The SBAS Integrity Concept Standardised by ICAO. Application to EGNOS

Benoit Roturier(DGAC/STNA), Eric Chatre(DGAC/STNA), Javier Ventura-Traveset (ESA)
roturier_benoit@stna.dgac.fr, chatre_eric@stna.dgac.fr, Javier.Ventura-Traveset@esa.int

BIOGRAPHY

B. Roturier graduated as a CNS systems engineer from Ecole Nationale de l'Aviation Civile (ENAC), Toulouse in 1985 and obtained a PhD in Electronics from Institut National Polytechnique de Toulouse in 1995. After 3 years in charge of Instrument Landing Systems at DGAC/STNA (Service Technique de la Navigation Aérienne) and 9 years of teaching and research activities on CNS systems at ENAC, B. Roturier is currently in charge of GNSS Navigation subdivision at STNA and is involved in several projects including GPS/ABAS, EGNOS and Galileo.

Eric Chatre graduated as an electronics engineer in 1992 from the ENAC (Ecole Nationale de l'Aviation Civile), Toulouse, France. Since 1994, he has been working with the Service Technique de la Navigation Aérienne (STNA) in Toulouse on implementation of satellite navigation in civil aviation. He is involved in the development of EGNOS and in the definition phase of Galileo. He is also participating in GNSS standardization activities in EUROCAE, RTCA forums and is currently the chairman of ICAO GNSSP technical group.

Dr. Javier Ventura-Traveset holds a MS in Telecom. Engineering from the Polytechnic Univ. of Catalonia (Barcelona, Spain, 1988); a M.S.E in Signal Processing by Princeton University (Princeton, NJ, USA) in 1992; and a PhD in Electrical Engineering by the Polytechnic of Turin (Italy) in 1996. Since March 1989, he is working at the European Space Agency (ESA) involved in mobile, fix, earth observation and satellite navigation programs; he is currently the Principal System Engineer of the EGNOS SBAS Project. Dr. Ventura-Traveset holds 4 patents and has co-authored over 100 technical papers. He is member of ION and Senior-member of the IEEE.

ABSTRACT

There have been a lot of debates, within the International Civil Aviation Organisation (ICAO) GNSS Panel (GNSSP) group of experts, on the proper way to ensure SBAS user safety while at the same time respecting the high availability requirement. The group finally validated a method at the GNSSP Seattle meeting in June 2000 which is reproduced in the GNSS Standards And Recommended Practices (SARPs) to be published in November 2001. However, if the technical relevant information for a SBAS system designer to implement the SBAS integrity concept is fully described in the SARPs, only the strict necessary information is reported there and it is quite difficult to a non specialist to properly understand this important concept.

Therefore, since the SBAS integrity concept is quite specific and new, some kind of complementary information to the SARPs was felt desirable. This paper tries to address this concern and will also illustrate how the integrity is being managed through the European EGNOS SBAS project.

I. INTRODUCTION

The integrity service of ICAO compliant GNSS systems may currently be provided by the three normalised augmentations known under the terms ABAS (Airborne Based Augmentation System), GBAS (Ground Based Augmentation System) and SBAS (Satellite Based Augmentation System) [1]. ABAS integrity concept relies on the single observation through the airborne user receiver of redundant pseudo range information, while GBAS (resp. SBAS) integrity elaboration relies on the use of a single (resp. a network) of ground reference stations.

In addition to integrity service, GBAS and SBAS also provide to the user differential corrections to improve the precision in a restricted area around a single reference station for GBAS and over a wide area defined by a network of reference stations for SBAS.

Finally, the SBAS geo satellites also transmit a ranging navigation signal similar to a GPS satellite.

Therefore, the SBAS integrity service which is addressed here should protect the user from both:

- failures of GPS/GLONASS/GEO satellites (drifting or biased pseudo ranges) by detecting and excluding faulty satellites through the measurement of GPS signals with the network of reference ground stations
- transmission of erroneous or inaccurate differential corrections. These erroneous corrections may in turn be induced from either:
  - undetected failures in the ground segment,
  - processing of reference data corrupted by the noise induced by the measurement and algorithmic process.

