GNSS RFI Detection in Switzerland Based on Helicopter Recording Random Flights

Maurizio Scaramuzza
Dr. sc. techn.
Head CNS Expert Group
Skyguide - Swiss Air Navigation Services Ltd.
Wangen, Switzerland
Fax: +41 43 931 66 19
E-mail: maurizio.scaramuzza@skyguide.ch

Heinz Wipf and Dr. Marc Troller
Skyguide - Swiss Air Navigation Services Ltd.
Wangen, Switzerland

Heinz Leibundgut
Swiss Air-Rescue, Rega
Zürich, Switzerland

René Wittwer
Armasuisse
Bern, Switzerland

Lt. Col. Sergio Rämi
Swiss Air Force
Dübendorf, Switzerland

ABSTRACT

In the framework of establishing Performance Based Navigation (PBN) in Switzerland a number of special issues have been identified. In conjunction with the implementation of Global Navigation Satellite System (GNSS) based rotary wing approaches, departures and low flight routes, special interest is on the probability of an aerial vehicle being affected by GNSS Radio Frequency Interference (RFI).

A project called Helicopter Recording Random Flights (HRRF) was launched, which objective is to install quick access recorders on board of three dozen helicopters operated by the Rega, the main Swiss Helicopter Emergency and Medical Service (HEMS), and the Swiss Air Force. Global Positioning System (GPS), Flight Management System (FMS) and Attitude and Heading Reference System (AHRS) data of every flight are recorded during a period of three years and under daily operation conditions. By this way large parts of Switzerland will be randomly covered. Common to all of these helicopter operations are low flight altitudes. Therefore it is expected, that the probability of them being exposed to RFI of GPS signal is higher than for fixed wing vehicles. Any exposure of this kind can be detected through the recorded GPS carrier to noise (CNo) measurements or position losses. The additional recorded data supports more in depth analysis of this kind of occurences.

INTRODUCTION

In the near future Switzerland's air space will primarily be managed by applying the performance based navigation concept. Therefore, the Swiss-wide Implementation Programme for SESAR-oriented objectives (CHIPS) has been initiated in 2008. In the frame of CHIPS a number of applied research and development efforts are undertaken in order to solve specific problems related to the peculiarities of Swiss air space.

A major topic is potential RFI impacting GNSS receivers used as primary navigation source. Different research studies are currently being conducted in this frame. One of them is called Helicopter Recording Random Flights (HRRF). Quick access recorders are being installed on board of roughly three dozen helicopters operated by Rega, the main Swiss Helicopter Emergency and Medical Service (HEMS), and by the Swiss Air Force. The objectives of this study are manifold: RFI detection, assessment of GNSS performance within a topographic challenging environment [1], assessing the potential of narrowed Required Navigation Performance (RNP) values and the quality of GPS performance and Receiver Autonomous Integrity Monitoring (RAIM) prediction tools.

It is of major interest that a large number of parameters from the onboard GPS receiver used for navigation as well as helicopter attitude and FMS data are recorded. These data sets allow to identify possible GPS RFI.

Data will be recorded randomly for a period of 3 years at each flight of each equipped aerial vehicle under normal operations conditions. Since most flights are carried out under Visual Meteorological Conditions (VMC) and have different missions, it is expected, that the lower part of the Swiss airspace will be randomly sampled.

This paper presents a model for RFI detection based on CNo and aerial vehicle attitude measurements.

TECHNICAL SOLUTION

The entire fleet of helicopters equipped with recording units consists of 11 AW109SP and 6 EC-145 operated by Rega, and 18 EC-635 (figure 1) operated by the Swiss Air Force. Due to the planned period of three years of data collection it was decided to have fixed installations. Figure 1 shows one of the Swiss Air Force's EC-635.

Figure 1. EC-635 of the Swiss Air Force (© VBS).

Installation

The technical solution is a mini Quick Access Recorder (mQAR) connected to the vehicle's ARINC bus, respectively RS-232 interface, depending on the architecture. The mQAR is a small size and small weight unit. Figure 2 depicts an installed mQAR.

As soon as the helicopter is powered up, the mQAR automatically starts recording the available data until the power is cut. Therefore no interaction by the pilot or ground crew is necessary.

Storage medium is a SD (Secure Digital) memory card which during normal operations can record several weeks of flight data. Ground crews at each helicopter base are instructed to download the recorded data periodically every 2 to 4 weeks and upload it to a common data storage.

