SX1280
Long Range, Low Power
2.4 GHz Transceiver

Application Note:
How to Perform Ranging Tests with the SX1280 Development Kit

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1. Introduction

In this Note we show you how to perform your first ranging measurements with the SX1280 development kit. Moreover, we'll show you what kind of results you should expect using the kit 'out of the box'. Along the way the full configuration and measurement setup is detailed allowing reproduction of the measurement setup to perform your own initial, outdoor, line-of-sight testing.

2. SX1280 Ranging

To employ the ranging functionality, it is useful to understand the basic principle of operation. The SX1280 ranging feature is based upon the measurement of a round trip time of flight between a pair of SX1280 transceivers. The basic ranging operation is outlined in the sequence below.

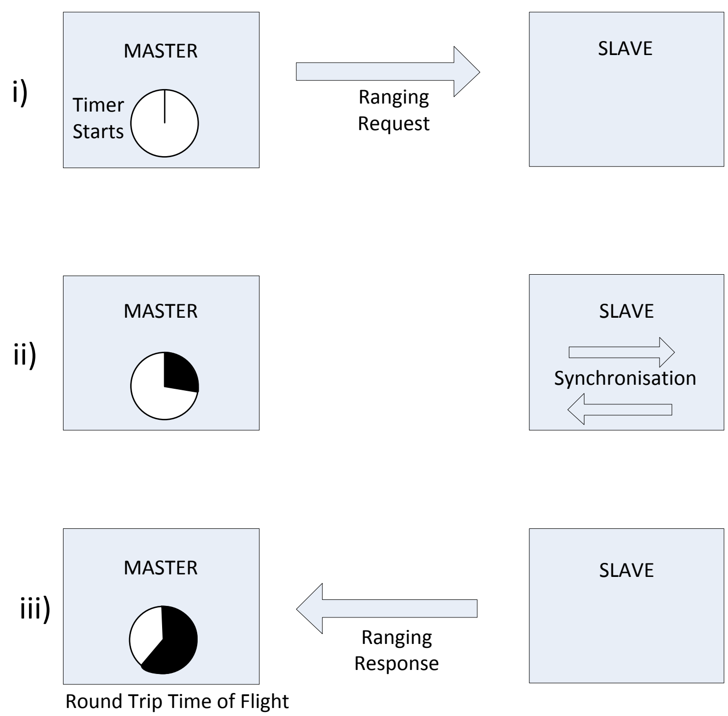


Figure 1: Principle of SX1280 Ranging

i) One SX1280 assumes the role of Master and initiates a ranging exchange by transmission of a ranging request. The ranging request is addressed to another SX1280, which must be configured in ranging Slave mode (i.e. ready to receive the incoming ranging request). At the moment that the Master sends the ranging request, the Master also starts its internal timer.

ii) The ranging request is received by the addressed Slave, which synchronizes itself with the incoming signal. The slave synchronization process requires a fixed amount of time. Note that the Master and the Slave do not share a common absolute timing reference.

iii) The Slave returns a synchronized ranging response back to the Master, upon reception of which the Master can deduce the round-trip time of flight from the time elapsed i.e. the time taken for the electromagnetic wave to propagate from Master to Slave and back again.

In the development kit a pair of transceivers are provided, either can be configured as Ranging Master or Ranging Slave through the touch screen user interface.

In addition to performing the basic ranging sequence outlined above, some additional processing is also performed in the kit itself, notably:

1) Rather than a single measurement, a series of measurements are performed, hopped over the 40 frequencies of the channel plan of the Bluetooth Low Energy protocol. The number of ranging requests per ranging operation performed on the kit is user defined. Where the number is higher than 40 the hopping sequence is repeated, where lower a subset of the channels will be used.

2) Some statistical post processing on the raw ranging results will be performed. For full details of the precise processing employed please refer to the latest SX1280 MBED project page [3].

3. Preparation for Range Testing

The ranging performance is a function of many system and environmental factors. A full description of these is given in [6]. All of the design specific calibration is already included in the development kit firmware, leaving only the environmental factors which may cause variability in the ranging performance seen when using the development kit.

As the starting point for any evaluation we therefore recommend performing a baseline test based upon the settings presented in this document. This can be used as the starting point for ensuring that the ranging is functioning as expected before going on to more challenging application environments.

