



*Pixel Networks Limited*

## **Assessment Results for Temporary Permit T00527**

**24 May, 2017  
v1.3**

## Contents

Preface .....	iii
Introduction .....	1
Assessment Summary .....	1
Test Methodology & Setup .....	2
Trial Equipment and Trial System Setup.....	3
Network Server .....	3
Application Server.....	3
LoRa End-Node .....	3
Gateway .....	4
RFID Tag Reading System.....	5
Tests.....	6
Class 1 Tests: Normal-Case Interference Tests.....	6
Class-1 Test Cases .....	7
Summary Observation 1 .....	11
Class 2 Tests: Intentionally-Induced Harmful Interference Tests.....	12
Class-2 Test Cases .....	13
Summary Observation 2 .....	14
Conclusions .....	15

## **Preface**

Pixel Networks is introducing the LoRa technology to Hong Kong and has been granted a temporary license from OFCA to conduct an assessment in Hong Kong to confirm that no harmful interference will exist with LoRa and RFID operating in the 920 – 925 MHz shared band. This assessment has now been completed and this document reports the findings of such assessment.

# 1 Introduction

Pixel Networks ("PN") was granted a temporary permit, T00527, to assess the potential for interference between LoRa and RFID systems operating in the 920 – 925 MHz band. This document reports the findings of 8 weeks of testing, 13<sup>th</sup> of March 2017 to 5<sup>th</sup> of May 2017. The testing locations were confined to indoors, inside of the Pixel Networks office located at "303 Hennessy Road, Wan Chai", and outdoors, externally at the rooftop of the LoRa gateway site located at "Times Media Centre, 133 Wan Chai Road, Wan Chai".

## 1.1 Assessment Summary

In this worst-case proximity scenario, the PN LoRa lighting system was not able to cause any detectable harmful interference to the RFID system even when operating in close proximity (about 1 meter) to the LoRa system. The LoRa system had been configured to transmit status updates every minute which is not normal configuration and 60 times more often than what is typically once per hour.

Furthermore, PN then conducted maximum interference tests (much worse than worst-case interference scenarios) with a LoRa signal within 1 meter of the RFID reader, 50% duty cycle (1 second on, 1 second off) stepping through 24 channels (920.2 - 924.8MHz) in an attempt to cause harmful interference to an RFID reader continuously reading a tag at the limits of RFID range (about 1 meter in this case). Again, PN was not able to detect any reduction in read rate during the period of the tests.

Conversely, tests of interference from RFID to LoRa show that LoRa can coexist with RFID satisfactorily. The LoRa gateway received messages from the end device with a success rate similar to that with without RFID present. In both cases, RFID interference was present and came from the trams (which run nearby the PN office) that have some sort of RFID reader onboard, this interference was outside our control.

The results of these tests suggest no harmful interference between LoRa to RFID systems. Given that the LoRa systems in the test comply with the technical requirements of HKTA1049 and given many global commercial deployments of LoRa in shared unlicensed bands in those jurisdictions, this is not unexpected. Furthermore, PN was not able to demonstrate harmful interference from LoRa To RFID under the worst-case test scenarios. We express a high degree of confidence that the LoRa systems and RFID system can coexist with no detectable harmful interference to each other.

## 2 Test Methodology & Setup

The type of interference to be assessed, in this case, is mutual interference where RFID and LoRa systems share the same band. Both systems have inherent mechanisms for dealing with this type of interference. Tests were performed to assess these mechanisms in the 920 – 925 MHz band. The tests were conducted at close range to highlight any interference effects.

Tests were partitioned into two classes: normal-case-operation interference at close range and intentionally-induced attempted harmful interference at close range.

One LoRa gateway was setup on a rooftop about 0.7km away from the test location which was inbuilding. At the test location, one RFID system, one LoRa node, and another indoor test LoRa gateway were present where these components were placed in close proximity, about 1 meter, of each other. These can be seen in Figure 1 and Figure 2.