This last type of failure, which may occur when the system is in a nominal state (no GPS/GLONASS/GEO satellite failure, no ground segment/user equipment failure) is usually known as "fault free case". Protection of the user against noise effects has been quite demanding during the process of definition and validation of the ICAO SBAS integrity concept. In fact, the potential for such non integrity events generated in fault free conditions is inherent to data measurement and processing, to provide users with basic and precise correction messages and is thus a permanent risk which has to be carefully managed. This has involved the definition of statistical error bounds called horizontal or vertical protection levels (HPL or VPL) which will be discussed in depth in section V.

Before dwelling in depth into the details of the elaboration of adequate parameters to protect users from non integrity events which might occur from system failure (section IV) or noise (section V), we will recall integrity requirements (section II) and integrity definitions (section III).

II. INTEGRITY REQUIREMENTS

The elaboration of a high level fault tree for all phases of flight leading to a given objective in term of Target Level of Safety (TLS)[1] and further decomposition for a number of phases of flight into aircraft, airborne database and signal in space (SIS) contribution to this risk has been provided by the ICAO All Weather Operational Panel (AWOP) [2], [3].

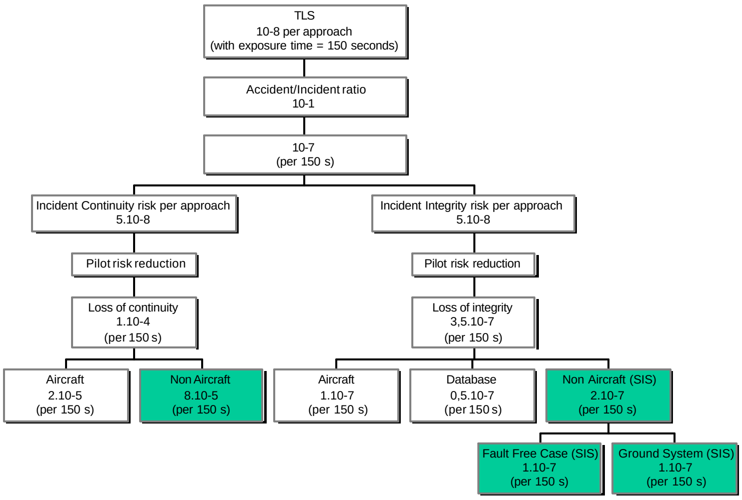

Figure 1. Fault tree allocation for SBAS APV I, II and Cat I operations

The fault tree for approach with vertical guidance (APVI,II and Category 1 approach type) corresponding to the most demanding operations supported by SBAS derived from AWOP work is shown in Fig. 1[2].

This paper will focus on Non Aircraft, signal in space (SIS) integrity risk corresponding to the bottom right part allocations of Fig. 1.

AWOP work has been used as input by GNSSP to define the high level integrity requirements summarised in Fig. 2.

Typical operation	***Time to Alarm***	***Integrity***	***Hor. alert limit***	***Vert. alert limit***
En-route	*5 mn*	$1\text{-}10^{-7}$/h	*4 NM*	*N/A*
En-route	*15 s*	$1\text{-}10^{-7}$/h	*2 NM*	*N/A*
En-route, Terminal	*15 s*	$1\text{-}10^{-7}$/h	*1 NM*	*N/A*
NPA	*10 s*	$1\text{-}10^{-7}$/h	*0.3 NM*	*N/A*
APV I	*10 s*	$1\text{-}2\text{x}10^{-7}$/app	*0.3 NM*	*50 m*
APV II	*6 s*	$1\text{-}2\text{x}10^{-7}$/app	*40.0 m*	*20 m*
CAT I	*6 s*	$1\text{-}2\text{x}10^{-7}$/app	*40.0 m*	*15 - 10 m*

Figure 2. ICAO SARPs high level integrity requirements on SIS

III. INTEGRITY DEFINITIONS

The provisions for integrity in the SARPs are complex for a non expert, but also are the definitions of non integrity events and three levels of definitions may be identified which are further discussed in this section.

