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Integration of a SBS-3 ADS-B receiver in to the SGF, Herstmonceux aircraft safety system

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Abstract. *Following the successes of other SLR stations, the SGF, Herstmonceux purchased a SBS-3 receiver which decodes positions and velocities in ADS-B messages broadcast by aircraft. The unit is accessed over the network and the raw data stream was interpreted to extract the required information. This setup was found to be very reliable. A TCP/IP server was built to permanently connect to the SBS-3, translate the raw data and provide the results to multiple client connections. A separate connection to the server provides the real time SLR telescope and laser direction. An aircraft audio alarm client has been developed as well as a visual display client. This technique is accurate with alarms coinciding closely with the sounding of the pre-existing radar safety system. Further integration into the SGF SLR system is underway.*

Introduction

Dazzling from bright, high-powered laser pulses is hazardous to the human eye. It is therefore essential that SLR stations have safety precautions in place to avoid directly pointing at aircraft. At the SGF, Herstmonceux, as with many SLR stations, a radar safety system detects aircraft in the near vicinity of the laser beam direction and automatically inhibits firing.

In the emerging ADS-B technique, aircraft broadcast updates of their GNSS derived positions and velocities at approximately 1-second intervals. An antenna and receiver at the SGF can pick up these broadcasts from all aircraft above the horizon, giving near real-time positional information. An additional and independent SLR safety system is therefore possible using this data, which can operate alongside the current radar system.

Data Acquisition and Interpretation

The SBS-3 from Kinetic Avionics (http://www.kinetic-avionics.com) performs onboard decoding of ADS-B signals from a dedicated 1090MHz antenna. This information is made available firstly using the BaseStation software package, provided and maintained by the manufacturer. BaseStation translates the binary messages, calculates aircraft positions and velocities, displays the aircraft positions visually and makes the results available on a network socket. Alternatively the SBS-3 can operate as a stand-alone unit providing the raw binary data stream on a TCP/IP port.

Using the raw data stream required a procedure of extracting the information contained in the aircraft messages. This meant additional work but resulted in a simpler end solution. Altitudes and velocities were read from the binary code but latitudes and longitudes had to be calculated from the Compact Position Reporting (CPR) data format. The CPR format divides the Earth's surface in to zones by 60 latitudes and evenly spaced longitude lines. Each zone contains 2^{17} latitudes and 2^{17} longitudes indexes. An aircraft broadcasts its indexes but not the zone it is in. This must be determined using an additional 'odd' positional message that uses 59 latitudes and up to 59 longitudes. Once a pair of messages is obtained within a short time period the latitude and longitude can be determined.

The results derived from the raw data at the SGF now agree exactly with the data from the BaseStation package. Using the station coordinates, the latitude, longitudes and altitudes are converted to azimuths, elevations and ranges for SGF, Herstmonceux. Figure 1 shows aircraft trails over the SGF collected over 1-2 days. The facility is about 100km south from London and the nearest major airport is Gatwick which is about 60km away. A single aircraft sends many messages in the time it takes to cross the sky over Herstmonceux. Loss of data messages can be seen in figure 1 at high elevations, this is due to reduced coverage from the antenna used.

