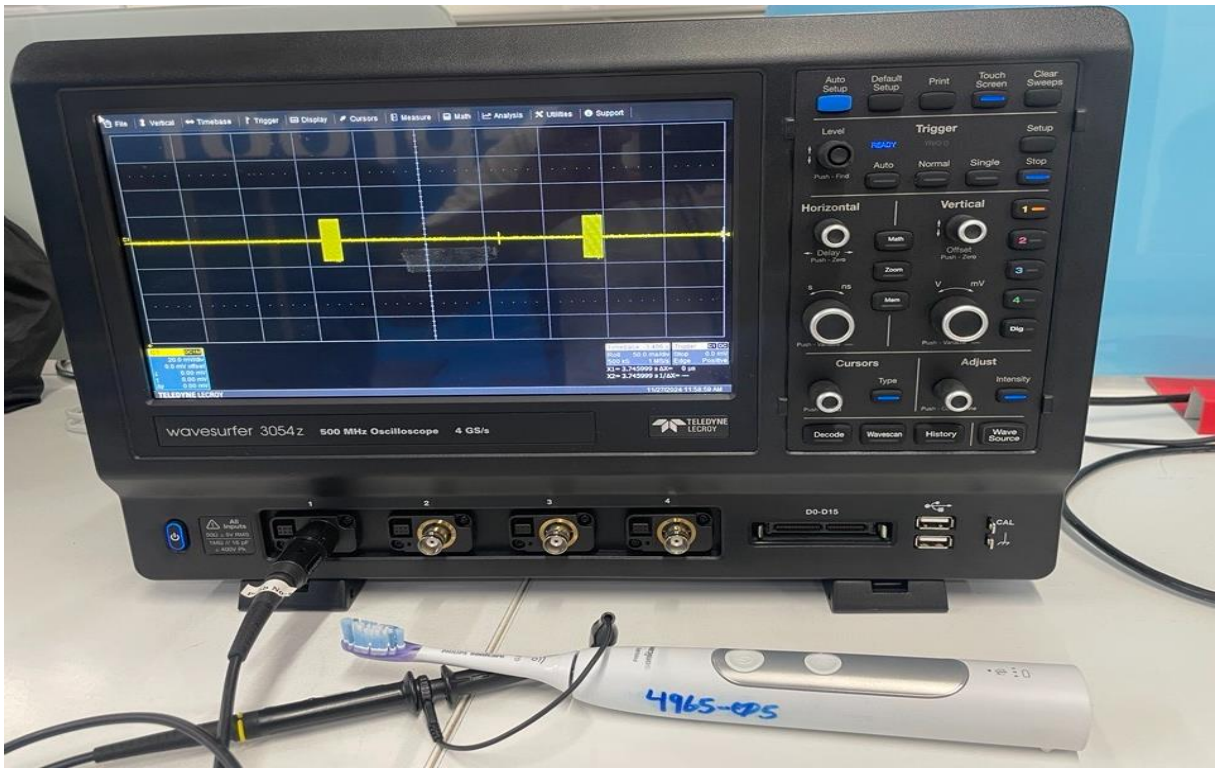
- ASK modulation is employed in the transmit carrier.

7. Nominals Transmit Frequency Details

- NFC Operating Frequency: 13.56 MHz
- Tool used for Testing: Wave Surfer 3054z 500 MHz Oscilloscope (Calibration Till 26th Feb 2025 Instrument ID STET/Baner/Osc2/043)

8. Device Under Test

- The below image shows the device under test and the equipment used



9. NFC Operation Details

9.1 General Information

- NFC is operational only in Standby mode of the power toothbrush.
- The Standby Mode is active only for **30sec** of time interval once the handles are woken up from sleep, basically this is the time when the user selects the options on the handle before starting the brushing session.
- Please refer to the below snippet for the same.

```
/// How long does standby last before a brushing?
#define TIMEOUT_PRE_BRUSHING_MS      (30*1000)
```

- The NFC is triggered periodically in the Application to check if any operation needs to be performed while the Power toothbrush is in standby state.
- Below Snippet shows the call rate of Nfc in the application (**Nfc trigger Time**).

```
#define NFC_POLL_INTERVAL    200
```

- The transmission (Tx) and reception (Rx) bit rates configured are both set to 106 Kbps (Kilobits per second).

```
// Set data rates and operating modes.
NfcStSetRegisterBits(REG_MODE_DEFINITION, MODE_REG_ISO_14443A);
NfcStSetRegisterBits(REG_BIT_RATE, BIT_RATE_106_KBS);
```