III.1 High level definition of integrity

The high level definition of *integrity* in the SARPs is ([1] §A.1):

A measure of the trust which can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts).

It has to be noted that the integrity requirement in Fig. 2 includes both an alert limit in horizontal and vertical dimensions and an allocated time to warn the user. Moreover, the integrity is often specified by its inverse, *integrity risk*, as in Fig. 1. The integrity risk may be defined as the probability of providing a signal that is out of tolerance without warning the user in a given period of time.

The out of tolerance condition is defined in the SARPs in the *user position domain*. Although it might seem obvious from the high level definition of integrity given above that a non integrity event corresponds to the situation obtained when any user navigation system error (NSE) in horizontal or vertical dimensions is superior to Horizontal or Vertical Alert Limit (HAL or VAL), while not providing timely and valid warnings to the user, the definition which has been retained in the SARPs is a little bit more conservative (as shown in [4]), and is described in the next section.

The above situation (NSE > HAL or VAL) is often referenced as “*Hazardously Misleading Information* case.

---

[1] The top TLS objective is that the probability of accident leading to hull loss should be inferior to 1.5 10-7 per flight

[2] The AWOP 2.10-7 figure for SIS integrity risk by approach (150 s) has been further decomposed by GNSSP into a 10-7/approach allocation for the ground system integrity risk and a 10-7/approach allocation for the fault free case.

III.2 Non integrity event definition applicable to the ground system designer:

This definition (in the most demanding case of APVII or Cat I) may be found in [1] §B.3.5.7.5.1 :

"Given any valid combination of active data, the probability of an out-of-tolerance condition for longer than 5.2 consecutive seconds shall be less than 2 x 10^{-7} during any approach, assuming a user with zero latency. An out-of-tolerance condition is defined as a horizontal error exceeding the HPL_{SBAS} or a vertical error exceeding the VPL_{SBAS} (as defined in B.3.5.5.6)."

The Horizontal and Vertical Protection Level (HPL and VPL) are elaborated within the user receiver (cf [1] B.3.5.5.6) at each epoch by combining ground transmitted parameters, aircraft parameters and geometry of the user with respect to satellites used in the position calculation. They will be further discussed in section V.

This definition (NSE > HPL or VPL) is often referenced as *"Misleading Information (MI)"* case.

It has to be used by a SBAS system designer to prove by simulation and/or tests that the SBAS design is SARPs compliant with respect to integrity requirements. It is also a high level requirement for the calculation of ground parameters used in XPL elaboration by a SBAS system designer, as further discussed in section V.3.

However, since this definition implies the knowledge of the NSE, a standard user may obviously not apply this out of tolerance test to raise a flag in case of non-integrity event.

III.3 Non integrity event definition applicable to a SBAS standard user:

The test to be done at user level to check the correctness of transmitted data is defined in SARPs ([1] §B.3.5.8.4.2):

"The receiver shall compute and apply horizontal and vertical protection levels defined in B.3.5.5.6"

This definition is not really explicit (!), but more may be found in the guidance material section ([1] §C.6.4.4):

"… If the computed HPL exceed the Horizontal Alert Limit (HAL) for a particular operation, SBAS integrity is not adequate to support that operation. The same is true for precision approach and APV operations, if the VPL exceeds the vertical alert limit (VAL)."

This test (HPL or VPL > HAL or VAL), which is implemented at each epoch, allows to declare the SBAS *"system unavailable"* for a given level of operation since in this case the probability of an MI (and HMI) event is high. Note that xPL and xAL (x stands either H or V) are now known by the user.

If a SBAS is SARPs compliant as defined in section II.2, then a user applying the above test will be protected to the required level.

