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Version control

Ver.	Date	Summary of changes
1.0	2019-09-23	Initial version
1.1	2021-05-04	Updated output in IGC files, $PFLAL and $PFLAN

Scope and summary

Verifying the radio performance is critical for any FLARM installation to maintain proper functioning and timely collision warnings. Performance may deteriorate slowly due to damaged cables, connectors, or antennas, without the user noticing. Traditionally, an online analysis tool was available, using data from IGC files to estimate range.

PowerFLARM firmware version 6.80 introduced the Continuous Analyzer of Radio Performance (CARP), facilitating and improving performance analysis.

This document explains how CARP works and how it can be best integrated into third party application.

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1 Introduction

Verifying and maintaining good radio frequency (RF) performance is critically important for every FLARM installation. The range must be sufficient for intruders to be detected in time, which is required for timely collision warnings. Even when there is no conflict, a better range allows for a better picture of nearby traffic and hence increased situation awareness.

Radio performance may sometimes seem elusive: Even when nothing in the installation is changed, it may deteriorate slowly or suddenly, due to e.g. crushed cables, oxidized connectors, bent antennas, electrostatic discharges, etc. Therefore the important rule:

Radio performance must be verified regularly for every FLARM installation!

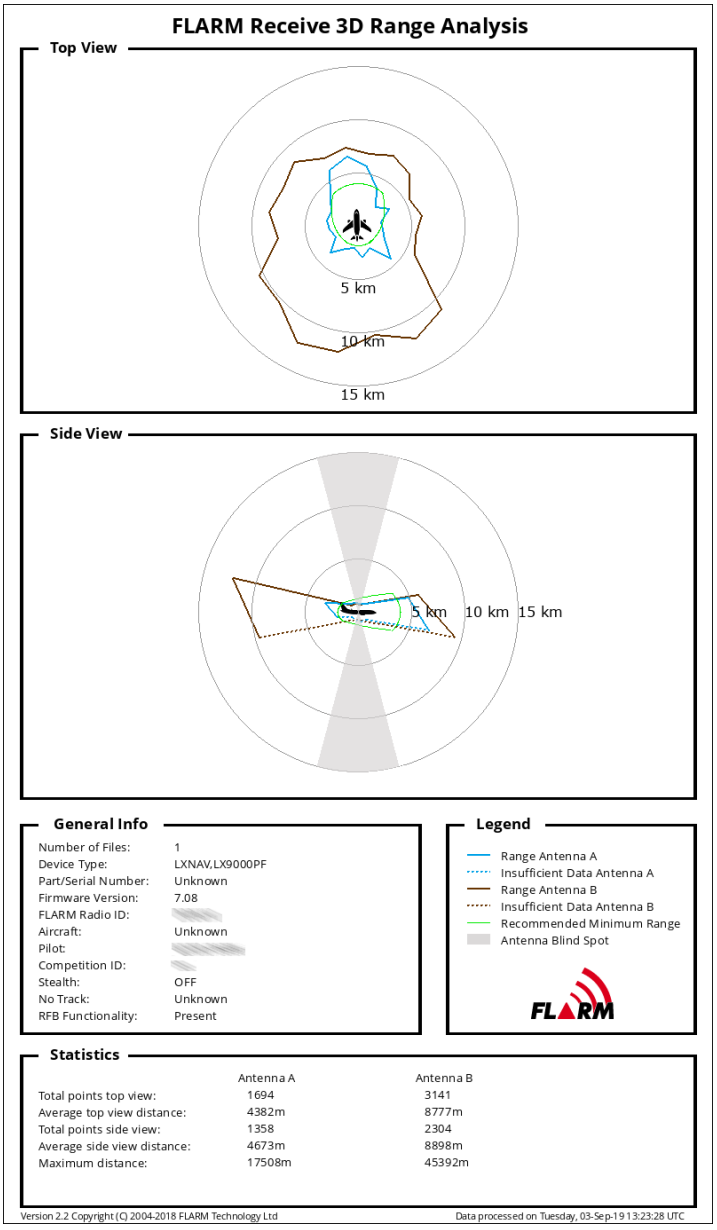
How? A simple and effective test is the online Range Analyzer tool[1]. More information on other means of radio range validation can be found in the FAQ[2].

The Range Analyzer works with one or multiple FLARM flight logs (IGC files). It uses data from received traffic for a statistical analysis, which is then presented graphically. A sample result is shown below.

For meaningful results, it requires an abundant number of traffic encounters (contacts) during flight. Hence, a log from a nice summer day with a lot of activity is better than a log from a night flight in the winter. However, not all relevant contacts can be stored in the IGC file due to size constraints. Especially in dense airspace, a large majority of the relevant contacts must be discarded.

This restriction is solved by the Continuous Analyzer of Radio Performance (CARP). It continuously registers and aggregates all contacts — nothing is discarded. The aggregate state can be queried or reset via the data port. The state is stored in non-volatile memory, so it is preserved when the device is powered off.