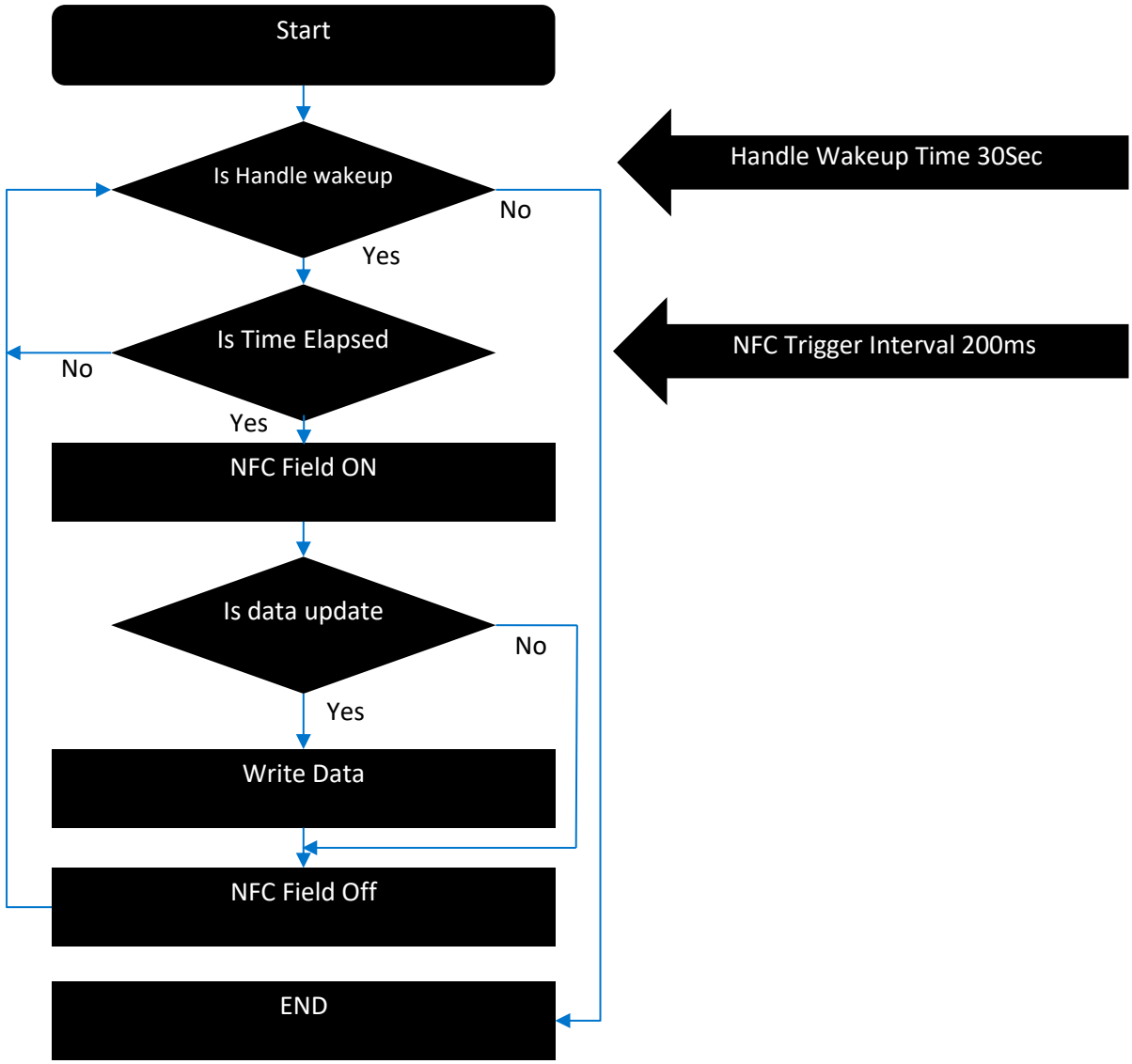
- The NFC module takes approximately **15.8 msec** to complete to check if it needs to carry out any write / read operation. This time doesn't not include any write / read operation time i.e. we consider this as the **NFC idle transmission Time** as shown in the below image.