III.4 Example

The three above discussed integrity tests (HMI, MI and system unavailable) appear more explicitly in figure 3:

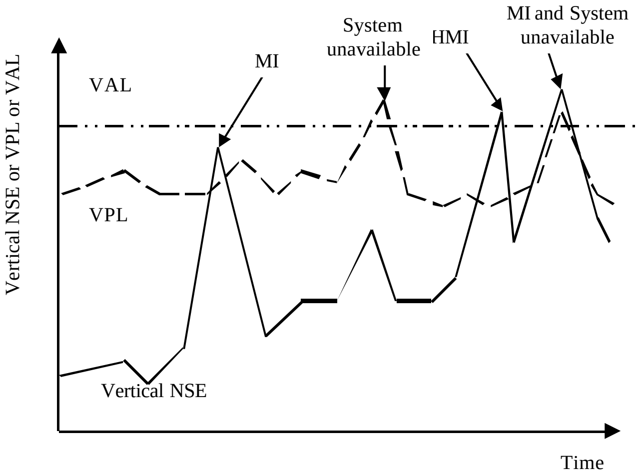

Figure 3. Example of the different non-integrity definitions and tests

Another practical representation of these different cases is obtained through a 2D plot of the Vertical Position Error (VPE) against the VPL where each pixel corresponds to a measurement epoch as in Fig. 4. These results correspond to 5 hours recording and may be obtained with a test receiver at a known location, using Eurocontrol Pegasus or ESA-ESPADA tools for example.

Fig. 4 illustrates the trade off between integrity and availability. The diagonal traces the limit between the safe operation of the system (left side) and the unsafe conditions (right side). The EGNOS System Test Bed is shown to be safe in the nominal test conditions of Fig. 4, with an availability of APV-II above 99.5% for this specific test period.

Fig. 5, obtained with ESA-ESPADA SW indicates for the same period of time Availability across Europe of APV-II (VAL=20 metres). It shows the encouraging result that despite the low number of reference stations of the EGNOS Test bed (8 against 34 of future operational EGNOS), service volume coverage is very good across Europe.

It may also be noted from Fig. 4 that the best way to tune SBAS integrity parameters would be to have the cloud of pixels located parallel to the diagonal and just above it in the safe area. This would mean that for a given vertical position error, the associated VPL would be just slightly higher, therefore impacting at the minimum the system availability while respecting integrity.

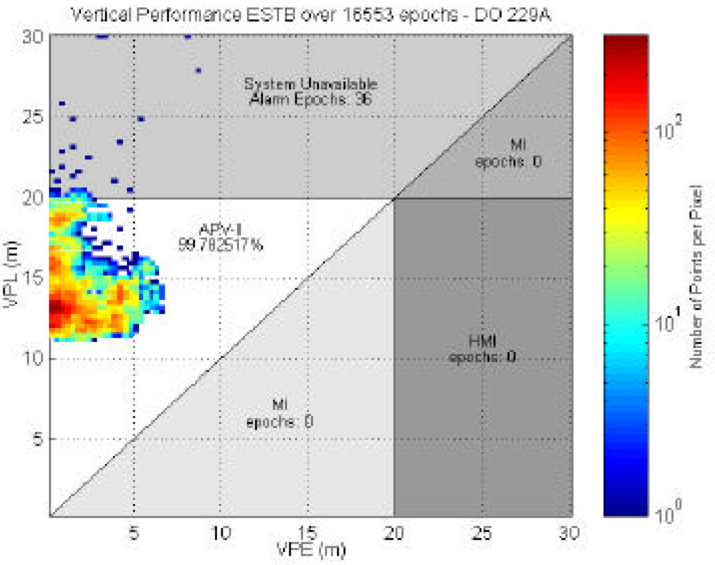

Figure 4. EGNOS testbed integrity test example for APVII.