[1] https://flarm.com/support/tools-software/flarm-range-analyzer/
[2] https://support.flarm.com/hc/en-us/articles/360016080953-How-can-I-check-the-range-of-my-installation-



The advantages of CARP over the online tool are:

- No data is discarded from the statistics, requiring less flight time for results
- The state is persisted, aggregated over many flights
- Can be queried and reset over the data port
- Results are available while the device is running
- Does not rely on proprietary tools
- Easy to embed into third party applications
- Results are consistent with the traditional online tool

There are two disadvantages:

- Only the mean range can be computed (i.e. no percentiles, etc.)
- No "side view" equivalent is available

1.1 Use Cases

CARP is suited for integration into third party applications since it does not require any proprietary tools. For example:

- A FLARM display can display radio performance in the diagnostic menu
- A reporting system in a maintenance organization may embed performance plots into a PDF report
- A technician can use it to test the device more effectively after modifications to the hardware
- A competition organizer can use it to identify poor installations prior to (or while) running the competition

2 Principle of Operation

CARP is queried and controlled with the `$PFLAN` data port command; see the ICD (FTD-012) for a full reference. It requires zero configuration and runs automatically, so there is no need to enable it.

2.1 Reset

This resets CARP by deleting the aggregated statistics, comparable to resetting the trip odometer in a car. This could be used e.g. prior to a test flight or after an installation change. To reset CARP, send

```
$PFLAN,S,RESET
```

The device will acknowledge the reset.

2.2 Data Collection

Data is collected automatically and continuously when the device is airborne. There is no (practical) limit for the duration of the collection, as received data is immediately aggregated and added to the statistics. The collection is persistent, i.e. the device can be reset/restarted without losing data.

A practical duration for collecting data is a 1-hour flight with multiple encounters with FLARM targets. More targets mean less flight time needed, and vice-versa.

Using any of the readout methods below, the user can check whether sufficient data has already been collected (STATS value).

2.3 Readout

Three methods of recovering the collected and aggregated data exist. Direct readout via the data port is the preferred method for display manufacturers, to present the results in graphical form.

2.3.1 Data Port

A direct readout is achieved by sending the following command:

```
$PFLAN,R,RANGE
```

The device will respond (NMEA checksums are omitted throughout after '*'):

```
$PFLAN,A,RANGE,RFTOP,A,5600,,3600,2400,1200,1200,…*
$PFLAN,A,RANGE,RFCNT,A,54,0,65,41,87,98,…*
$PFLAN,A,RANGE,RFDEV,A,1200,900,1450,700,1100,1400,…*
$PFLAN,A,RANGE,RFTOP,B,4800,3600,2400,1200,1200,1200,…*
$PFLAN,A,RANGE,RFCNT,B,51,95,27,49,42,111,…*
$PFLAN,A,RANGE,RFDEV,B,1800,1100,1500,900,1200,1300,…*
$PFLAN,A,RANGE,STATS,5000*
$PFLAN,A,RANGE,TIMESPAN,1562000000,1563000000*
$PFLAN,A,RANGE*
```

Note the individual results for RF A and B, depending on the availability of radio diversity. The 20 values represent for each channel the average ranges in the respective azimuths, arranged clockwise around the aircraft, starting from the front. There are 20 values, hence the azimuth values are 0°, 18°, 36° and so forth.

Azimuth slots can be empty if not enough data was collected for statistically significant results (see second slot in the A-channel above). This should be indicated to the user.

The RFCNT value should be used to indicate to the user the statistical significance of each azimuth. A reasonable number is 50 or larger. If this number remains low in spite of multiple encounters with FLARM traffic, it might indicate insufficient range by itself.

The time span should be presented to the user as well, hinting the duration of the data collection. Note that it memorizes the moment of first/last registered contact, i.e. not when CARP was reset/read out.

For more details, see the ICD (document FTD-012).

2.3.2 IGC File

The state of the aggregation will be appended to every IGC file:

```
LFLA102831RANGE RFTOPA0560000360240120…012
LFLA102831RANGE RFCNTA0540000650410870…012
LFLA102831RANGE RFDEVA0120000090140070…012
LFLA102831RANGE RFTOPB0480360240120120…014
LFLA102831RANGE RFCNTB0510950270490420…014
LFLA102831RANGE RFDEVB0180110150090120…014
LFLA102831RANGE STATS0000003458
LFLA102831RANGE TIMESPAN15620000001563000000
```

The content is equivalent to the data port method. The azimuth ranges (RFTOPx) and standard deviation (RFDEVx) are encoded in 3-digit numbers with a scaling of 100 m. Empty slots (not enough data for statistical significance) is indicated with the value '000'. RFCNTx contains the number of data points per azimuth slot. The timestamps have 10 digits each.