File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Support
Measure
P1:duty(C1)
P2:period(C1)
value
50.451 %
16.81 µs
mean
50.338 %
221 µs
min
22.906 %
13.11 µs
max
99.995 %
204.20594 ms
sdev
3.573 %
6.454 ms
num
1.000e+3
1.000e+3
status
X
X
C1 DC1M
100 mV/div
-198 mV ofst
1.3 mV
1.3 mV
0.0 mV
Roll 50.0 ms/div
500 kS 1 MS/s
Stop
Edge
Positive
X1= 354.964 ms ΔX= 15.776 ms
X2= 370.740 ms 1/ΔX= 63.39 Hz
11/25/2024 3:12:19 PM
TELEDYNE LECROY
wavesurfer 3054z
500 MHz Oscilloscope
4 GS/s
TELEDYNE LECROY

Figure 1

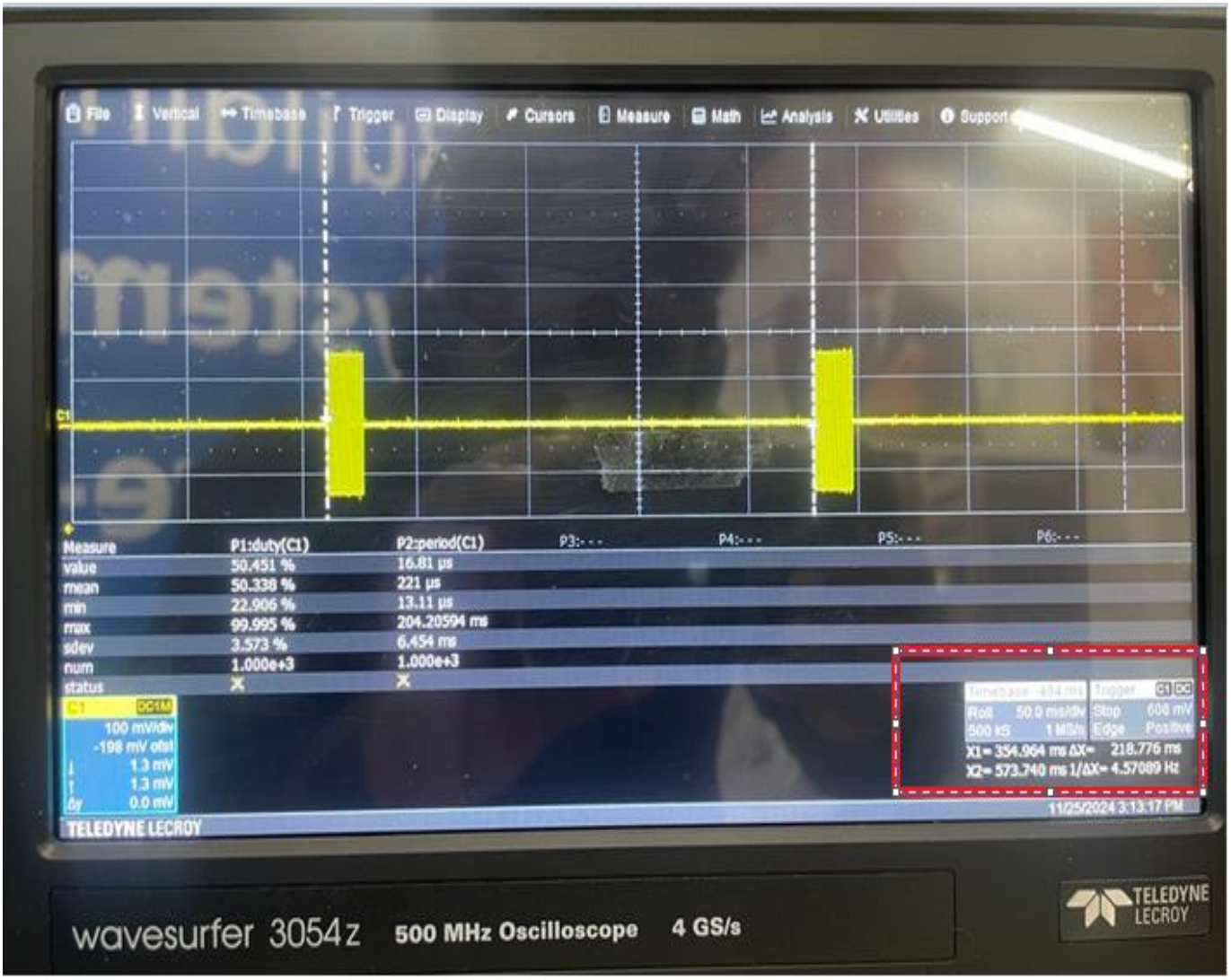
9.2 NFC Operation Flow Chart

The Below flow diagram shows the general operation of the NFC



9.3 NFC Module Captured waveform

The below image shows the NFC trigger time Interval waveform



NOTE:

- The total time interval captured in the above image also include other process that get executed in the standby state in the handle and the NFC module process time.
- Total NFC Interval Time = Other Processes Time + NFC idle transmission Time + NFC Trigger time

  218 msec = 2.2 msec + 15.8 msec + 200 msec

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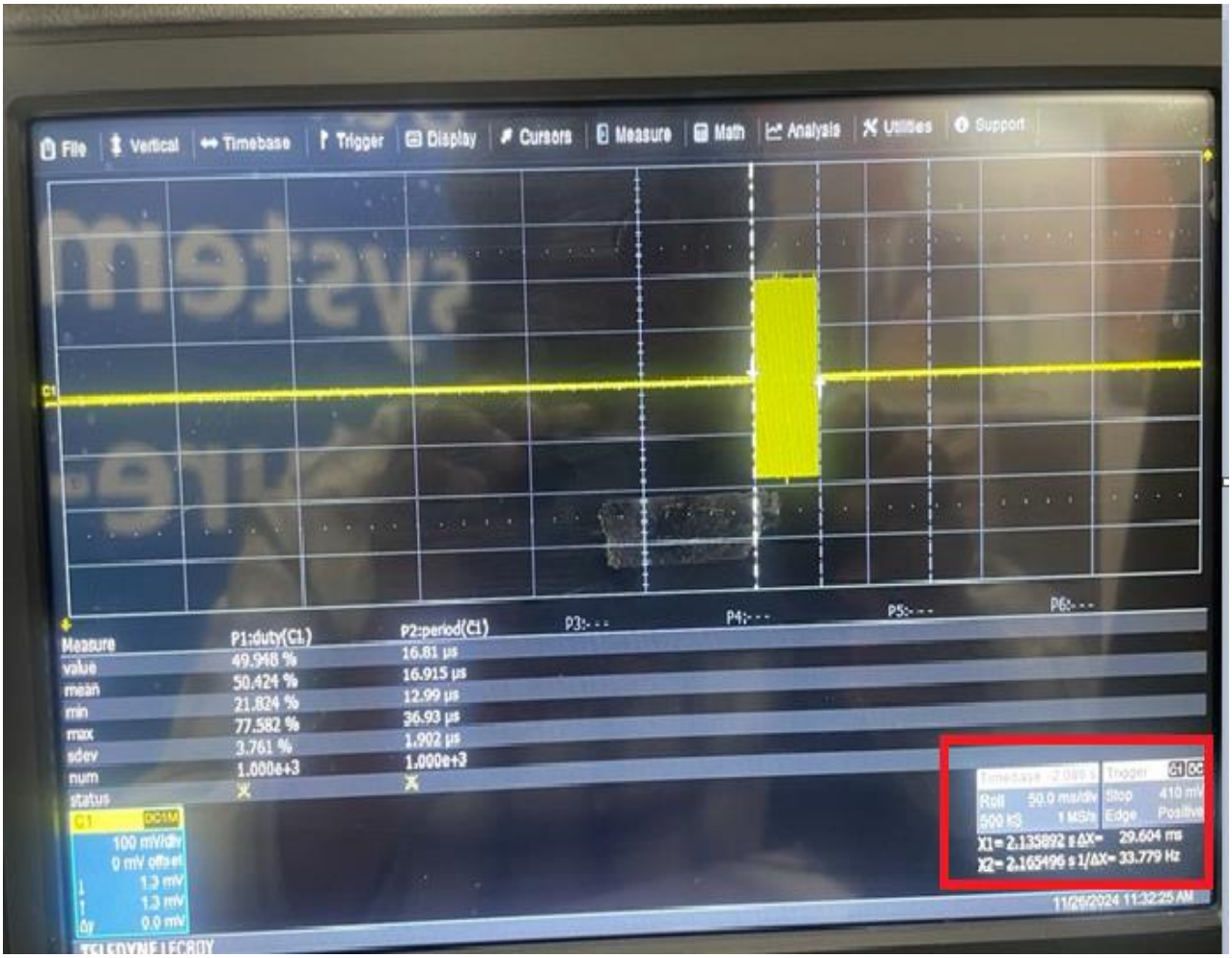
Total NFC Interval Time = 218 msec

Please refer to Section 9.1 for details of Nfc Idle time and Nfc trigger time

The below image shows the maximum transmission time for data being read and written to the brush head tag, which is **29.604 msec** (one-time for each brushing session).



