GRAS SAF Open Loop Workshop
Helsingør, Denmark
June 6-8, 2005

DMI Technical Report 05-11
ISSN: 1399-1388
Kent B. Lauritsen and Frans Rubek, editors

GRAS SAF Open Loop Status and Plans

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GRAS SAF Open Loop: Status and Plans

OUTLINE

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- ✓ The Open Loop Observables
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  - ✓ GPS Open Loop Architecture
  - ✓ OL parameters
  - ✓ Description of the level 1a OL Observables
  - ✓ Other OL Observables with possible interest
- ✓ Questions
- ✓ Plans

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The purpose of this presentation is to gather information on the open loop GRAS functions, in order to understand the features of the OL observables. This understanding is required for extracting its information content

In the first part, we will review relevant OL documentation

At the end we will list a set of questions

These questions, as well as those that will emerge during this GOLW, will help the GRAS SAF

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1. [CCICD, 2004] SES AB, Measurement Data Interface Document
2. [MDICD, 2004] SES AB, Measurement Data Interpretation and Description
3. [Sokolovskiy 2001] Sokolovskiy, S., Tracking tropospheric radio occultations from low Earth orbit, Radio Science, Vol 36, Number 3, Pages 483-498, May/June 2001
4. [Beyerle et al,2005] Beyerle, G., T. Schmidt, J. Wickert, S. Heise, Ch. Reigber and G. König-Langlo, An Analysis of refractivity Feb 2005
5. [Marquardt et al ,2003] Marquardt, Ch., K. Schöllhammer, G. Beyerle, T. Schmidt and Ch. Regber, Validation and Data Quality of CHAMP Radio Occultation Data, in "First CHAMP mission results for gravity, magnetic and atmospheric studies", 384 – 396, Springer, 2003
6. [Nogués et al,2004] Nogués, O.,J. Sanz, J. Torrobella, A. Rius,GOLD-RTR: A PARIS Open Loop GPS receiver, NAVITEC 2004 Proceedings, 8-10 December, WPP 239, ESTEC
7. [Olsen et al ,2004] Olsen, L. , A. Carström, P. Hoeg, Ground-Based Radio Occultation Measurements Using the GRAS Receiver, ION GNSS 17th International Technical Meeting of the Satellite Division, 21-24 Sept. 2004, Long Beach CA

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[CCICD, 2004] SES AB, Measurement Data Interface Document

- ✓ This document is addressed, among others, to the customers to give an understanding of the data products from the space segment
- ✓ It defines the following concepts, data and formats:
  - ✓ Single frequency raw sampling (as OL data)
  - ✓ Gain Setting data (analog and digital)
  - ✓ Carrier phase and amplitude data in the "Single Frequency raw sampling"

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[MDICD, 2004] SES AB, Measurement Data Interpretation and Description

Connects, in its section 5, the low level instrument measurements data products and the high level physical products to be considered here:

- Carrier phase
- Signal amplitude
- Noise amplitude

Gives a GRAS Simplified Receiver model (Figure 5.1-1)

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[MDICD, 2004] SES AB, Measurement Data Interpretation and Description (cont.)

Describes the Single Frequency Raw Sampling (RS) data
Mentions a model guiding the L1-carrier frequency and the existence of "periods when both raw sampling and single frequency tracking measurements are reported simultaneously as the function is implemented to give an overlap of data"

.

For sampling rates below 50 Hz the navigation data is demodulated, but in the RS mode

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- [MDICD, 2004] SES AB, Measurement Data Interpretation and Description (cont.)

The section 5.1.2.2 gives details on the Single Frequency Raw Sampling data. The Figure 5.1-3 visualizes data assembly of the Raw Sampling Packet.
The section 5.4 describes in detail the content of the Occultation Raw Sampling. Essentially in the subheader, there are:

- ✓ time tags using IMT (Instrument Measurement Time)
- ✓ an initial phase,
- ✓ NCO frequencies,
- ✓ scale factors for the I/Q samples,
- ✓ total integration times for the measurements in the packet.
- ✓ And in the body there is a set I and Q L1 C/A punctual counts.

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- [Sokolovskiy, 2001]
  - PLL tracking of RO signals propagated trough the moist troposphere is inadequate because of the complicated structure of those signals which contains multiple tones
  - In the GPS/MET mission the errors of the PLL tracking are believed to be the main source of refractivity retrieval errors in the lower troposphere
  - OL tracking should include calculation of a Doppler model prior to an occultation. The accuracy of the model can be about +/- 15-20 Hz

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[Sokolovskiy, 2001]

- ✓ Introduces the functions which should have an OL receiver for occultations
- ✓ In addition to the down conversion controlled by the model an additional downconversion based on the residual phases could be implemented
- ✓ Discusses the effect of the thermal noise in the reconstructed RO signal

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- **[Beyerle et al,2005]**
  - ✓ They have analyzed 156,180 profiles of the fractional refractivity (FR) deviation between CHAMP and ECMW. For high latitudes the FR errors remains below +/- 0.3%. At mid and low latitudes the biases reaches about –1% on a global scale. These biases are larger in south America and over the eastern tropical pacific
  - ✓ The paper discusses possible sources for this biases: receiver induced biases

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[Beyerle et al,2005] cont

- Simulation of a fly-wheeling capable receiver reproduce qualitatively the negative refractivity bias present in CHAMP The simulator is simple but sufficient for a qualitative study
- They present a possible scheme for wipping-off the navigation bit. The assumption is that the data bits are not available to the public prior the transmission and the demodulation is performed with predicted navigation data bits. They state that the the agreement between the real and predicted navigation bits was 98 %