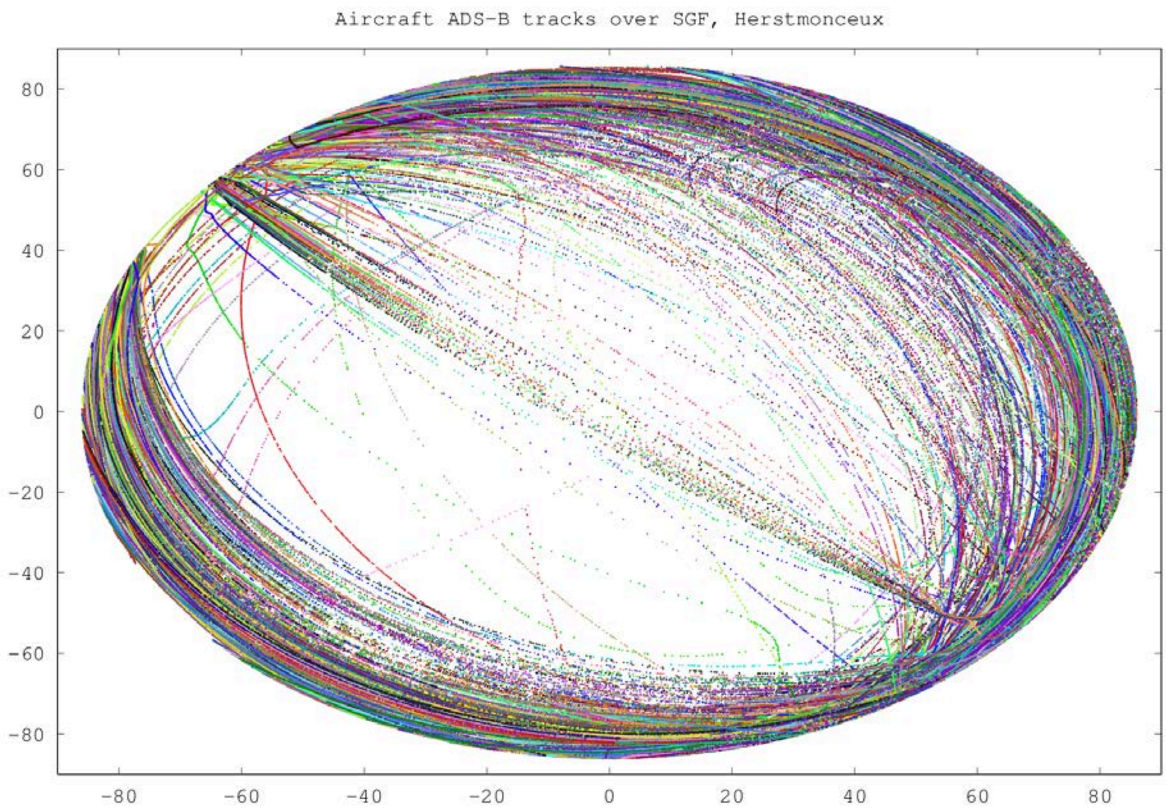

Figure 1. A sky plot of ADS-B aircraft positional data received by the SBS-3 installed at the SGF, Herstmonceux. Each aircraft traces a single colour line across the sky. Data loss can be seen at high elevations due to the antenna, which has good coverage at the horizon but poorer performance at higher elevations.

A TCP/IP Server and Applications

As only one connection is made to the SBS-3, a server was built to make the connection and run continuously. It also performs the necessary data operations and provides the results, including the calculated azimuths and elevations, to multiple connections. An additional connection to this server is made by the SLR ranging system to provide real-time laser telescope positional updates, which are then passed on to the output data stream. This server is stable and reliable and allows applications to connect and perform independent tasks.

A Python display application connects to the server and plots aircraft trails to inform the SLR observer standing beside the telescope and looking out for aircraft during ranging. Figure 2 is a snapshot from the display output in which aircraft trails can be seen. The laser direction is plotted in green and the Sun position is also included.

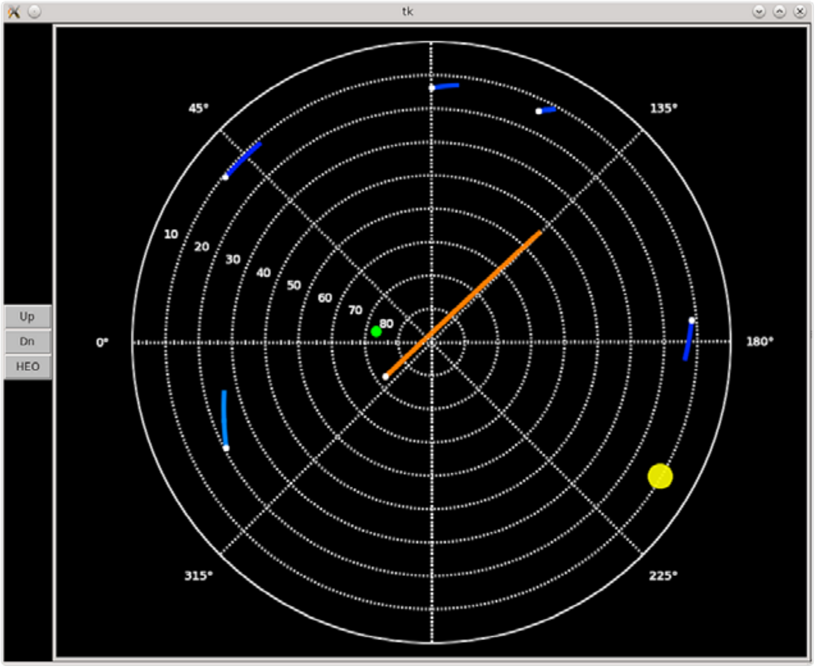

Figure 2. A real-time sky plot of aircraft trails over the SGF, Herstmonceux. Also included are the telescope pointing position and the Sun.