We Consider **29.6 msec as the Data Write time**

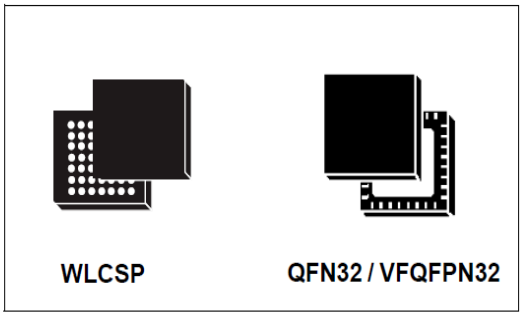
10. RF Exposure duty cycle calculation

As per the ST data sheet we have 1W max at Differential output.

Attached snippet from the ST data sheet

High performance HF reader / NFC initiator for payment applications with 1 W output power

Datasheet - production data



Features

- ISO 18092 (NFCIP-1) Active P2P
- ISO14443A, ISO14443B, ISO15693 and FeliCa™
- Supports HBR up to 848 kbit/s PICC to PCD and PCD to PICC framing
- Inductive sensing - Wake-up
- Automatic modulation index adjustment
- AM and PM (I/Q) demodulator channels with automatic selection
- Up to 1 W in case of differential output

Description

The ST25R3912 is a highly integrated NFC initiator / HF reader IC, including the analog front end (AFE) and a highly integrated data framing system for ISO 18092 (NFCIP-1) initiator, ISO 18092 (NFCIP-1) active target, ISO 14443A and B reader (including high bit rates), ISO 15693 reader and FeliCa™ reader. Implementation of other standard and custom protocols like MIFARE™ Classic is possible using the AFE and implementing framing in the external microcontroller (Stream and Transparent modes).

The ST25R3912 is positioned perfectly for the infrastructure side of the NFC system, where users need optimal RF performance and flexibility combined with low power.

The device is optimized for applications with directly driven antennas. The ST25R3912 is alone in the domain of HF reader ICs as it contains two differential low impedance (1 Ohm) antenna drivers.

The ST25R3912 includes several features that make it very suited for low power applications.

Philips Design **doesn't use the Differential output topology** in the design so the output power would be less than the mentioned value i.e. 1w which also mentioned in the data sheet, as per the data sheet Section 1.2.2 Transmitter page 15 attached snippet below

Using the single driver mode the number of the antenna LC tank components (and therefore the cost) is halved, but also the output power is reduced. In single mode it is possible to connect two antenna LC tanks to the two RFO outputs and multiplex between them by controlling the *IO configuration register 1* bit rfo2.

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As per the SAR power exclusion limit we need to have power less than **308mW** for a period of exposure for 30 mins as per regulation **FCC Part 1.1310** for the (KDB 447498 D01) attached snippet below (depends on the operating frequency and the Distance measured)

Appendix C

SAR Test Exclusion Thresholds for < 100 MHz and < 200 mm

Approximate SAR test exclusion power thresholds at selected frequencies and test separation distances are illustrated in the following table. The equation and threshold in 4.3.1 must be applied to determine SAR test exclusion.

MHz	< 50	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	mm
100	237	474	481	487	494	501	507	514	521	527	534	541	547	554	561	567	
50	308	617	625	634	643	651	660	669	677	686	695	703	712	721	729	738	
10	474	948	961	975	988	1001	1015	1028	1041	1055	1068	1081	1095	1108	1121	1135	
1	711	1422	1442	1462	1482	1502	1522	1542	1562	1582	1602	1622	1642	1662	1682	1702	mW
0.1	948	1896	1923	1949	1976	2003	2029	2056	2083	2109	2136	2163	2189	2216	2243	2269	
0.05	1019	2039	2067	2096	2125	2153	2182	2211	2239	2268	2297	2325	2354	2383	2411	2440	
0.01	1185	2370	2403	2437	2470	2503	2537	2570	2603	2637	2670	2703	2737	2770	2803	2837	

Considering the above reference and PTB specification (13.5MHz, 12mm distance) to have the exempt we have the below calculation

Using the maximum advertised power of 1watt, the PTB should be allowed to have the field ON only for 30.8% in a 30-minute period, which is **9.24** min.