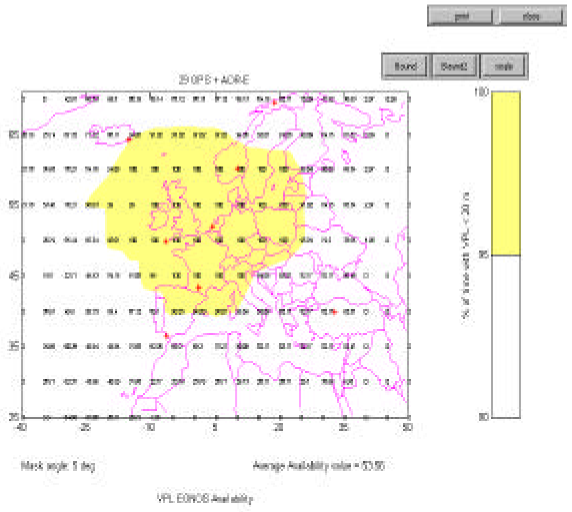

Figure 5: EGNOS test bed availability test example for APVII

IV GROUND SYSTEM INTEGRITY

The ground system integrity risk allocation shown at the bottom of Fig. 1 (10-7/app in case of APV and Cat I operations) should cover:

- ❑ Failures on navigation code and data transmitted by GPS/GLONASS satellites (including evil waveforms).
- ❑ Corruption of data to be transmitted to the user, through the geo satellites.
- ❑ Failures issued from the ground system hardware, software design or corruption of data through the Wide Area Network connecting the ground elements.

IV.1 Faulty GPS/GLONASS satellites

When such a failure occurs, the ground segment will provide the appropriate corrections along with the parameters allowing XPL calculation, unless the error gets too large in which case the faulty satellite is flagged with a ”don’t use” status. When the error is not significantly large, the user equipment will process these data and the only impact will be on system availability and continuity through XPL inflation at user level.

In EGNOS system, specific modulation distortion failures (evil waveforms) are also managed through Signal Quality Monitoring (SQM) defined in [1] using specific Reference and Integrity Monitoring Stations type C (RIMS C).

IV.2 Corruption of data through geo link

EGNOS has implemented the following techniques defined in ICAO SARPs [1] to minimise at the lowest possible level the risk of data corruption through the geo link:

- ❑ convolutional encoding adding a bit to each information bit, allowing Forward Error Correction (FEC) at the receiver level and providing a high level of robustness to channel burst errors.
- ❑ 24 bit Cyclic redundancy check (CRC) providing a very low probability of undetected error within a message.

Bit to bit comparison of transmitted messages in the ground segment is also realised. The impact of errors induced by this type of failures at user level should therefore be very low.

IV.3 Hardware, Software and Wide Area Network failure

No recommendation exists in the SARPs on the design of the ground segment. The SBAS system designer has to demonstrate that the probability of undetected failures transmitted through the SIS will be inferior to the integrity risk allocation for ground system failures given in Fig. 1.

Due to space restriction, it is not possible to go into details in this paper of ESA recommended techniques to provide the required integrity level for EGNOS. Some important features are listed below:

- ❑ Two independent processing chains, one checking the other, fed by two different reference stations (RIMS A and B) developed by separate manufacturers to avoid common modes of failure are implemented
- ❑ Specific and independent RIMS –C network for evil waveform detection
- ❑ Software integrity is managed through appropriate design methodology (based on DO178B Standards).

- A complementary set of integrity mechanisms which are automatic safety devices (no actions of operators required as the time to alarm requirements does not allow it) and they are independent of the EGNOS monitoring & control,
- All data transported over the EGNOS Wide Area Network is protected by a 32 bit CRC.

The interested reader might consult [5] for example for more details.

The undetected failures from the ground segment could introduce corrupted data in the transmitted messages. If the integrity requirement is not met, the user will obviously not be protected against such failures by the XPL algorithms. To fulfil the integrity requirements, the ground system shall reduce the probability of failure of each critical function and shall be able to detect this kind of failures with a global probability of missed detection (Pmd) defined by:

$$Pmd_{ground\ monitor} = Integrity\ requirement\ /\ Pr_{failure\ ground\ segment}$$

V FAULT FREE CASE INTEGRITY

V.1 The XPL algorithms

To protect the user against misleading information (MI) due to data corrupted by the noise induced by the measurement and algorithmic process when the system is in a nominal state (no GPS/GLONASS/GEO satellite failure, no ground segment/user equipment failure), it has been shown that SARPs require the elaboration by the ground segment of two different parameters used in the XPL computation. These parameters give an indication on the error uncertainty, which is modelled by:

- the variance (σ_{UDRE}) of a zero-mean normal distribution which describes the user differential range errors (UDRE) for each ranging source after application of fast and long-term corrections, and excluding atmospheric effects and receiver errors,
- the variance (σ_{UIRE}) of a zero-mean normal distribution which describes the L1 residual user ionospheric range error (UIRE) for each ranging source after application of ionospheric corrections. This variance is determined from the variance (σ_{GIVE}) of an ionospheric model based on the broadcast grid ionospheric vertical error (GIVE)[3].

The other potential errors to affect user integrity in nominal conditions considered by GNSSP are:

- aircraft pseudo range errors due to the combination of receiver and aircraft multipath (ground multipath is not considered here). This error is well characterised by a zero mean normal distribution whose variance σ_{air} is given by the sum of SARPs modelled variance of receiver and aircraft multipath error.
- The residual pseudo range error of a tropospheric correction model, characterised by a variance σ_{tropo} which is defined by a standard model in the SARPs

Since all these individual pseudo range errors are supposed to be characterised by independent, zero mean, normal distributions, the global residual pseudo range error for the i^th^ ranging source (σ_i) may also be characterised by a zero mean normal distribution whose variance is:

$$\sigma^2_{i} = \sigma^2_{i,flt} + \sigma^2_{i,UIRE} + \sigma^2_{i,air} + \sigma^2_{i,tropo} \quad (1)$$

Where $\sigma_{i,flt}$ may be straightforwardly derived from σ_{UDRE} through a tedious calculation given in SARPs ([1] B.3.5.5.6.2) to take into account degradation parameters in case of missed SBAS messages.

From (1), and for a given user to ranging sources geometry, it is quite straightforward to derive the vertical protection level (VPL) equation by[4]:

1) going from the pseudo range variance domain through the position variance domain (this is necessary because the integrity definitions are all in the position domain)
2) by scaling the position domain variance to the integrity requirement.

The first step is straightforward since it is well known that the position domain residual error can be considered as a linear combination of pseudo range errors used in the navigation solution. Therefore the variance in the position domain residual error is a linear combination of σ_i^2 and is also representative of a zero mean Normal law:

$$\sigma^2_{Vposition} = \sum_{i=1}^{N} S^2_{V,i}\sigma^2_{i} \quad (2)$$

Where $S_{V,i}$ are geometrical parameters defined in [1], [6]. The second step is obtained by multiplication of the position domain variance by a factor K that propagates this variance to a level compatible with the integrity requirement. The VPL equation is then simply:

$$VPL_{SBAS} = K_V \sqrt{\sum_{i=1}^{N} S^2_{V,i}\sigma^2_{i}} \quad (3)$$

The derivation of K, which not very explicit in the SARPs, is given in section V.2.

V.2 Derivation of K factors for XPL computations

First it is important to note that the probability of missed detection of a MI event associated to the XPL algorithm (Pmd_{XPL}) has to be expressed per sample (per each XPL computation). In order to establish the link between this Pmd and the integrity requirement, it is necessary to make

---

[3] More precise definitions of the ground segment elaborated parameters σ_{UDRE} and σ_{GIVE} may be found in [1], §C.6.4.6 and C.6.4.7.

[4] The derivation of horizontal parameters proceeds in a similar way.

assumptions on the number of independent sample per time unit.

For example if there are n independent samples/operation, and the integrity requirement for this operation is 10^{-x}, the Pmd to be specified for the XPL will be:

$$Pmd_{XPL} = 10^{-x} / n \qquad (4)$$

Therefore in order to establish the appropriate value of K, it is necessary to first determine the number of independent samples per time unit. Based on ionospheric corrections, 360 s has been adopted as a reasonable assumption to ensure independence. Using this value, it is possible to compute the required probability of missed detection associated to HPL for each phase of flight.

