pingStation CPR Test Summary

1 Background

uAvionix performed cross-comparisons of live ADS-B position data to assist with customer observations of incorrectly tracked aircraft. The data collection utilized two approaches:

- Multiple pingStations with overlapping coverage were used to compared aircraft position data in real-time to detect erroneous reported positions. This yielded an average of 1 or 2 mis-reported positions per day. Data was sampled for approximately 1 week.
- Single pingStation receivers were also analyzed to identify any jump in aircraft position greater than a reasonableness threshold. This yielded an additional 2 aircraft per week.

Per DO-260B Appendix A, pingStations are capable of performing 3 types of CPR decodes to establish and update an aircraft's position.

1. Local CPR decode based on even *or* odd CPR data and the existing known position of the aircraft.
2. Local CPR code based on even *or* odd CPR data and the known position of the pingStation receiver.
3. Global CPR code based on *both* the even and odd pairing CPR data.

In the types of CPR decodes above, #1 can only be conducted after an initial unambiguous position has been established by either #2 or #3. Under most circumstances, #2 will be used to establish an unambiguous position with subsequent CPR data utilizing #1. In cases where the pingStation may not have a GPS lock or a clear view of the sky, #3 would be used to established an unambiguous position, with subsequent CPR data utilizing #1.

1.1 Local CPR Decoding with pingStation Known Position (#2)

Per DO-260B Section A.1.7.1 Notes 4 and 5 and A.1.7.4, local CPR decoding based on a known position of the receiver, works only if the aircraft is within 180NM of the receiver. Findings indicate the pingStation's RF subsystem was able to detect aircraft over 220NM away from receiver, which lead to an incorrect unambiguous position calculation based on method #2 and subsequent jumps in CPR decoding thereafter.

1.1.1 Example

In the table below, initial aircraft position decode data (Packet 2) indicates a position of 39.9526, -94.9113 based on a #2 decode. Only 38 seconds later, the pingStation decoded a position of 39.9136, -92.7690 (Packet 6) again via a #2 decode. The velocity required for these two positions to be true over a 38 second timespan was not reasonable and was flagged for investigation.

Upon further analysis, uAvionix verified the local CPR computation was done correct for both packet 2 and 6. However, after performing a #3 global unambiguous CPR decode on subsequent packets to 6, it was found the *true* position of the aircraft was actually 33.8994, -94.4002. This was 197NM from the true known position of the pingStation. This highlights the limitations of the local CPR decode.

To be sure, a "synthetic" receiver position of 33.8994, -94.4002 was used to simulate a receiver in close proximity to the aircraft, well within the 180NM limit. By manually calculating Packet 2 and 6 CPR positions via method #2 while using the synthetic pingStation position (yellow highlights below), correct position data was observed with no major "jumps" in position over the 38 second span between packets 2 and 6.

It's also noted, the observed aircraft in the data below was at 41,000ft. These high altitudes are more susceptible to long-range reception by pingStation receivers.

	Packet 2 - 12:43:22	Packet 6 12:44:00	Synthetic Packet 2	Synthetic Packet 6
Lat	39.952698	39.913696	33.952697	33.91369
Lon	-94.911315	-92.769088	-94.51039	-94.4436288
evenCPRLat	86348	85496	86348	85496
oddCPRLat	0	0	0	0
evenCPRLon	17837	19159	17837	19159
oddCPRLon	0	0	0	0
cprOdd Flag	0	0	0	0
initialCPRLat	86348	85496	86348	85496
initialCPRLon	17837	19159	17837	19159
cprDecodeType	1	1	1	1
initialHostLatDDE7	370901370	370901410	3389947	3389947
initialHostLonDDE7	-934572884	-934572901	-944002546	-944002546
Callsign	EJA511	EJA511	EJA511	EJA511

1.1.2 Solution

Due to the pingStation's high RF sensitivity, local CPR decodes utilizing the on-board GPS position of the pingStation (#2) is not advised to establish an aircraft's first unambiguous position, especially aircraft at high altitudes. Method #3 should be used to establish a global unambiguous aircraft position with no 180NM limitation.

1.2 Local CPR Decoding (#1) Reasonableness Testing

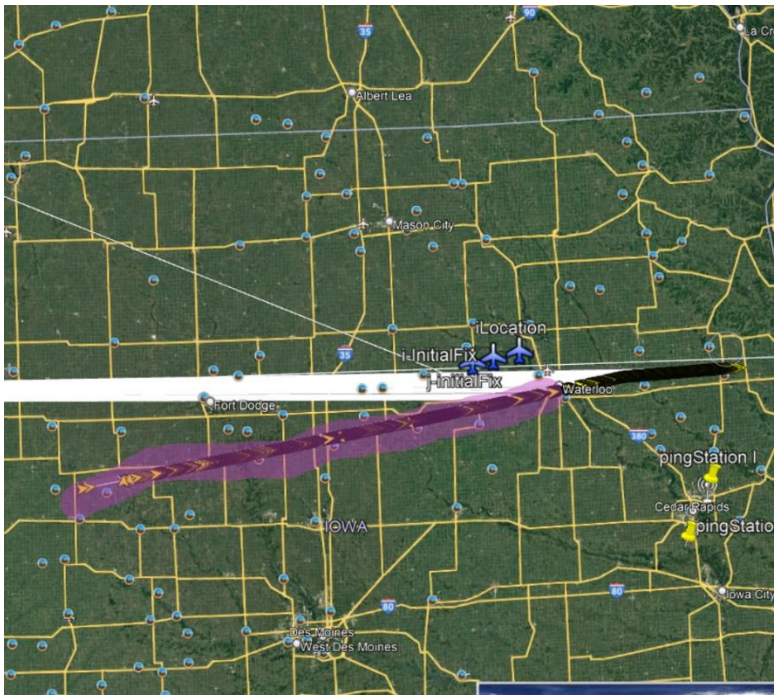
Local CPR decodes utilize the last known unambiguous lat/long of a target aircraft plus the latest CPR even or odd data from the 1090Mhz ADS-B Position Message (#1 above). Method #1 is vulnerable to cumulative error injected by a bad CPR decode or erroneously transmitted transponder position. Both of which are acknowledged by the need for reasonableness tests in DO-260B.