10.1 NFC RF transmission Timing Calculation

Practical Use of the PTB at End User

- The user may not brush more than twice in the 30 min time interval.
- When the user picks up the PTB handle it will enter standby mode until either the power button is pressed or 30 second's elapses.
- When the user presses the power button, the motor runs for Max 2 minutes 30 Sec (150 seconds) while the NFC remains off.
- After brushing, the motor stops.
- The handle re-enters standby mode.

10.2 Max Timing Calculation for Each Brushing Session

Standby Transmission Time.

Standby Time	30000 msec (30 sec)
Total NFC Interval Time	218 msec
NFC idle transmission Time	15.8 msec
Data Write time	29.6 msec

No. of NFC Triggers in 30 Sec = Stand by time / Total NFC Interval Time

= (30000) msec / 218 msec

= 137.61 ~= 138 (The Nfc would be Triggered for this count)

Total Field ON time = No. of NFC Triggers* Nfc Ideal Field Transmission + Data write time

= (138 * 15.8) + 29.604 (one-time only for write data)

= 2210msec (~= 2.2 Sec)

Stand by time in Second	NFC Poll Time in msecs	Number of polls in 30 Sec	Ideal Field Transmission time in msec	Total Field ON time in second
30 Sec	218 msec	138	15.8 msec	2.2 Sec

Total Ideal Max Field On time for each brushing session =

Total Field ON time * Standby Instances per Session = (2.2sec) * 2 **= 4.4 Sec**

10.3 Worst case Scenario calculation for 30 Min RF exposure

Case 1:

The user brushes only once in the 30 mins so the nfc on time would be **4.4** sec.

Case 2:

We considered a worst-case scenario where the user brushes continuously for 30 minutes with a 30-second gap between attempts.

Assuming each brushing cycle lasts 2 minutes with a 30-second standby period, the user could brush up to 12 times within 30 minutes.

No. of Session in 30 minutes = total time / (Session time+ Standby time)

= 30 /2.5 = 12

Total standby time: 12 × 0.5(30sec) = **6 minutes = 360000 msec**

RF exposure Time is following

No. of Nfc Trigger in 6 minutes = Total Stand by time / Total NFC Interval Time

= **360000** / 218

= 1651.37 ~= 1651

Total Field ON time = NFC idle transmission Time *Number Nfc Trigger in 6 minutes

= 15.8 * 1651

=26085msec (~= 26 Sec)

Stand by time in minutes	NFC Poll Time in msecs	Number of polls in 30 Sec	Ideal Field Transmission time in msec	Total Field ON time in second
6 min	218 msec	1651	15.8 msec	26 sec

In this case RF exposure will be available for **26 Second Max**.

Case 3:

We consider the handle remains in standby mode continuously for 30 minutes without the motor running. This situation could occur if the user intentionally switches brushing modes repeatedly using the mode button.

NFC Transmission time for 30 minutes is following:

Total Standby time = 30 minutes = 1,800,000 msec

No. of Nfc Trigger in 30 minutes = Total Stand by time / Total NFC Interval Time

= 1,800,000 / 218

= 8256.57 ~= 8257

Total Field ON time = No. of Nfc Trigger in 30 min* Ideal Field Transmission Time

= 8257 * 15.8

=130460msec **(~= 130 Sec)**

Stand by time in Minutes	NFC Poll Time in msec	Number of polls in 30 minutes	Field Transmission time in msec	Total Field ON time in second
30 min	218 msec	8257 times	15.8 msec	130 Sec

As per calculations **130 Seconds** RF exposure will be happen out of 30 minutes

11. Conclusion

The worst-case scenario shows that we have only 130sec (2.2min approx.) which is less than 9.24 min as per the exemption limits that too if the handle remains in the Standby state for continuously 30 minutes which can never be an actual situation at the user end.

The practical scenario would be 4.4 seconds in 30 min of Power toothbrush operation at user end.

The worst-case RF exposure value occurs in Case 3, with an exposure duration of 130 seconds (or 2.2 minutes). The duty cycle is calculated as:

Duty Cycle = RF Exposure ON Time/ Total Time*100

= 2.2 min / 30 min * 100

= 7.3%

Using the ST25R3912 datasheet value of maximum output power 1 W, the RF exposure value is:

RF exposure Value = Duty cycle * Max Output Power

= 0.073 x 1 W

= 7.3 mW

- **This value is significantly lower than the threshold of 308 mW.**