2.3.3 $PFLAL

This is output in the data port $PFLAL message when the flight has ended. It is otherwise identical to the previous method.

```
$PFLAL,102831RANGE RFTOPA0560000360240120…012*
$PFLAL,102831RANGE RFCNTA0540000650410870…012*
$PFLAL,102831RANGE RFDEVA0120000090140070…012*
$PFLAL,102831RANGE RFTOPB0480360240120120…014*
$PFLAL,102831RANGE RFCNTB0510950270490420…014*
$PFLAL,102831RANGE RFDEVB0180110150090120…014*
$PFLAL,102831RANGE STATS0000003458*
$PFLAL,102831RANGE TIMESPAN15620000001563000000*
```

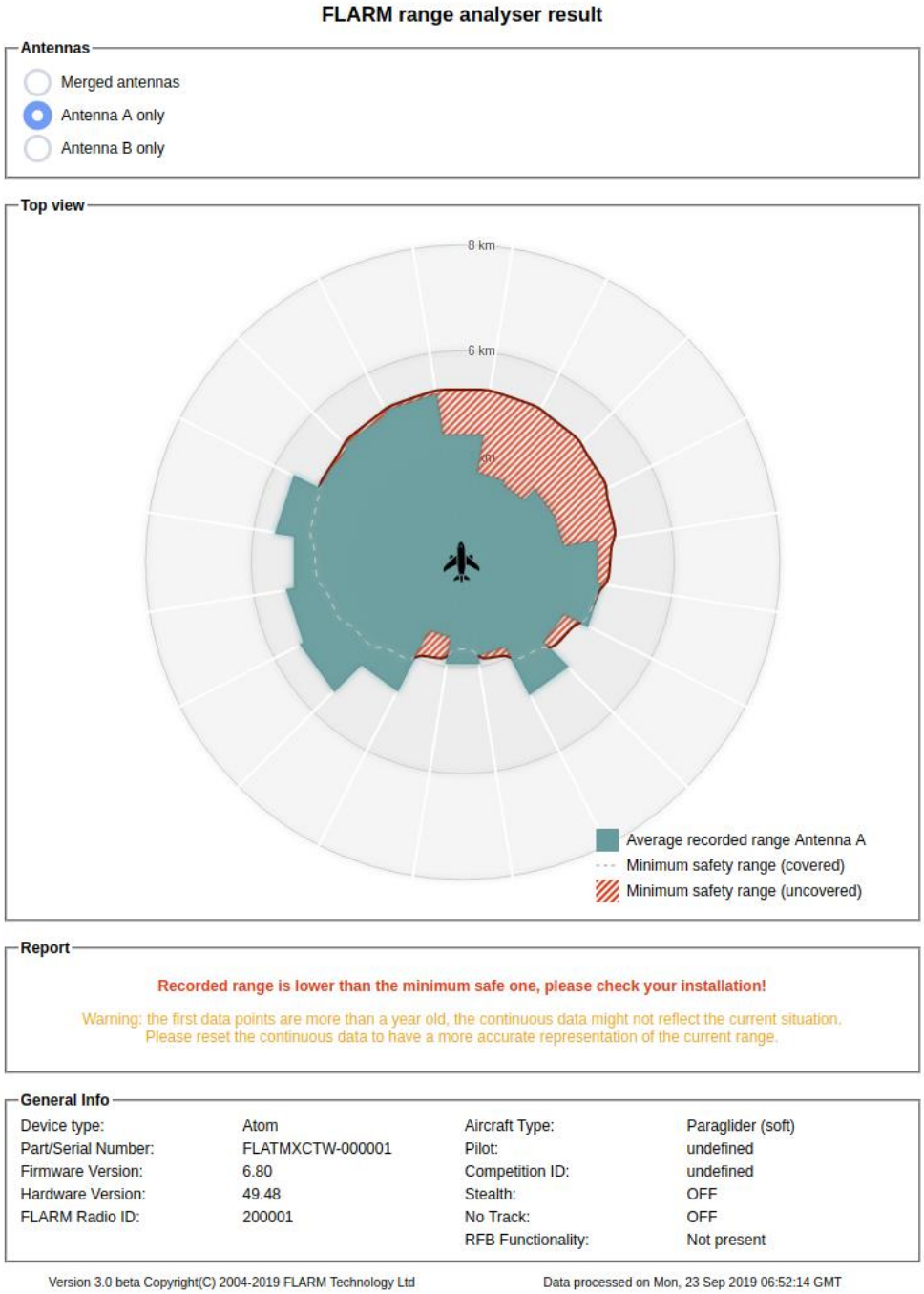
2.4 Visualization

Use cases for CARP can be manifold, whether it is on an LCD display in the cockpit or in a PDF document as part of a maintenance process. Some key elements should be present in all applications though:

- One range circle, indicating the scale
- A minimum-range plot, indicating the minimum acceptable range.
- Make A and B channels visually separable. This can be on the same or individual plots
- Indicate missing data clearly
- Indicate the number of contacts processed

- Indicate the time span for collection

Another sample visualization is given below.



3 Conclusion

We introduced the Continuous Analyzer of Radio Performance (CARP), improving on the existing, web-based Range Analyzer. CARP collects significant data much faster, is automatic and persistent, and can be embedded deeply into third party applications such as FLARM displays.