Advance Warning Alarm

In addition to an aircraft broadcasting its position 1-2 times a second, regular messages are also sent updating its latitude, longitude and altitude velocities. Using this information allows predictions to be made, giving advance warning if an aircraft is approaching the laser beam. The loss of data at high elevations is compensated for by having these predictions. In figure 3 the path of an overhead aircraft is plotted in red crosses as elevation against azimuth. The blue circles plotted are the positions predicted 10 seconds in advance. Not only do the predictions agree very well with the eventual actual position but they fill in the gaps seen in the data at higher elevations.

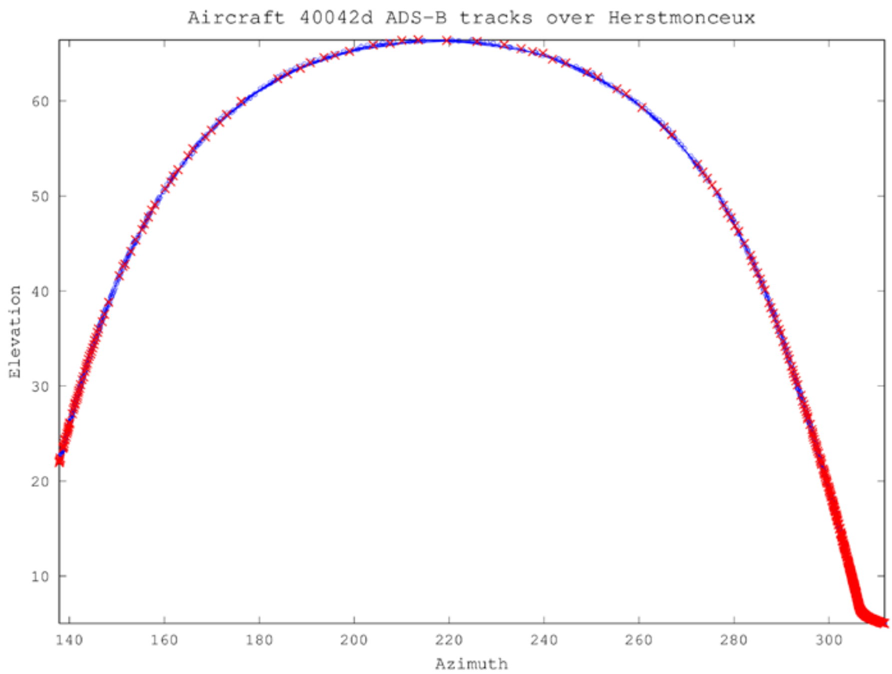

Figure 3. Positions of an aircraft in the sky above the SGF, Herstmonceux plotted as red crosses. Any gaps in the data are filled by the blue circles which are 10 second predictions from the broadcast velocities.

A client connects to the server and uses the positions and velocities to predict the location of each aircraft 10s in to the future. Also by knowing the position of the telescope provided by the server, the proximities of the planes in the sky to the beam are monitored. A suitable 'no-fire' boundary around each plane is required and this should be shaped so that it is larger in the direction that the plane is moving. Figure 4 shows a simulation of the boundary used for an example aircraft. The blue cross indicates the aircraft position and the blue circle is its predicted location. The plotted points are randomly generated telescope positions, green indicates that is safe to fire and the red points will trigger an audible alarm. The audible alarm system is working very well and is a helpful aid to the observer watching for aircraft. A higher pitch audible warning is also included using a tighter boundary and 2 second prediction.