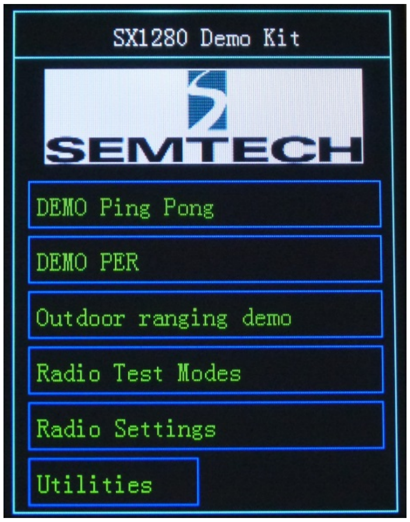
The following preparatory steps are recommended:

- **Configuration of the Kits for Ranging**: through the user interface on the kit, configure the ranging demo so that you can compare your results with those presented here.
- **Hardware Preparation**: ensure that your hardware setup is equivalent and avoid common pitfalls.
- **Site Selection**: find a site with Line-of-Sight, ideally free of vegetation, and far from buildings or other objects that might reflect radio waves.

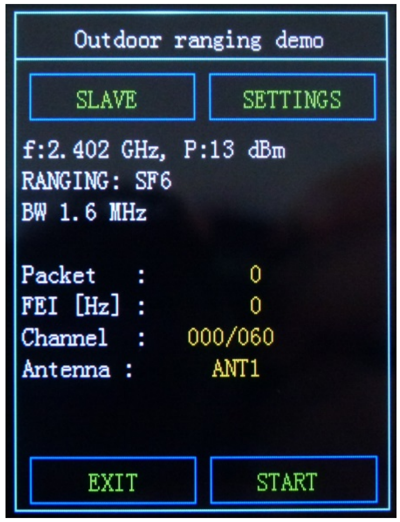
The remainder of this document goes on to describe each of these steps in detail and presents the results of our Line-of-Sight measurement campaign.

3.1 Ranging Kit Settings

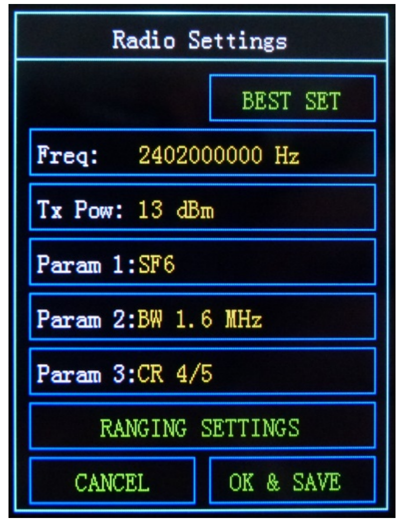
The SX1280 MBED page [3] should be consulted for the latest drivers. Once updated, the default kit settings are used (full instructions can be found in [2]) it may however be necessary to ensure that the following settings are enabled on the kit:



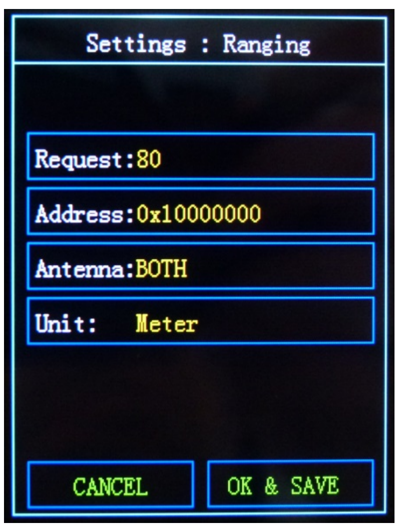
1. Upon power-up you will be presented with the default menu, select “Outdoor Ranging Demo”



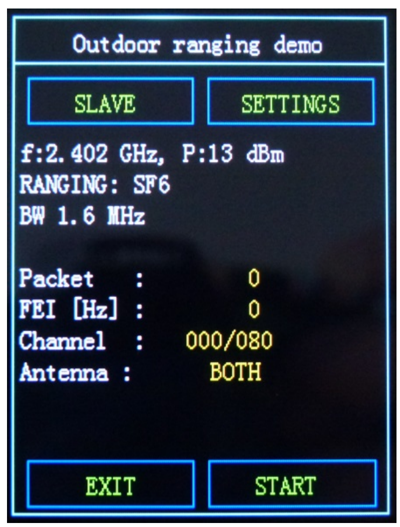
2. By default the kit may be configured to 60 trials and to use only Antenna 1. Select “Settings”.