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[Marquardt et al ,2003]

- GFZ CHAMP retrievals of stratospheric temperatures agree well with ECMWF and radiosondes
- Tropospheric refractivity obtained from CHAMP suffers from a systematic bias up to 10% in tropical lower troposphere; in mid latitudes, bias in the order of 5% are found near the ground

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[Marquardt et al ,2003] cont

- Systematic biases of this magnitude question the usefulness of lower tropospheric RO data for NWP and climate research
- They provide evidence that degradations in the quality of the amplitude and phase measurements are linked to details of the tracking algorithms when the CHAMP receiver switches to the “flywheeling” mode
- They suggest the role of the GPS receiver requires more attention than previously anticipated

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[Nogués et al,2004]

- This reference describes a specific GPS Open loop receiver. We use this reference as an example of Open Loop receiver

[Olsen et al ,2004]

- This reference presents an analysis of OL data recorded with a prototype of the GRAS receiver
- Uses a model similar to the one described in Sokolovskiy, but more “straight –forward”
- They conclude that the open loop tracking of the GRAS instrument performs as expected

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OL vs CL modes

The following points outlines differences and analogies between the OL and the CL instruments:

- **First of all: the complex field observed with a GPS receiver is obtained using a cross correlation process between the sampled signal and a model of this signal. In the model enter the delay and the frequency of the signal**

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- **The difference between OL and CL resides in the form in which these parameters are treated. In CL, the receiver tries always to extract information based on the peak of the cross correlation, and the phase and the amplitude represent quite well the phase and the amplitude of the received wave**

- **This is not necessarily the case for the OL: changes in the phase and the amplitude will reflect also the departure between the chosen delay and frequency values and the real ones**

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- OL is a standard technique in radio interferometry, used when the signal to be studied is noise, or has been filtered trough a noisy channel. The correlation is made in post processing after aligning the signals in delay and delay rate.
- The OL mode was used when the planetary occultations were observed trough the NASA Deep Space Network. The extraction of the field was performed in post process. The CL mode is used when it is possible to extract from the signal the carrier frequency (standard communication channels).
- Presently, the high quality GPS occultation data is obtained in CL mode. The OL mode in the current GPS Occultation Receivers is a research activity.

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- ✓ In the OL mode the signal is filtered using a priori information: the center frequency and the bandwidth is determined by a general model.
- ✓ In the CL mode the filter adapts to the behaviour of the phase of the signal (i.E.: Phase lock loop). The CL is not efficient when the signal is multitone or the tropospheric Doppler is larger than its bandwidth.
- ✓ The OL should work if the general model and the associated windows in frequency and delay capture the signal. But its noise will be larger
- ✓ The fly wheeling (FW) mode is intermediate between CL and OL. Filters the signal using a prediction of the Doppler and the bandwidth of the signal. Only is valid for setting occultations

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- ✓ The basic products of the OL and CL loops instruments are similar: phasor (time tagged tables with amplitudes and phases). If the instrument is properly designed and implemented the CL products should be a subset of the OL ones. The products should be similar

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- ✓ model the filter model before the occultation. This requires external information. In the GOLD_RTR a navigation receiver provides this
  - ✓ GPS data reception with a suitable antenna.
  - ✓ Preamplification. Complex down conversion to a base band and sampling
  - ✓ complex cross correlation with models of the GPS signals
  - ✓ coherent integration of the complex cross correlation functions, taking into account the possible navigation bit transition

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- ✓ extraction of the residual mean frequency
- ✓ down conversion of the of the coherently integrated complex cross correlation functions
- ✓ Uncoherent integration of the amplitude of the down converted cross correlation functions
- ✓ synthesize the amplitude and the phase using the information collected in the previous steps

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Description of the level 1a OL Observables

- ✓ We expect that the observables acquired in OL mode are, formally, equivalent to the corresponding CL mode
- ✓ The differences are in the sampling rate, the noise, etc

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- Another possible difference, which should be understood, is the definition of the measured phasor
- In the case of the closed loop observables the phase and the amplitude are extracted from the “punctual” correlator, which follows approximately the peak of the correlation function
- In the case of the open loop this is not necessarily true, and this could produce artefacts in the interpretation of the observables, because the measurements do not represent the incoming field

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Other OL Observables with possible interest

if the phases are unconnected because the noise, it is possible to extract products like the power spectrum of the signal, containing information on the atmospheric turbulence.

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- A GRAS receiver prototype has been used in OL mode in coastal experiments
- Simulation studies have been performed with simplified models of OL receivers
- And there are studies with the JPL receivers operating in FW mode
- The information included in the applicable or reference documents do not provide details on the operational implementation of the OL concepts in the GRAS receiver

GRAS SAF Open Loop: Status and Plans:Questions

The following is a preliminary list of questions:

- Frequency model used in OL: climatic, NWP, flywheel? What is the expected accuracy?
- There are comparisons between the model implemented and actual NWP models?

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- It is possible to use simultaneously two links with one occulting satellite and two different models? The second model could be the standard with a bias in delay or in frequency
- Integration times in CL and OL
- Predetection bandwidth
- Expected SNR differences between OL and CL

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- Removal of the navigation bit: wipe-off or sensitivity assistance
- Samplig rate of the observables in CL and in OL
- Number of correlators used in the estimation of the peak amplitude
- Process chain for the OL: from the RF signal to the level 1a products

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- Switching from CL to OL: the OL model matches the CL information?
- Are expected other products in addition to those termed level 1a