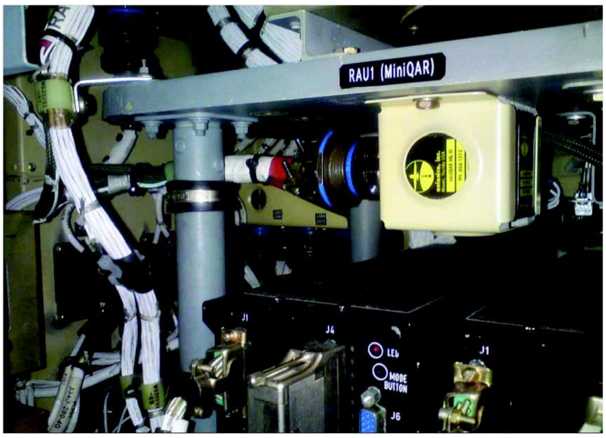

Figure 2. Installed mQAR, the gray Box on the Right Side of the Image.

Recorded Data

A large amount of data is available onboard. Basically, data from the three sensors GPS, AHRS and FMS are recorded on the EC-145/635 and GPS, FMS on the AW109SP.

GPS data on EC145/635 consist on GPS position, satellite vehicle position, pseudo range and pseudo range rate, horizontal and vertical integrity limits and figure of merits, carrier to noise ratio and different status parameters. Position domain data only is available on the AW109SP. AHRS data consist on roll, pitch and heading information. Finally the flight plan as well as the selected waypoints are available from the FMS. Sampling interval on GPS and AHRS is 1Hz.

RFI DETECTION

The main parameter used for GNSS RFI detection is the CNo of each tracked satellite. Any RFI would negatively affect all CNo.

RFI on a Static GPS Receiver

Assessing the CNo of each tracked satellite could give an indication on a possible RFI. Such an occurrence would decrease the CNo by a constant value at each single epoch because the entire GPS receiving antenna is affected by the same interference level. Figure 3 shows a real interference measured by a static GPS receiver. The interference appeared instantaneously and the CNo decreased by 5dB for all tracked satellites.

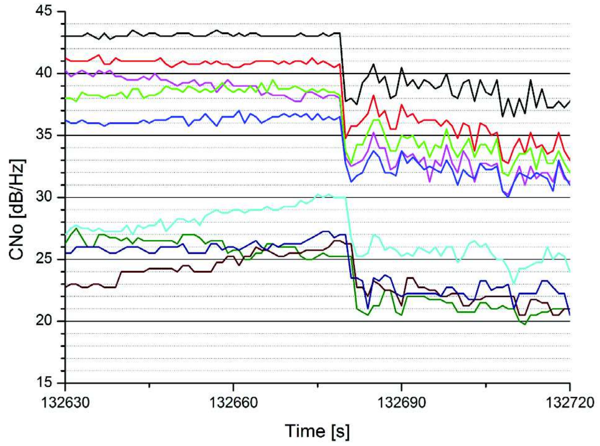

Figure 3. RFI on a Static GPS Receiver.

RFI Detection on a Dynamic GPS Receiver

RFI detection for a GPS receiver under dynamic conditions can be treated analogously, but two difficulties have to be taken into account. First a moving vehicle that approaches a RFI source would usually be gradually affected and the CNo would smoothly decrease in contrast to the example shown in figure 3. Second the positions of the satellites referred to the antenna have an impact on the CNo. Changes of attitude of vehicle affects the CNo values as shown as an example in figure 4.

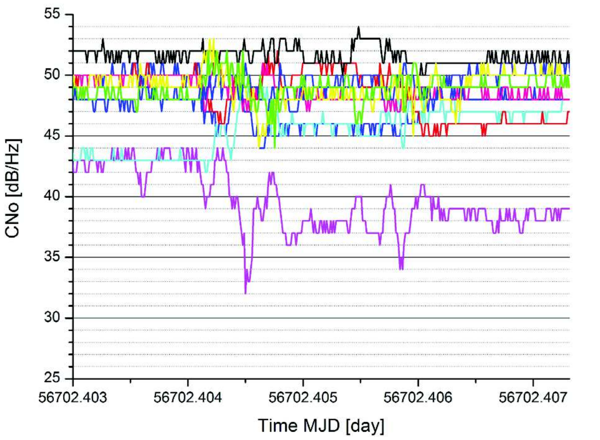

Figure 4. Helicopter Maneuver Affecting GPS Satellite's CNo.