- En route to NPA: the requirement is $0.5.10^{-7}$/h

  $$Pmd_{HPL} = 0.5.10^{-7} * 360 / 3600 \sim 5*10^{-9} \text{ per sample}$$

- APV I, II, Cat I: The apportionment between HPL and VPL has been chosen such that the continuity of service is maximised. Since there is a conformable margin on the horizontal position (larger alert limit and better accuracy performance), the integrity allocation has been minimised. The following Pmd have been chosen ([1],[6]) for HPL and VPL (a decorrelation time of 360s implies that during the approach (150s) there is only one independent sample):

$$Pmd_{HPL} = 10\text{-}9 \text{ per sample.}, Pmd_{VPL} = 10^{-7} \text{ per sample}$$

Using appropriate statistical laws for the distribution of residual position errors, it is now possible to compute the K factor that scales the variance to a level compatible with the integrity requirement. K is determined from a Rayleigh distribution for En route to NPA applications since the protection has to be bi-dimensionnal. For APVI, II and Cat. I applications, two uni-dimensional k factors are determined from a Normal distribution corresponding to the lateral (crosstrack) and vertical protections.

Looking at Fig. 6, it may be seen that the value of K may be directly calculated from the knowledge of the cumulative distribution function (cdf) of the relevant statistical law.

- For en route to NPA applications, the value for K is therefore:

  $$K_{H\ NPA} = \text{Rayleigh cdf}^{-1}(1\text{-}5*10^{-9}) = 6.18.$$

- For precision approach (PA) applications (APV I, II, Cat 1), the K values for lateral and vertical protections are:

  $$K_{V\ PA} = \text{Normal cdf}^{-1}(1\text{-}10^{-7}/2) = 5.33$$

  $$K_{H\ PA} = \text{Normal cdf}^{-1}(1\text{-}10^{-9}/2) = 6.0$$

These values are in accordance with the K parameters given in the SARPs in section B.3.5.5.6.1.

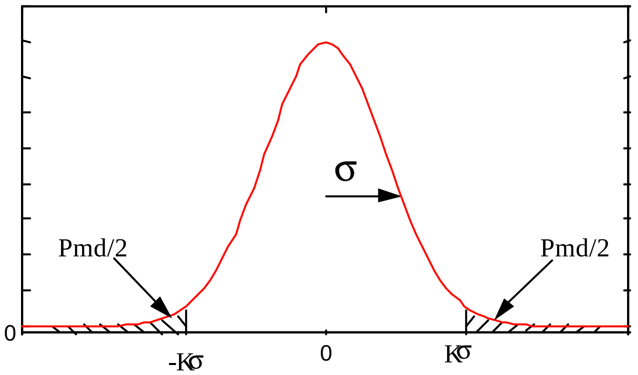

Figure 6. Evaluation of K for a zero mean normal law distribution of residual position errors

V.3 Discussion on zero mean, normal distribution assumption

As stated in the SARPs ([1] §C.6.4.5):
challenging tasks for an SBAS provider is to determine UDRE and GIVE variances such that the protection level integrity requirements are met without impacting availability. The performance of individual SBAS depends on the network configuration, geographical extent and density, the type and quality of measurements used and the algorithms used to process the data."

An important item in the background of this statement is that the variances representative of the ground system residual errors for each ranging sources have to be derived from zero mean Normal laws for the XPL computation to be valid. It has been shown in the previous section that this assumption is important in several steps of the XPL algorithm elaboration.

However in practice the distribution of individual pseudorange residual error, although in practice not very different from Normal laws, may not have Normal tails, or not have a zero mean, or sufficient data to demonstrate the distribution may not be available.

When this issue was first investigated in the aviation community, the idea was that overbounding the individual arbitrary error distributions contributing to the position domain error by zero mean normal distributions[5] would allow to overbound the distribution of total error with a zero mean normal distribution which could then be used in the XPL algorithm.