3. SF and Bandwidth Settings can be modified here according to your application’s needs. For our baseline measurement select “Ranging Settings”.



4. Tap on the number of requests until 80 is displayed. Tap on the Antenna until BOTH is displayed. Then select “OK & SAVE” until you are returned to the “Outdoor Ranging Demo”.



5. From this screen you can select the Master or Slave role and start the ranging exchange process. For more details please see the SX1280 Evaluation kit User’s Guide [2]

Figure 2: Preparing the Kit Settings for Baseline Testing

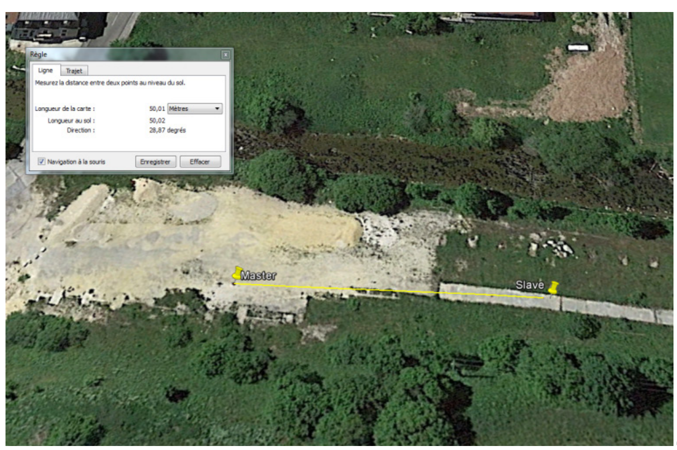
3.2 Range Testing Hardware

In addition to the kit, we'll also need a source of power. We use a Silicon Power P81 USB battery pack [1]. The advantage of this specific pack is that, even with the low consumption of the SX1280 evaluation kit, the pack remains on. Some other battery packs are incapable of detecting such low current drain and power down after a short duration.

Figure 3: SX1280 Powered from the P81 Battery Pack, Ready for Ranging Testing

4. Ranging Site Location

The next task is to select a suitable location for line-of-sight testing. Although SX1280 can provide reliable ranging results in excess of 7 km, we seek a reliable, easily repeatable test distance over which we can establish our ranging performance baseline. In this Note we have selected two test sites: the first gives us over 50 m of optical line of sight range, the second 2 km optical line of sight range.



(Source: Google Maps)

Figure 4: Satellite View of 50 m Test Site

5. Ranging at 50 m

5.1 Setup

The setup is shown both schematically (right) and the real layout on the ground (left) in the figure below. We mount the kits at 1.8 m to avoid any form of diffraction loss from the terrain between the Master and Slave. Both kits are mounted vertically (see photo) and are mounted them in waterproof enclosures for convenience.