Figure 1: Test Setup

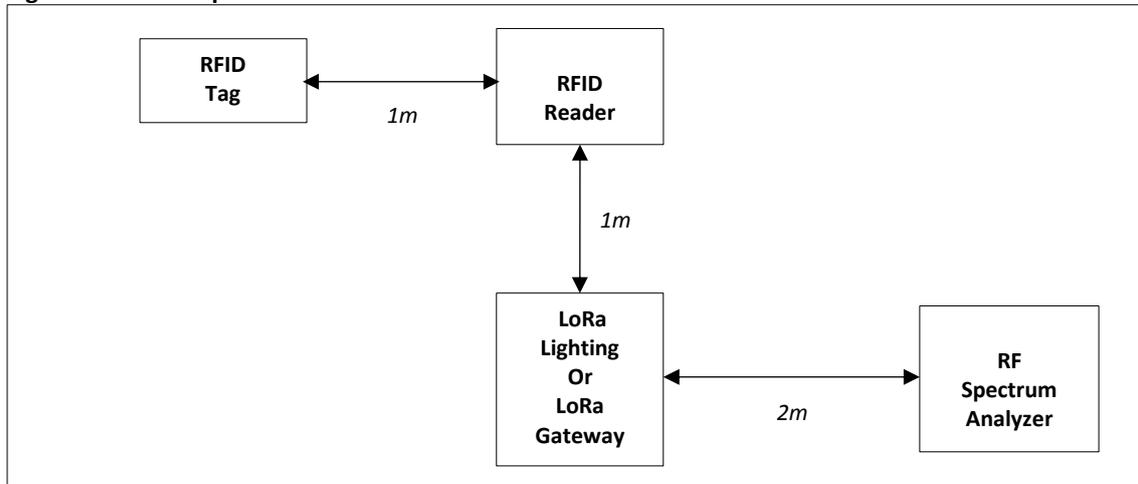


Figure 2: Test Setup – Actual View



The LoRa node is lighting controller. The LoRa-based controller is configurable to send data (e.g., current, voltage, lamp status) at predefined time intervals to the gateway. For the trial, the controller is predefined to send one transmission per minute to the gateway. The lighting controller was used for the normal-case interference tests, but still 60 times more often than what would be typical, while the LoRa test gateway was used for harmful interference tests.

Tests were repeated daily for the trial period. Concurrent transmission for LoRa and the test RFID system are performed in predefined ways.

At the end of each test session, transmission logs and RF spectrum captures were manually analyzed for our observations.

The following general test method was used:

1. Perform only RFID transactions (no LoRa transmissions active for this time) for the test period and record and check the success rate results.
2. Perform only LoRa transactions (no RFID transmissions active for this time) for one the test period and record and check the success rate results.
3. Perform concurrent LoRa and RFID transactions and record and check the success rate results for both against the rates in (1) and (2). Inspect the spectrum captures to make interference-related observations of the tests.

## **2.1 Trial Equipment and Trial System Setup**

For this trial, PN's Network Server ("NS"), an Application Server ("AS") specific to the Smart Lighting system, a single end-node (a lighting controller with integrated sensor), an RFID system, and two LoRa gateways (one live outdoor unit and one indoor test-only unit) were used.

### **2.1.1 Network Server**

The NS is a HK-based cloud server. The NS performs the full network stack of the LoRa protocol in addition to gateway population management, application population management, end-node population management, billing records processing, security management, and data distribution. This server is the intermediary server to capture the LoRa node data.

### **2.1.2 Application Server**

The AS for the Smart Lighting system will host the software that enables full management and visualization of the LoRa node and data.

### **2.1.3 LoRa End-Node**

The end-node that will be used for this test is a LED-based light connected to a lighting controller integrated with a LoRa sensor as show in Figure 3.

**Figure 3: LED-Lamp with Controller/LoRa Sensor**



Key features of this controller system are the following:

- Enables individual remote management of streetlight lamps with electronic ballast of up to 500W.
- Specially designed and optimized for LoRa (+14dBm, 25mW).
- Autonomous operation based on predefined schedules and light level sensor.
- Bandwidth efficient with minimal communication requirements.
- Uses the latest data encryption technology to ensure that information transfer and system operation cannot be affected by outside intervention.
- High availability.

#### **2.1.4 Gateway**

The basic features and specifications of the gateway are the following:

- License-exempt band LoRa bidirectional communications capabilities;
- One LoRa RF module with 8 Tx/Rx channels to fit in the 920 – 925 MHz band (under external control it can access all 24 channels – test “CL-2-T1” executed in this experiment);
- Transmit power output set to 1W EIRP;
- Configured for single omnidirectional antenna;
- LoRa geo-localization combining RSSI and Time Difference of Arrival (TDOA);
- Backhaul connectivity over GPRS/EDGE/HSPA/LTE (Europe/APAC or Americas bands) or Ethernet over IP/TDM;
- Highly secured device relying on a hardware-secured core;
- Carrier grade or compact casing;
- Dimensions: 357 x 189 x 150 mm (including mounting kit);
- Weight: about 3Kg (including mounting kit); and
- 60W PoE or DC power supply (ex: solar panel use): 11 to 56V DC.

### 2.1.5 RFID Tag Reading System

The purpose of collocating this RFID system with the LoRa sensor is to show that the system can coexist in the same band, i.e., 920 – 925 MHz. This system is shown in Figure 5. It is the UHF-RW-MP-232-V1-7dBi integrated antenna and RFID transmitter and receiver. This system is compliant with JKTA-1049.

**Figure 5: RFID Tag Reading System**



Key features of this system is the following:

- Operation mode: read/write UHF Tag ID & memory
- Supports multi-tag reading
- Antenna: build-in circular polarization antenna
- Standard Frequency: 902-925Mhz
- Optional interface: RS232 / wiegand
- Transmission Power: < 30dbm (software programmable)
- support: ISO18000-6C EPC G2 or ISO18000-6B UHF tag
- power supply: +9V DC ,3A
- free software pack  
(VC, C#,VB.Net & Delphi demo program with source code)
- 7 dbi antenna built-in version
- reading range: ~3-5 meters
- (Effective distance depends on tag characteristics and installation environment)
- Peak power Transmitter: < 1 watt
- Dimensions: (220x220x30)mm
- Weight: 2kg

### 3 Tests

The set of tests categorized into two classes: Class 1 and Class 2. Under each class, a series of configurations are established followed by some actions where a set of RF spectrum data is captured and transmission logs are stored for observations.