However further inspection revealed that this idea might not be valid for any individual error distribution. It was shown [7] that a *sufficient condition* for the above overbounding strategy to hold was that each initial error distribution was not necessarily normal but unimodal and symmetric. Still, it was not possible to ensure that for any SBAS this condition would be true, since the ground segment architecture is not specified in the SARPs.

---

[5] overbounding in the probability density function (pdf) sense then in the cumulative density function (cdf) sense were successively investigated, cf. [7]

ICAO GNSSP then finally decided at Seattle meeting in June 2000 that since the shape of the error distributions will be very dependant of the SBAS system architecture and algorithms and no general overbounding method could be identified, it would be the responsibility of the system designer to provide a method to compute UDRE and GIVE variances in compliance with the high level 2.10-7/app requirement given in section III.2. Two detailed work plans (called Integrity & Continuity work plans) have been launched in the case of EGNOS, specifically, to assess that methodology in detail for the case of EGNOS own architecture and algorithms.

VI SUMMARY

The ICAO validated SBAS integrity concept which will be published in SARPs in November 2001 has been summarised in this paper and some examples issued from ESA current design of EGNOS have tried to illustrate how it may be practically implemented. This paper has tried to highlight the following items:

- ❑ integrity allocation between the different potential error contributors,
- ❑ difference between the integrity definitions existing in the SARPs and their domain of application,
- ❑ XPL concept to protect the user in nominal (fault free) conditions,
- ❑ final recommendation of GNSSP on the derivation of ground parameters used in XPL calculation

The concepts presented in this paper are all described in the SARPs but they may be disseminated through several sections and also since the SARPs have to be as compact as possible, the rationale for particular choice of parameters or methods is usually not explicit in the SARPs.

Therefore it is the authors wish that this paper might contribute to bridge the gap from the SARPs requirements to an exhaustive vision of SBAS integrity issues.

VII REFERENCES

[1] ICAO Annex 10, Vol. I Radionavigation Aids, Chap 3. To be published in November 2001.

[2] ICAO AWOP/15 Report, 15th meeting, Montreal 26 September- 12 October 1994.

[3] ICAO AWOP/16 Report, 16th meeting, Montreal 23 June- 4 July 1997.

[4] Liu Fan, “Analysis of Integrity Monitoring for The Local Area Augmentation System Using The GNSS”, PhD. Report, Ohio University, August 1998.

[5] ESA-EOIG/PTT “Integrity Executive Summary” Draft document.

[6] RTCA, “Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment”, RTCA-DO 229 B, October 6, 1999.

[7] Bruce DeCleene, “Defining Pseudo Range Integrity – Overbounding” ION Conference, September 2000

VIII ACRONYMS

ABAS	Airborne Based Augmentation System
APV	Approach with vertical guidance
AWOP	All Weather Operation Panel
CDF	Cumulative Density Function
CRC	Cyclic Redundant Code
EC	European Commission
ECAC	European Civil Aviation Conference
EOIG	Egnos Operator and Infrastructure Group
EGNOS	European Geostationary Navigation Overlay Service
ESA	European Space Agency
FEC	Forward Error Correction
GBAS	Ground Based Augmentation System
GEO	Geostationary Earth Orbit
GIVE	Grid Ionospheric Vertical Error
GNSS	Global Navigation Satellite System
GNSSP	GNSS Panel
GPS	Global Positioning System
HAL	Horizontal Alert Limit
HMI	Hazardously Misleading Information
HPL	Horizontal Protection Limit
ICAO	International Civil Aviation Organisation
MI	Misleading Information
MOPS	Minimum Operational Performance Specification
NPA	Non Precision Approach
NSE	Navigation System Error
PA	Precision Approach
PDF	Probability Density Function
RIMS	Reference and Integrity Monitoring Stations
SARPs	Standard and Recommended Practices
SBAS	Satellite Based Augmentation System
SIS	Signal In Space
SQM	Signal Quality Monitoring
TLS	Target Level of Safety
UDRE	User Differential Range Error
UIRE	User Ionospheric Range Error
VAL	Vertical Alert Limit
VPL	Vertical Protection Limit
XAL	HAL or VAL