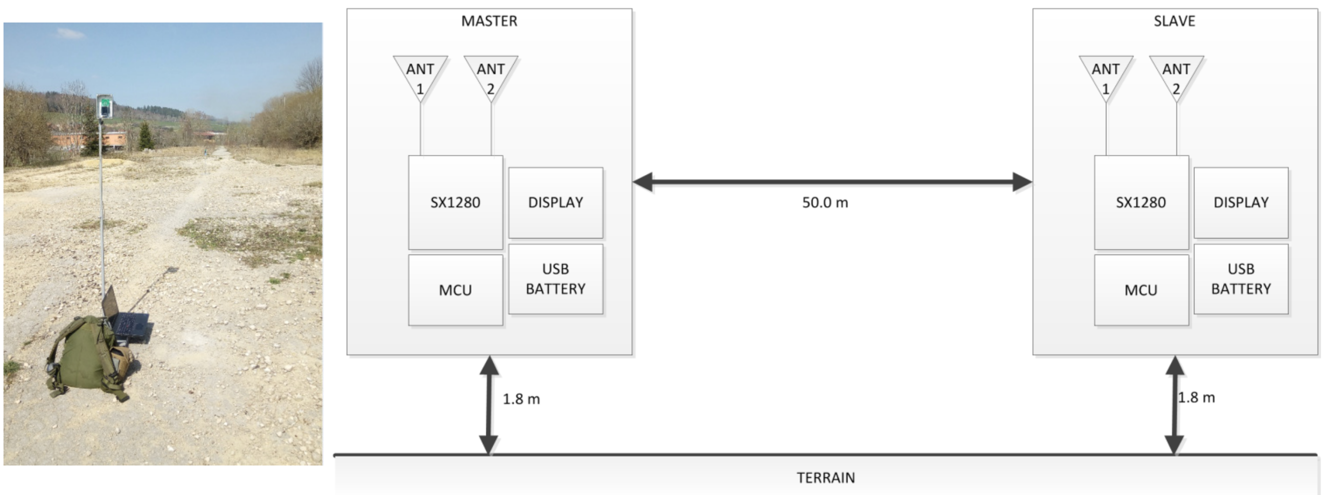


Figure 5: Photo of Ranging Setup (Left) and Schematic of Setup (Right)

5.2 Ground Truth

One of the most challenging aspects of performing a reliable ranging evaluation is establishing the real distance by which the SX1280 kits are separated. This is another reason for the selection of a 50 m range for initial evaluation. There are a wide range of commercially available 50 m surveyor's measurement tapes available [4] which guarantee reliable measurement of the actual separation of the kits. This real distance is referred to as Ground Truth.

Laser range finders have been found to vary significantly in quality and accuracy – often requiring a large reflective surface to guarantee a measurement result. Moreover, operator error is a significant source of error, a useful survey of which can be found in [5].

5.3 Measurement Technique

To compile the results, using the setup and configuration above, we simply perform 50 measurements (each one the result of the 80 hopped exchanges) by hitting the refresh button on the user interface and manually recording the results. It is important to note that each result is the output of statistical post processing, as detailed in [3], on those 80 frequency hopped exchanges.

We choose to perform the ranging tests at four extremes of performance of the LoRa modem namely:

1) Max BW, Max SF (highest ranging precision)
2) Max BW, Min SF (lowest energy, highest data rate)
3) Min BW, Max SF (longest range)
4) Min BW, Min SF

The compiled results at each of these settings are presented in the following section.

5.4 Results

In this section we present a histogram of the 50 measured results. Recalling that the x axis is the range in meters and that ground truth is 50 m, the average reported distance and the range of distance values seen are reported at the top of each figure.

As described in our introduction to ranging application note [6], the highest ranging precision available is at the highest bandwidth and highest spreading factor setting, SF10, bandwidth = 1.6 MHz. At this setting we see the distribution shown below for multiple ranging trials conducted using the kit. The ranging measurements lie within +2 to -3 m of the actual (ground truth) distance, the average distance (49.7 m) of all exchanges is also included on each plot.