The spectrum recordings were centered on 922.5MHz with an 8MHz sample rate = 16MBps for both I+Q.

#### 3.1 Class-1 Tests: Normal-Case Interference Tests

The objective is to test co-channel interference under normal-case, more real-life like situations. The setup for Class-1 tests was as follows.

##### **Class-1 Test LoRa Setup:**

- The LoRa lighting node is set to transmit status report every 60s. This is not normal setting but can be selected for demonstration purposes. The status transmission is sent independent of the on/off status of the light.
- The LoRa lighting transmitter is set to use 8 LoRa channels centered on 922.6-924.0MHz, 200kHz raster.
- When in use, the lighting node will send a LoRa packet on a random channel (out of 8 programmed) every 60s.
- Spectrum Analyzer SDR and Recording Software - uncalibrated - for indication only.

##### **Class-1 Test RFID Setup:**

Figure 6 shows RFID reader and Tag setup. The RFID reader was configured using default parameters in the 920-925MHz band with RS232 output. RFID Reader settings (mostly default except for frequency range and RS232 output).

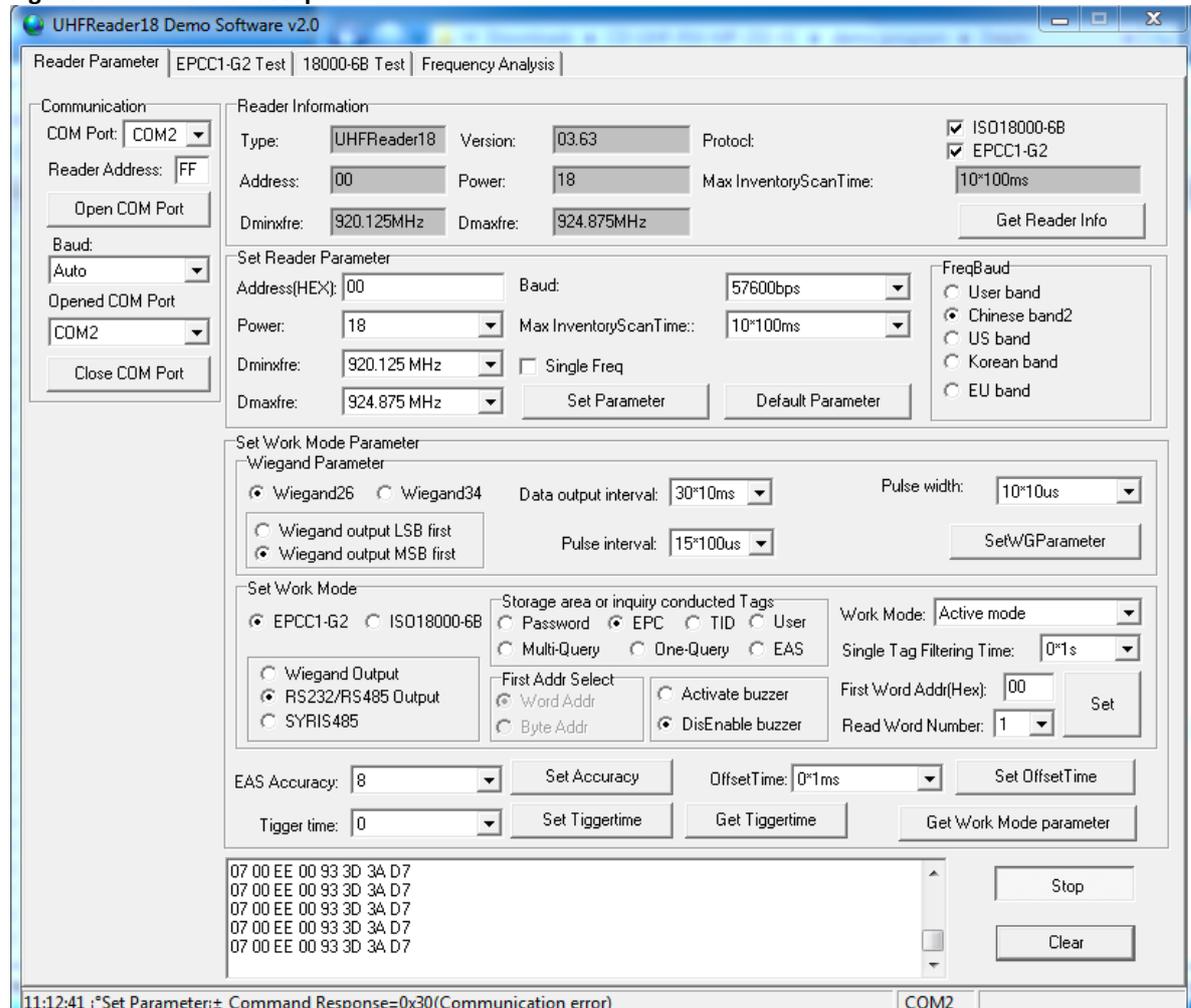
These settings cause the reader to read at continuously at a rate of about 27 reads/second, about 16,200 reads per a 10-minute test period. A longer period was not used due to the buffer limitation in the RFID reading program. The 10-minute tests were repeated multiple times.