The CNo alteration at the time of 56702.404, given in days within MJD (Modified Julian Date) calendar, cannot be attributed to a RFI as some satellites are negatively and some positively affected. The observed values of roll and pitch angles indicate that a maneuver has taken place at this moment (figure 5).

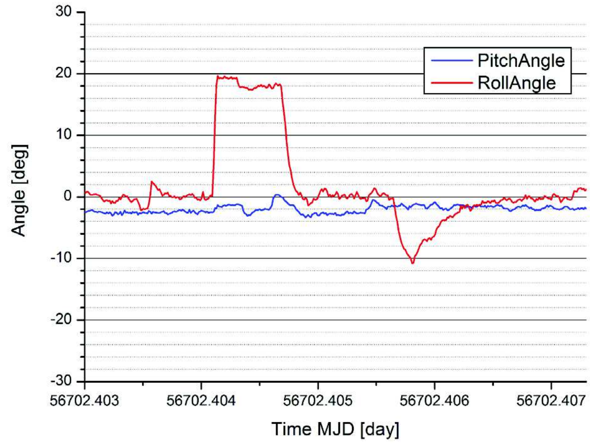

Figure 5. Pitch and Roll Angles Affecting the CNo Shown in Figure 4.

Following reasons apart from RFI might have an impact on the CNo measurements:

1. signal fading caused by multipath from environment outside the airframe
2. signal fading caused by multipath at the airframe
3. signal attenuation caused by the air frame (shadowing)
4. antenna gain pattern
5. variations in attenuation of cabling and gain of amplifiers (antenna and receiver)
6. troposphere
7. ionosphere

Reason 1 can be brought under control by limiting the measurements, where the helicopter has a minimum velocity over ground. By doing that it can be avoided that the geometry between satellite, reflector and GPS antenna remains constant over a longer period and therefore signal fading is very short and averaged.

Reasons 2 to 4 are always present and have to be taken into account. Common to these reasons is, that the signal attenuation depends mainly on the satellite position with respect to the local coordinate system of the antenna.

Reason 5 is neglected as these amplifications and losses are constant for all tracked satellites.

Reasons 6 and 7 are always present analogously to reasons 2 to 4, but are independent on the vehicle's attitude. In this case it is of interest to have an estimation on the signal attenuation due to troposphere and ionosphere. A major reason for the selection of the L-band for GNSS purposes is the low signal attenuation due to atmosphere. The tropospheric attenuation is far below 1dB for signal paths entirely within the troposphere [2], [3]. It is even lower for space-earth signal paths. The ionospheric attenuation is assumed to be negligible [4]. Particular care should be taken under ionospheric scintillation conditions, where the attenuation can be increased at levels over 20dB [5], [6]. Ionospheric scintillation is maximum near the geomagnetic equator and smallest in the mid-latitude regions [5]. Despite the location of Switzerland at mid-latitudes it is advantageous to avoid RFI detection recordings during ionospheric scintillation activities.

Finally only causes 2 to 4 are relevant for RFI detection. These impacts on CNo can be derived empirically by determining the CNo of the tracked satellites referred to the antenna over a long period. Figure 6 shows a polar plot of the mean CNo for bins of the size of 5° by 5° measured during 8 hours of flight for one helicopter type.

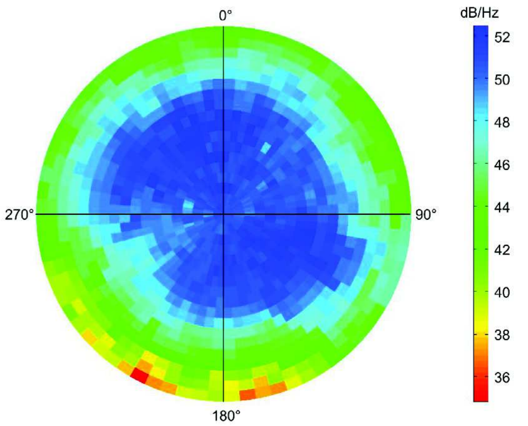

Figure 6. Polar Plot of Mean CNo Referred to the Antenna.