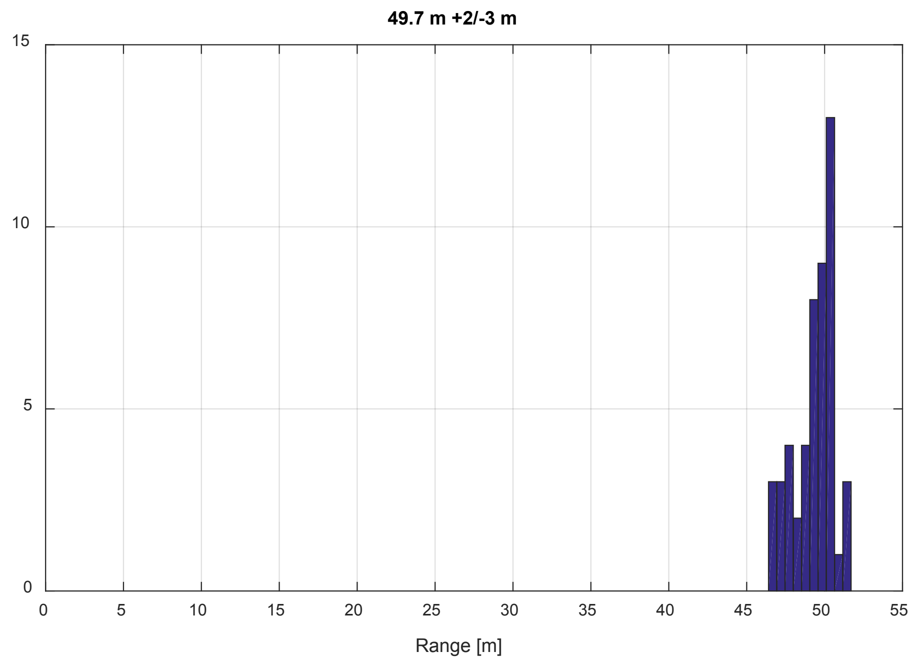


Figure 6: Highest Precision Setting is 50 m Range Test SF10 1600 kHz

Next we present the lowest energy setting, this corresponding to the shortest time on air, SF5 1.6 MHz bandwidth. Here we see mildly degraded precision, with a spread of results of ground truth +3 m to -6 m.

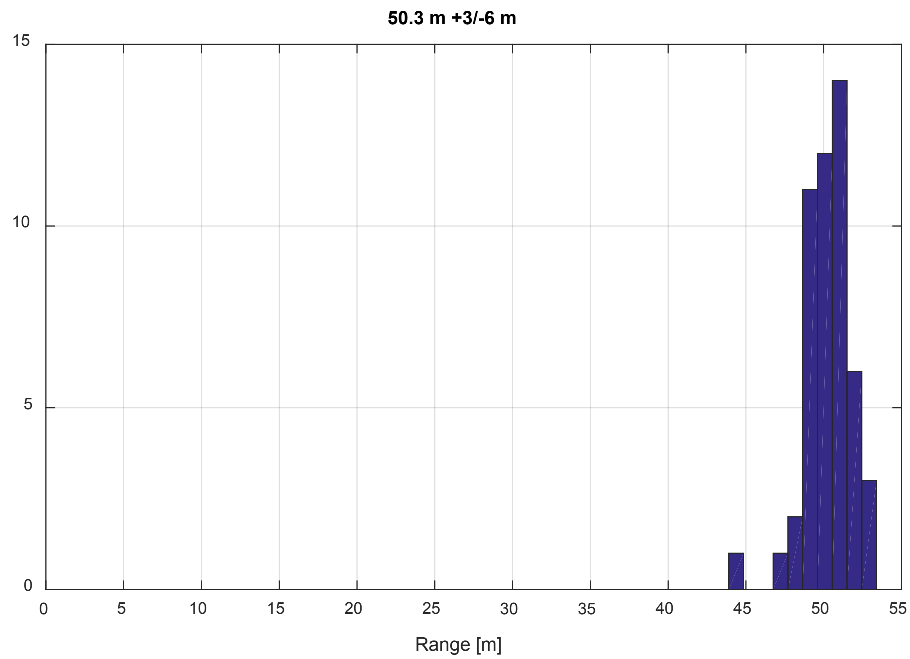


Figure 7: Lowest Energy Setting is 50 m Range Test SF5 1600 kHz

The next plot shows the longest range setting, using the minimum bandwidth and highest spreading factor possible, SF10 400 kHz. In spite of a similar range of distance results, the histogram clearly reveals reduced precision (i.e. a wider spread of results) due to the narrower bandwidth.