These default settings caused the reader to stop on a frequency and read continuously for the duration of the trial. While this is probably not normal behavior in compliance with TA1049 requirement of continual frequency hopping, it meant that we could observe what happens when we intentionally attempt to apply severe interference to the single frequency.

It should be noted that the RFID reader was reading at the limit of its configured range, in this case +18dBm of about 1 meter. If the RFID tag was positioned at a distance of greater than 1.2 meters from the RFID reader, it was only intermittently readable.

Occasional formatting errors in the log output (usually missing or extra linefeeds) were due to the serial port limitations, not because there were errors introduced by RF interference.

**Figure 6: RFID Reader Setup**



Using the above setup, test procedure listed below was executed and repeated.

**Test Procedure: LoRa-RFID Normal-Case Interference. Run step #3 and step #5 for 10 minutes each and repeat.**

1. With nothing transmitting, observe and record spectrum analyzer in the 920-925MHz band.
2. Enable RFID reader, no tag present, observe and record spectrum.
3. Enable RFID reader + Tag present, observe and record spectrum, record RFID reader output.
4. Enable LoRa transmission (RFID off), observe and record spectrum.
5. Enable RFID reader with card present and LoRa transmission enabled, observe and record spectrum, record RFID reader output.

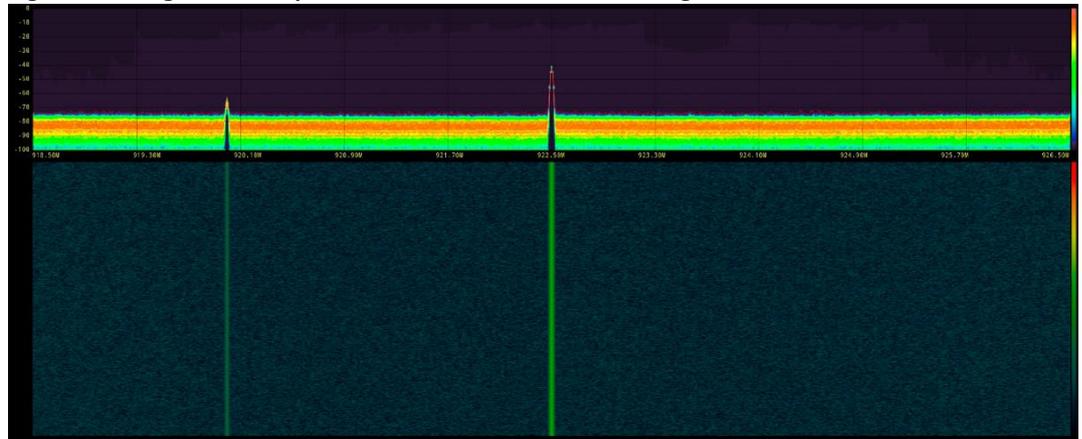
### 3.1.1 Class-1 Test Cases

There were six sets of tests conducted under the Class-1 tests.

#### Class-1 Tests and Results:

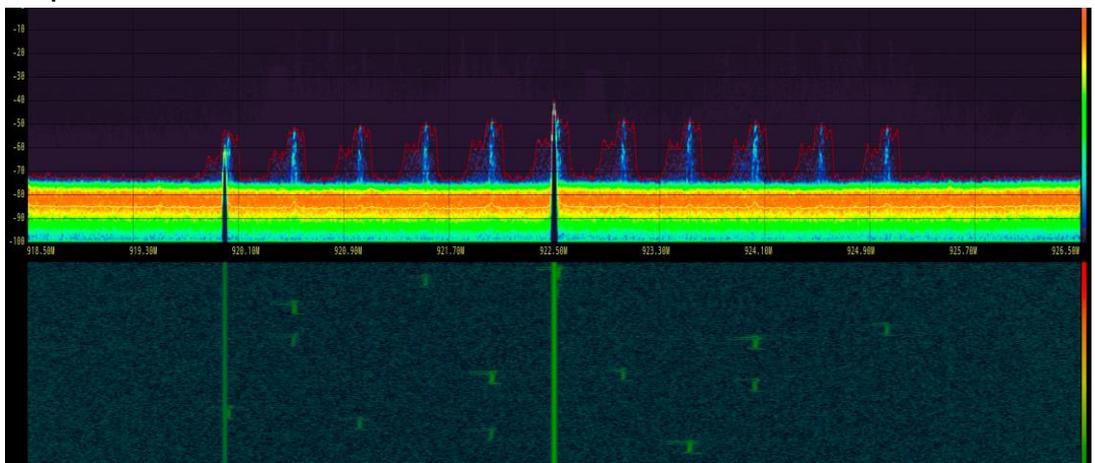
1. **CL-1-T1: Background interference level, Test RFID off, no Trams (see CL-1-T2).** Please refer to Figure 7. Please note that the peak at 922.5MHz is actually a characteristic of the receiver used and is not a real off-air signal.