A CNo of roughly 50 dB/Hz is measured for satellites at the antenna zenith. The difference between this 50 dB/Hz and the measured CNo for satellites at other positions than the antenna zenith indicates the signal attenuation depending on the antenna azimuth and zenith distance. With the knowledge of these differences the measured CNo can be compensated to a nominal value of 50dB/Hz. Figures 7 and 8 show the effect of this compensation. The measured CNo are shown in figure 7 where the compensated CNo are represented in figure 8 (red lines).

A simple indicator for RFI is the mean value of the compensated CNo, which is represented as blue line in figure 8. This mean value is 50 dB/Hz with small noise. Because a RFI affects the CNo of every satellite signal by the same level, the mean value of the compensated CNo is affected by the same level too. Therefore a RFI reducing the CNo by only a few dB can be detected with this model.

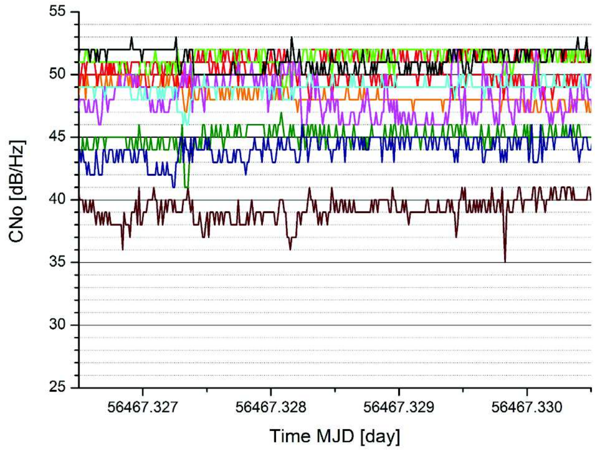

Figure 7. Measured CNo.

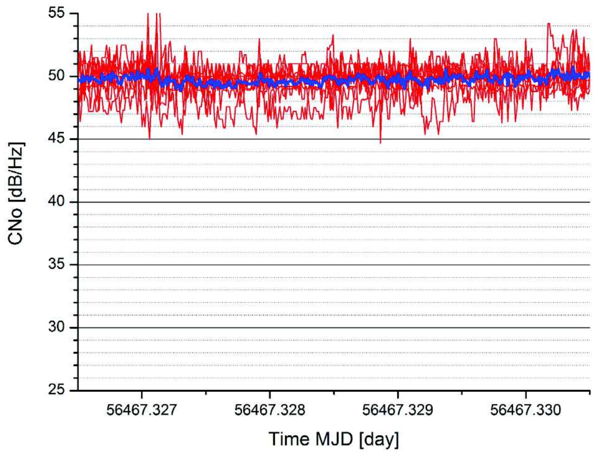

Figure 8. Compensated CNo (Red Lines) and Mean of Compensated CNo (Blue Line).

CONCLUSIONS

A model has been developed, which enables to detect potential RFI based on measurements of CNo and aerial vehicle attitude. CNo attenuation due to the antenna pattern and antenna environment is taken into account. RFI affecting the CNo by only a few dB can be detected with this model.

FUTURE WORK

Improvement of this RFI detection model can be achieved by refining the antenna CNo attenuation pattern. This is done by assessing a larger amount of data recorded on flight. Further it is expected that additional recorded parameters are also affected under RFI conditions. Taking these parameters into account will reduce the probabilities of missed and false RFI detection.

ACKNOWLEDGMENTS

Special thanks go to CHIPS and the Swiss Federal Office of Civil Aviation for the financial support of this project within the frame of the applied research and development programme for implementation of future navigation applications in Switzerland.

REFERENCES

[1] Scaramuzza et al., 2013, GNSS Navigation Performance versus Aerial Vehicle's Trajectory in Mountainous Terrain, ISPA 2013.

[2] Curry, Richard, 2012, Radar Essentials, Scitech Publishing Inc.

[3] ITU, 2013, Attenuation by atmospheric gases, Recommendation ITU-R P.676-10, P Series, Radiowave propagation, 09/2013.

[4] Christie, Jock et al., 1996, The Effects of the Ionosphere and C/A Frequency on GPS Signal Shape: Considerations for GNSS-2, Proceedings of the 9th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GPS 1996).

[5] ITU, 2013, Propagation data and prediction methods required for the design of Earth-space telecommunication systems, Recommendation ITU-R P.618-11, P Series, Radiowave propagation, 09/2013.

[6] ITU, 2013, Ionospheric propagation data and prediction methods required for the design of satellite services and systems, Recommendation ITU-R P.531-12, P Series, Radiowave propagation, 09/2013