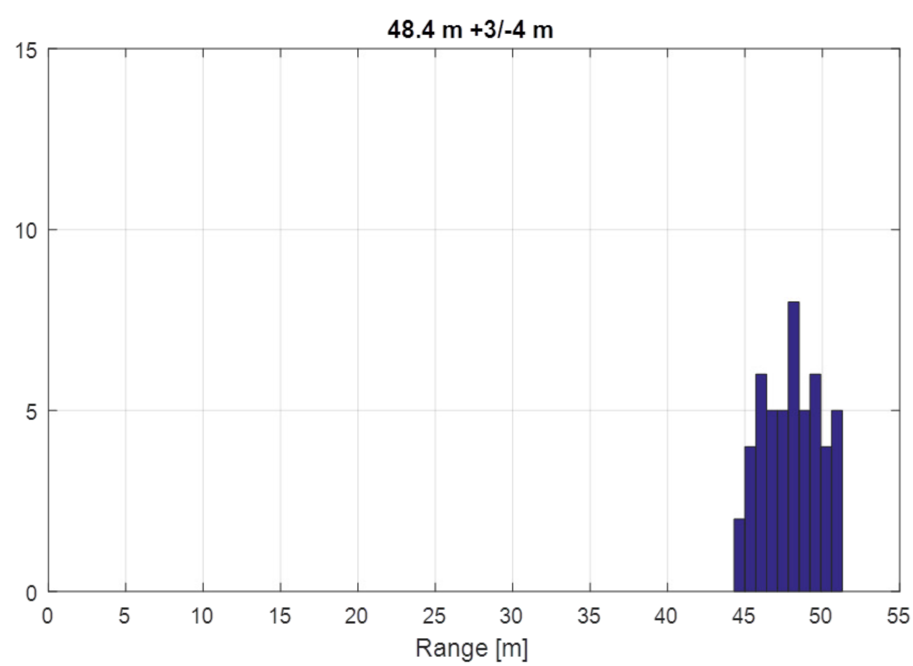


Figure 8: 50 m Range Test SF10 400 kHz

Finally the lowest bandwidth and lowest spreading factor setting is tested. Whilst this doesn't correspond to a case of extreme performance as in the 3 preceding plots, it does help to show the positive influence of increased bandwidth on ranging precision when compared with Figure 7 at the same SF but higher bandwidth.

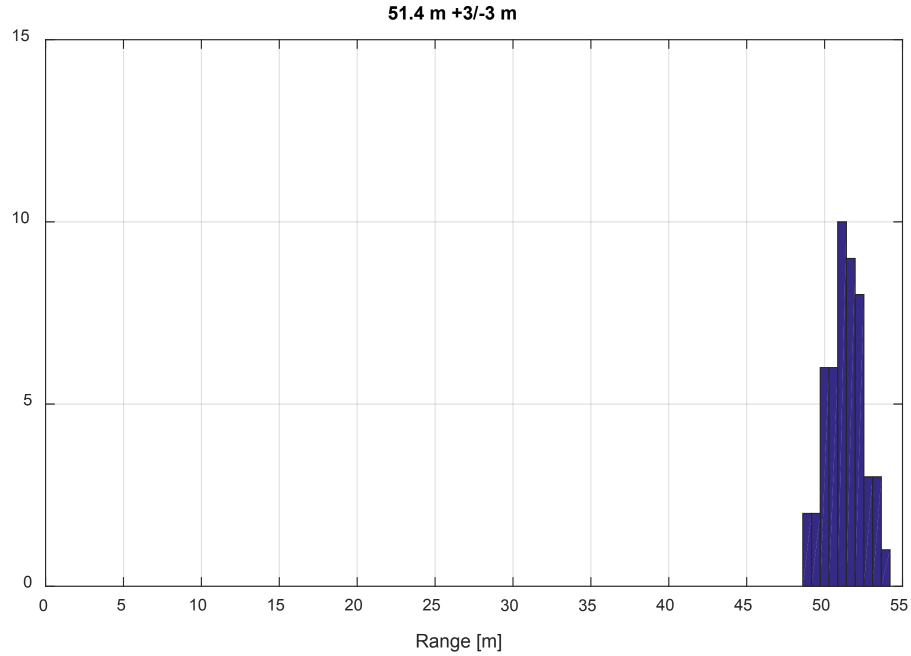


Figure 9: 50 m Range Test SF5 400 kHz

6. Ranging at 2 km

6.1 Setup

The 2 km range site is shown in the image below, Google maps reports the distance between the two sites to be 2005 m.

Figure 10: Google Maps View of the 2 km Test Site

6.2 Ground Truth

Again, the difficult question of how to accurately assess the ground truth distance is confronted. In this case local landmarks could accurately assist in the determination of the map based distance measurement performed on Google maps. For comparison, GPS was also used to determine the coordinates of the Master and Slave sites. In this case multiple, strong satellite signals were received but the GPS reported a circular error probability of approximately 5 to 7 m (CEP is the circle within which 50% of measurement results will fall).

The coordinates from the GPS were substituted into the Vincenty formula [7], yielding a range of 2008 m. However, compared with the significant CEP of the GPS measurement, it is difficult to attribute higher confidence to this very precise distance calculation.

6.3 Measurement Technique

In this long range testing a single configuration was tested, the high precision setting with the high bandwidth (1.6 MHz) and high SF (SF10) modem settings. 50 Results were recorded and are plotted overleaf in the same histogram form as the previous results.