Figure 7: Background RF Spectrum When No External RFID Signals Detected

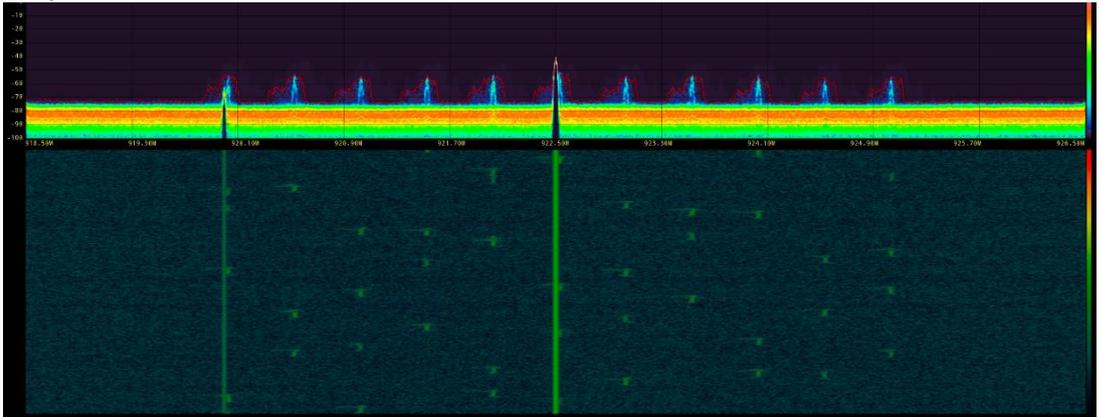


2. **CL-1-T2: Background interference level, Test RFID Off, Trams Present.** Please refer to Figure 8 and Figure 9. There are intermittent RFID signals present in the band at the PN Wan Chai office. The source was identified to be the trams which run along Hennessy Road outside. The trams have an RFID reader on the roof of each tram used to identify position for the onboard signage and location telemetry. This is the real-life situation in the PN Wan Chai office, essentially there is continuous RFID signals from the trams.

Figure 8: Background RF Spectrum With RFID Signals present (trams nearby) – Snapshot 1



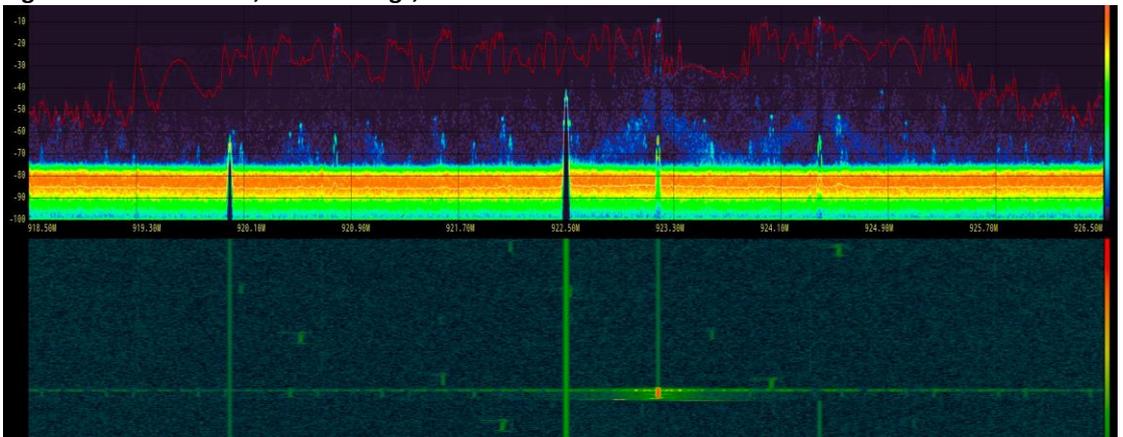
**Figure 9: Background RF Spectrum With RFID Signals Present (trams nearby) – Snapshot 2**



- 3. CL-1-T3: Test RFID On, No RFID Tags, Trams Present.** Please refer to Figure 10. The test RFID reader is on but no RFID tags are close enough to the test RFID reader. The background noise level increased significantly. RF spectrum with RFID reader on (and background RFID) is captured. RFID continually transmits hopping signals which effectively increases the noise across the band.