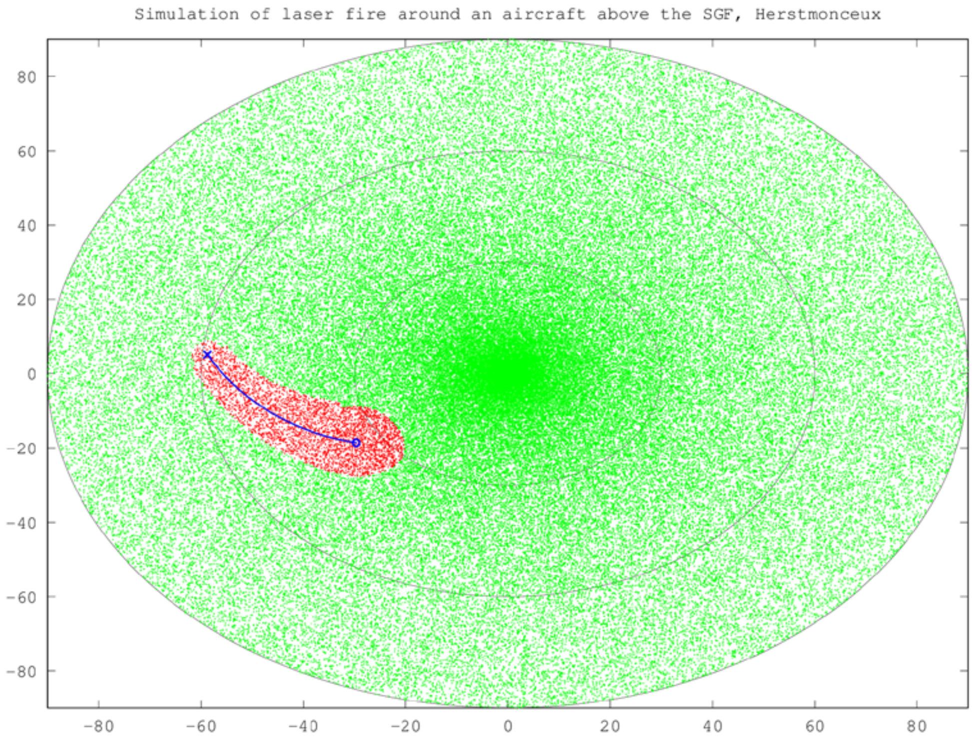

Figure 4. Telescope positions for which it is safe (green) and unsafe (red) to fire the laser due to the aircraft present. Plotted are the position and prediction for the aircraft and the boundary used around the plane is heavily stretched around the prediction to provide advanced warning to the observer

The SGF relies on the radar for in sky safety which has a total beam width of 3 degrees and also gives an audio warning when it shuts the laser off. At present, on occasions when an aircraft approaches the beam the 10 second alarm sounds first and alerts the observer to manually switch off the beam. As the aircraft moves even closer to the direction of the telescope the 2 second alarm and radar alarm sound at more or less the same time. From observer experience, the ADS-B technique agrees with the radar detection at the 1-2 degree level.

Future Development

The ADS-B has already proved to be a very useful tool for the observer as and early warning system. The shorter prediction has shown to agree well with the radar alarms and so will be further integrated in to the SLR system to automatically inhibit the laser firing when an aircraft is detected. This will provide an additional and independent layer of safety during SLR tracking.

Further work is planned to test the performance of the radar safety system by tracking aircraft to confirm full sky coverage. An antenna with better performance at high elevations is required and an investigation to identify a suitable upgrade is planned.

Conclusions

The SBS-3 is a reliable ADS-B receiver that allows access to the raw data stream of aircraft messages. The server built at the SGF to connect to the SBS-3 has been shown to be reliable and stable and able to accept multiple connections by different applications.

The accuracy of the continually updated positions and predictions from aircraft means the early warning alarms are very useful to the SLR observer. The technique agrees with the SGF radar aircraft detection system to about 1-2 degrees.

While the results have been impressive, this only applies to those aircraft carrying ADS-B systems, which at present is not all commercial flights and does not include light aircraft, gliders or hot air balloons.

References

Coote J., *Mapping planes using ADS-B.* Dissertation at University of Sussex, 2012.

Eckl J., Ettl M., *WLRS: In-Sky-Laser-Safety*, 17th ILRS Workshop, Bad Kötzting, Germany. 2011.

Marshall, A., *An Expanded Description of the CPR Algorithm*, RTCA, 2009.

Ploner M., Jaeggi A., Utzinger J., *Skyguide and Flarm - 2 in-sky-laser-safety systems used at Zimmerwald*, 17th ILRS Workshop, Bad Kötzting, Germany. 2011.

RTCS, *Appendix A: Extended Squitter and TIS-B Formats and Coding Definitions* in "*Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*".

Salminsh K., *Air traffic patterns near SLR site Riga and In-Sky laser safety*, 17th ILRS Workshop, Bad Kötzting, Germany. 2011.