6.4 Results

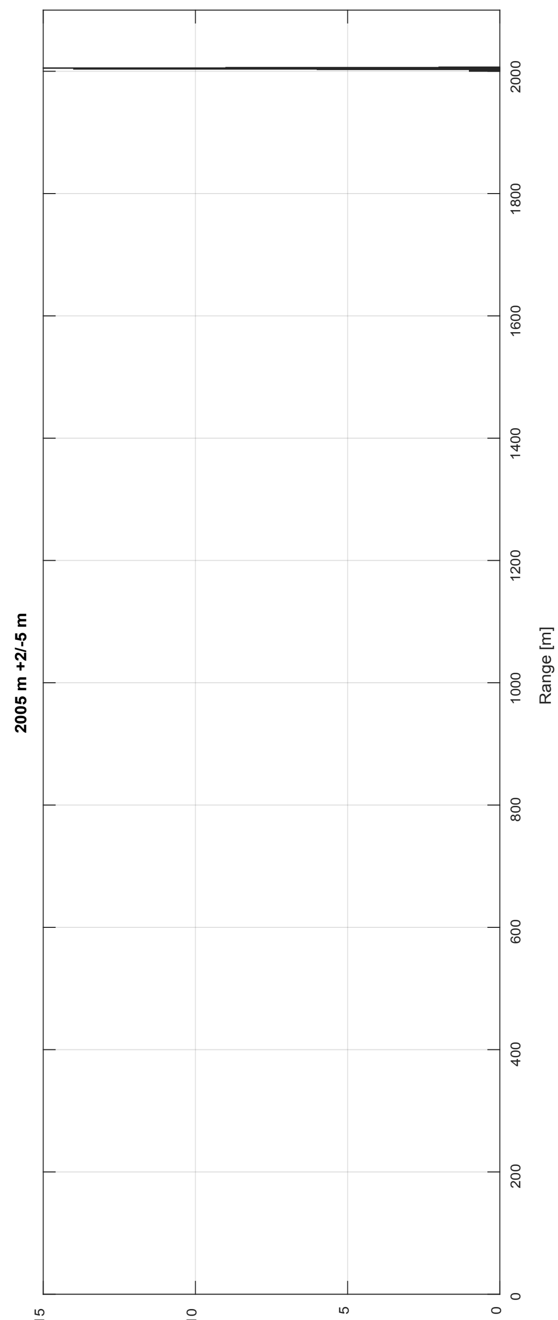


Figure 11: 2005 m Range Test at SF10 1600 kHz

7. Conclusion

Here we see that the measurement precision is not a function of range. The reported range of 2005 m +2, -5 m exhibits a mild degradation of precision when compared with the same settings at 50 m (a range of distance values spanning 7 m rather than 5 m).

Thanks to the statistical processing employed in the development kit firmware [3], the underlying extremes of ranging performance simply change the distribution of results within approximately ±3 m.

In conclusion, all of the key aspects of ranging test preparation and execution have been outlined to allow reproduction of both the ranging setup and ranging results.

These recommendations can be used to reproduce the measurement results presented here to permit comparison with measurements taken at other range testing sites.

8. References

[1] Silicon Power P81 Battery Pack Website
https://www.silicon-power.com/web/product-16

[2] User Guide for the SX1280 Development Kit
http://www.semtech.com/images/datasheet/sx1280_81_userguide.pdf

[3] SX1280 Development Kit MBED Project Page
https://developer.mbed.org/components/SX1280RF1ZHP/

[4] Example of Surveyors Tape, here from FISCO
http://surveyequipment.com/fisco-surveyor-50m-steel-tape/

[5] Lois P. Sicking, in Rangefinder Comparison, US Forest Service February 1998
https://www.fs.fed.us/eng/pubs/html/98241307/98241307.html

[6] Application Note: An Introduction to Ranging with the SX1280 Transceiver
http://www.semtech.com/images/datasheet/introduction_to_ranging_sx1280.pdf

[7] Online calculators of the Vincenty Formula
http://www.movable-type.co.uk/scripts/latlong-vincenty.html
http://www.ga.gov.au/geodesy/datums/vincenty_direct.jsp

Important Notice

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