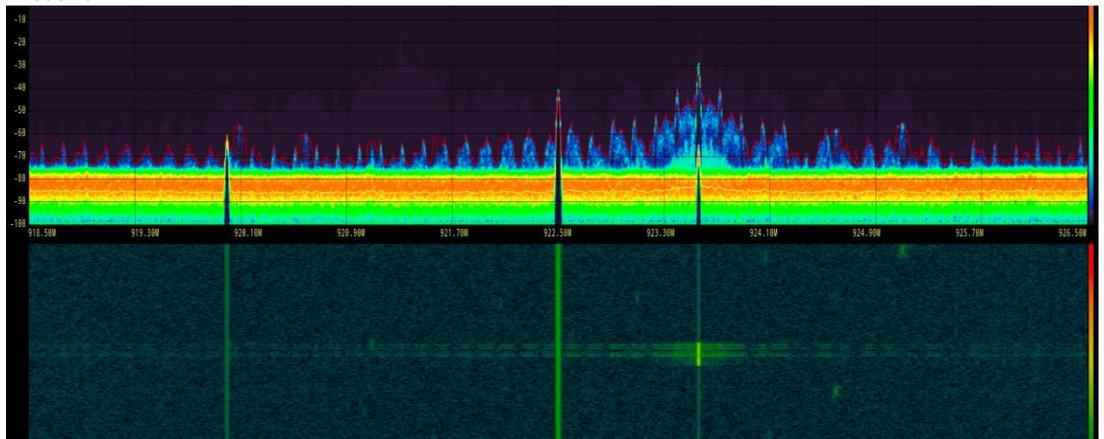
RFID readers transmit continuously, regardless if there is a RFID tag or not. Since the RFID reader and spectrum analyzer are in close proximity, the noise appears to be very high level. The red trace is a peak hold with decay, it is high across the band due to the hopping RFID signal.

**Figure 10 Test RFID On, No RFID Tags, Trams Present**



4. **CL-1-T4: Test RFID On, RFID Tag Present, Trams Present.** Please refer to Figure 11. The test RFID reader is on with RFID tags close enough to the test RFID reader. This caused the RFID reader to lock to a single frequency and continuously read the tag at around a rate of 27 times per second. In a 10-minute test interval, the tag is read more than 16,200 times as counted by the RFID reader log files. Locking to a single frequency channel (no frequency hopping) may not be normal RFID behaviour but suited our test methodology which was to attempt to cause interference to RFID. No data errors were encountered on the RFID system.

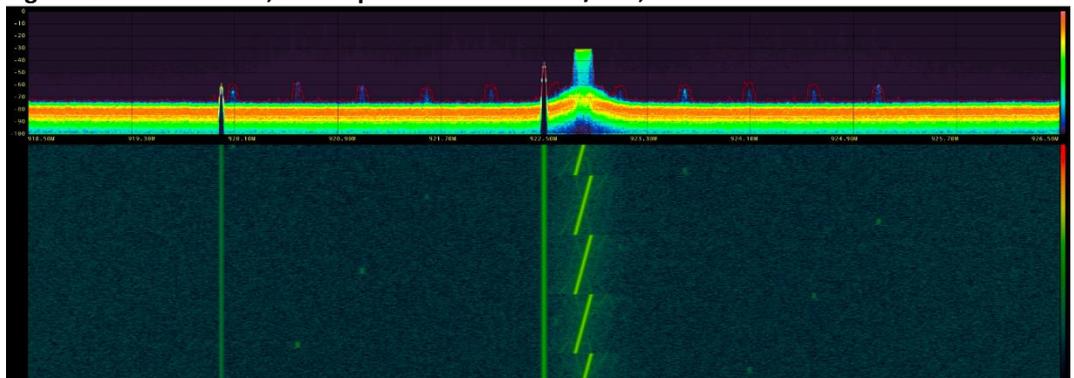
**Figure 11: Test RFID On, RFID Tags Present (27 reads per second on our system), Trams Present**



5. **CL-1-T5: Test RFID Off, LoRa Intermittent On, Trams Present.** Please refer to Figure 12. With the LoRa signal intermittently transmitting and RFID off, we captured the intermittent LoRa transmission.

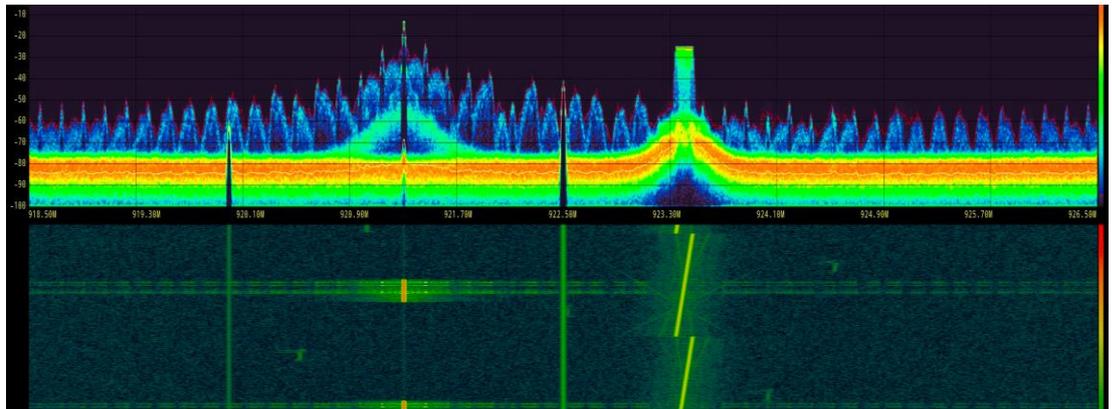
LoRa uplink transmission on 922.8MHz was captured. The LoRa lighting controller node transmits for less than 200ms, once per minute. This is much more often than would be used in a real-life configuration. The once per minute setup is used in our test for quick response during demonstrations. Real-life lighting controller configurations would typically transmit once per hour, or less often like once per day. No data errors were encountered on the LoRa system.