After analysis of such events, and despite passing the weak DO-260 prescribed parity checks, it was observed the test pingStations were occasionally receiving (2/day) bad CPR data from various aircraft. Since the bad data was used to update the cumulative aircraft position based on a local CPR decode, this led to an incorrect aircraft position for the remaining duration of the track.

1.2.1 Example

Below is one example of the phenomenon observed by uAvionix.

1. The pingStations observed the correct position of the aircraft north of Des Moines, IA on a heading of approximately 070°, shown in the purple highlight below.

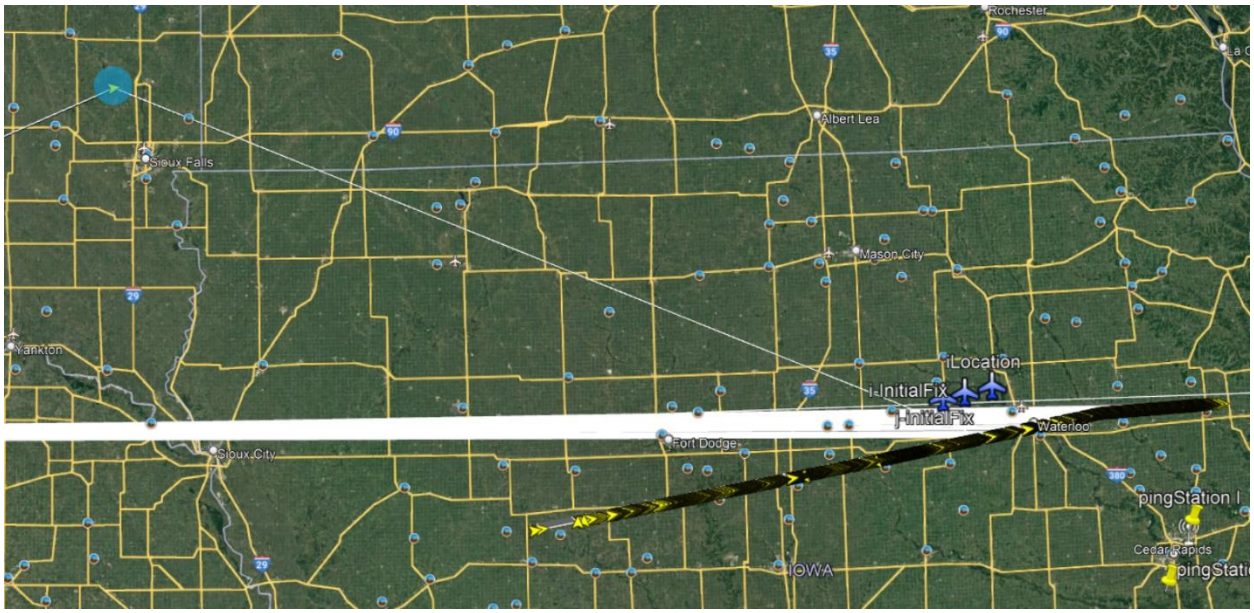


2. Then an erroneous lat/long CPR odd pairing arrived from the target aircraft (highlighted yellow below).

Wireshark Packet	Even Latitude CPR	Odd Latitude CPR
201907	10089	125705
201966	10089	125708
202041	10089	125708
202049	10089	125708
202051	10089	23257
202114	10106	23257 (coasted)
202174	10106	125721
202366	10106	125724

Wireshark Packet	Even Longitude CPR	Odd Longitude CPR
201907	88499	122260
201966	88499	122282
202041	88499	122282
202049	88499	122282
202051	88499	91347
202114	88613	91347 (coasted)
202174	88613	122365
202366	88613	122391

3. This caused an incongruous jump in the aircraft's track for both an even and odd local decodes. see blue highlight in the top left corner below:



4. Subsequently received CPR data was valid and track resumed on the correct heading but offset to the west in the adjacent longitudinal zone. Refer to orange highlight below.

1.2.2 Solution

Implement a local decode reasonableness test associated with method #1 for airborne aircraft. This test is based on DO-260B Section 2.2.10.6.3, whereby an individual CPR data is ignored if the position jumps by more than 6NM within a 10 second timespan which equates to an aircraft traveling more than 1,877knots.