**Figure 12: Test RFID Off, LoRa Uplink Transmission 1/min, Trams Present**



6. **CL-1-T6: Test RFID On, RFID Tags Present, LoRa Intermittent On, Trams Present**. Please refer Figure 13. Since this particular situation only appears for around 200ms per minute it was hard to capture. The RFID reader continued to produce tag readings at a rate of 27 times per second where the total number collected in the 10-minute test interval being the same as before (about 16,200 readings). No data errors were encountered on the RFID or LoRa systems.

**Figure 13: Test RFID On, RFID Tags Present, , LoRa Uplink Transmission 1/min, Trams Present**



### **3.1.1.1 Summary Observation 1: RFID reader and LoRa lighting systems were unaffected under a normal-case shared band interference configuration (more real-life like configuration).**

After the tests, observations were made with regards to the impact of LoRa on RFID and vice versa.

With regards to the impact of RFID on LoRa, The RFID system did not cause any degradation of the message receive success rate.

It was likely the tram RFID system represent a much higher level of in-band interference than the test RFID system, by virtue of being outdoors (lower path loss to the live gateway) and closer to the live gateway.

Inherently, LoRa maintains good link performance in the presence of strong in-band interference. Many radio systems stop working if the interference is even 10dB weaker than the signal being received. With LoRa, the interference can be 19dB stronger than the signal being received and the receiver will receive the signal correctly. LoRa systems will keep working reliably as the frequency channels get crowded. We observed this during our testing.

Additionally, LoRa radios have integrated Forward Error Correction (FEC) into the protocol. FEC effectively increases the energy per bit and enables the device to correct

for bit errors. By adding extra overhead bits to groups of bits being transmitted, the data throughput gets reduced but the bit-error-rate is lower with weak signals, increasing the sensitivity of the receiver.

This demonstrates that LoRa itself is highly robust against in-band interference, similar to RFID, or anything that operates in a shared band must be.

With regards to the impact of LoRa on RFID, with the lighting trial setup, it was not possible to detect any degradation to the RFID reading system neither a reduction in read rate (27/s) or errors introduced. This is hardly surprising given that RFID has powerful error correction and robustness to interference (it was designed to tolerate multiple readers co-located) and massive message redundancy with many repeated readings while transmitting all over the band to avoid interference.

This does not take into account the worse than worst-case interference setup with interfering transmitters and receivers in close proximity, orders of magnitude more transmissions from the LoRa system - an unrealistic situation that will never occur in real life.

However, we wanted to try harder test the limits of interference rejection of our RFID system in the license-exempt band. To this regard, we performed Class-2 tests, to attempt to cause harmful interference to RFID.

### **3.2 Class-2 Tests: Intentionally-Induced Harmful Interference Tests**

The objective is to test limits of RFID resistance to LoRa interference by attempting to intentionally cause harmful interference to RFID by transmitting LoRa signal in the following way: 1-second transmit (On) and 1-second no transmit (Off) continually. The setup for Class-2 tests was as follows.

For this case, we used a similar setup as CL-1-T6. However, instead of merely using LoRa lighting controller node transmitting 200ms/minute to generate the LoRa signal, we configured an in-office special test gateway to transmit a LoRa 'interferer' signal at 50% duty cycle (1 second On followed by 1 second Off) sequentially on every frequency channel (24 channels in 920.2-924.8MHz @200KHz raster). Stepping across the band sequentially was only possible by using an external computer to reconfigure the 8-channel module after each transmission. The rate of "1-second On and 1-second Off" was a limitation of the hardware and script used to reconfigure the LoRa channel module between transmissions. It was not possible to transmit for shorter intervals or step faster with this configuration. Transmit power was set at 14dBm (25mW) at about 1 meter away from the RFID reader (the same as the lighting controller). The nature (bandwidth and power) of the LoRa signal is the same whether transmitted by the lighting controller or this test gateway; however, this test gateway allowed us to increase the intensity (number and duty cycle) of the LoRa transmissions to once per 2 seconds. This is an impossibly high level of 'interference' from a LoRa endpoint or a LoRa Gateway operating normally.

It must be remembered that this is not a simulation of real-life situation. Firstly, a LoRa transmitter will never transmit with anything like 50% duty cycle or even close to it. Typically, it transmits at 1% duty cycle. In this test, the LoRa transmitter (a specially configured gateway with external controller and special control script) is transmitting about 10,000 more often than the simple lighting controller operating normally (at a few milliseconds of transmission once per hour). Secondly, the close proximity of the LoRa and RFID systems will unlikely happen in real life situations. Thirdly, LoRa will typically only use 8 channels (8 x 200kHz, 1.6MHz of the band), not the whole band as in this experiment. This was an attempt to break RFID; so, we tried extreme conditions in the confines of our office limited only by what the technology would allow us to do.

The same RFID setup and the same test procedure as in the Class-1 tests was executed except that the external rooftop gateway is not used as we no longer needed the lighting controller for this test.

### **Class-2 Test LoRa Setup:**

- We configured the indoor test gateway to transmit at 50% duty cycle (1 second on followed by 1 second off) on every frequency channel (24 channels in 920.2-924.8MHz @200KHz raster) across the band by stepping through the channels sequentially under control of external computer as described above.
- Spectrum Analyzer SDR and Recording Software - uncalibrated - for indication only.

### **3.2.1 Class-2 Test Cases**

There was one set of tests conducted under Class-2 tests.

#### **Class-2 Tests and Results:**

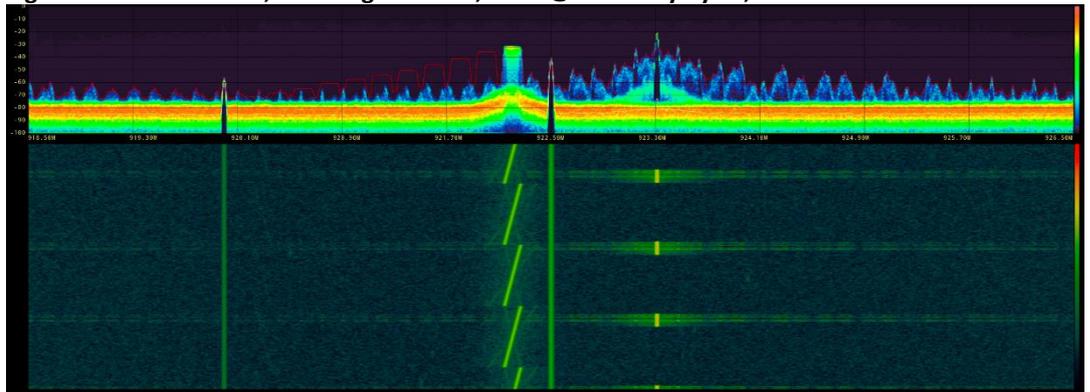
1. **CL-2-T1: Test RFID On, RFID Tags Present, LoRa @50% Duty Cycle, Trams Present.** Please refer Figure 14. Under this test, RFID reading with LoRa transmitter stepping across all the channels in the whole band was established.

When the LoRa stepper signal reaches the RFID signal, either of the following two scenarios were observed. Either nothing and the RFID would keep reading as if no interference was present; or, it would simply hop to a new frequency without losing any readings. If it did lose readings, we were not able to identify this from the log of the readings as these contained about the same number of readings as the case without intentional harmful interference about (16200 readings per 10 minutes regardless of presence of LoRa interference).

As an additional observation which is unrelated to LoRa, walking near or in front of the RFID reader it while in operation could cause it to lose

readings while RF intentional RF interference attempts from LoRa had no discernable effect.

**Figure 14: Test RFID On, RFID Tags Present, LoRa @50% Duty Cycle, Trams Present**



### **3.2.1.1 Summary Observation 2: RFID reader unaffected by LoRa co-channel interference under extreme maximum interference case, non-realistic case.**

Even using the maximum interference and stepping it across the band we were not able to disrupt, or interfere with, the RFID reader or reduce the number of readings or increase the error rate. The RFID simply hopped to a new frequency and carried on reading if the LoRa signal collided with it. Sometimes the RFID kept operating on the same channel even when the LoRa signal was a direct co-channel 'hit'.

This demonstrated the strength of the error correction, interference mitigation and frequency hopping techniques used by RFID that the performance was not affected.

## 4 Conclusions

PN conducted an assessment test of the mutual interference between LoRa and RFID given that they will share the same license-exempt radio frequency band of 920-925MHz. We found that both systems are robust against in-band interference and can co-exist successfully without causing harmful interference to each other.

We used the FCC Part 15 guiding principles as the basis of our testing, namely,

- a) the device must not cause harmful interference and
- b) accept interference received, including interference that may cause undesired operation.

RFID is particularly robust against interference. PN was not able to use LoRa to interfere with RFID in any meaningful way, even when using unrealistic and high duty-cycle LoRa interference sources in close proximity, conditions that will never happen in real-life with LoRa due to its inherent design.

LoRa, similarly, maintained good link performance in the presence of strong in-band interference from RFID.

The designers of these radio systems considered in-band interference and made them robust and secure so that they can co-exist without causing harmful interference. They both serve specific requirements. At the limits of coverage, interference will cause signal degradation to any radio system but this is true regardless of the technology of the source of interference. However, both LoRa and RFID are sufficiently robust that during our lab tests we were not able to 'break' either system.

The testing demonstrates there is no performance affecting interference issue between RFID and LoRa and no issues were found preventing shared use of the 920 - 925MHz band.

*End Of Document*