

One Year in Orbit - GIOVE-B Signal Quality Assessment from Launch to Now

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BIOGRAPHY

Matthias Soellner is expert on navigation signal engineering at EADS Astrium. He received a Ph.D. degree in physics from the Technical University of Munich. Since 2000, he works at EADS-Astrium on satellite navigation with focus on navigation end-to-end signal performance, signal design and application experiments.

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Wolfgang Kogler received the diploma degree in computer science and communications from the Graz University of Technology in 1999 and the Ph.D. in 2005. In Graz, he worked as a research assistant until 2007, with emphasis on satellite communication systems and measurement systems. Since 2007, he is navigation signal engineer at EADS Astrium, dealing mainly with signal performance verification aspects.

Stefan Erker received his diploma degree in Information Technology in 2007 from the Technical University of Kaiserslautern. He joined the Institute for Communications and Navigation at the German Aerospace Center (DLR) in September 2007. Now he works on the validation and signal analysis of satellite navigation systems.

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Michael Meurer received the diploma in Electrical Engineering and the Ph.D. degree from the University of Kaiserslautern, Germany. After graduation, he joined the Research Group for Radio Communications at the TU Kaiserslautern, Germany, where he was involved in various projects in the field of communications and navigation. Since 2005 he has been an Associate Professor (PD) at the same university. Additionally, since 2006 Dr. Meurer is with the German Aerospace Centre (DLR), Institute for Communications and Navigation, where he is currently the director of the Department of Navigation.

INTRODUCTION

After the successful launch of the second Galileo test satellite GIOVE-B in spring 2008, first measurements of the transmitted navigation signals were recorded during the night of May 7th. Within the in orbit test phase which last about 3 month intensive measurements were performed from DLR and EADS/Astrium using the 30m high gain antenna at Weilheim (Germany). These first measurements indicated that the payload did not suffer any damage or degradation concerning SIS-quality and power during the launch of the satellite. After the IOT phase the satellite was set into operational mode. A re-characterization of GIOVE-B is performed every 6 month. To ensure the long term stability of the navigation payload in space a constant monitoring of the radiated signals is necessary. After the presentation of the initial results of the GIOVE IOT campaign DLR and Astrium continued the measurements and analysis on GIOVE B. In this time also some eclipse passages of GIOVE B were observed. These passages, where the satellite is de-coupled from solar radiation, are known to be stressful for the satellites thermal control. The impact of corresponding temperature variations on signal transmis-

sion characteristics and corresponding key navigation parameters needs a closer look.

This paper illustrates all basic evaluation parameters derived from the recorded spectra and a detailed I/Q sample analysis which is based on sample-files recorded with the BayNavTech Signal Experimentation Facility (BaySEF). A corresponding analysis focuses on so called ‘instantaneous’ signal quality, which analyzes short signal-periods of one second or even below. Based on that, evaluation parameters are considered which are beyond others, scatter-plot evaluations, correlation-loss, S-Curve-bias and transfer-frequency-characteristics. Especially these parameters are very sensitive to signal distortions and therefore are quite challenging to be evaluated reliably. Furthermore a spectral power analysis is introduced for the detection of frequency and elevation dependent asymmetries in EIRP.

The high quality measurement setup in Weilheim is described in the following which includes major part of the equipment for calibration purposes. More details are given on the applied calibration approach and its performance as the accurate calibration is a pre-condition for successful characterisation of satellite signal performance.

GIOVE-B measurement and evaluation results will be shown and discussed for the introduced parameters first from the initial in orbit operation phase. These measurements that are recorded over a complete satellite pass provide constant observation and short term analysis of the navigation payload in space over several hours focusing mainly on elevation/ satellite antenna-off-axis-angle dependency. Moreover, also measurements from later phases are compared, including also aspects of eclipse paths, providing a first rating of the satellites characteristics long term stability.

This comparison of measurement results distributed over the first year of GIOVE-B transmission finally demonstrates its excellent stability of these signal quality aspects.

EVALUATION PARAMETERS

For the basic assessment of the satellites key parameters the radiated power levels of the individual navigation bands is quantified using a set of different measurements. With the help of absolute calibrated spectral measurements a first insight in power asymmetries, distortions or variations to the theoretical signal spectrum become visible.

During the In-Orbit-Test phase of GIOVE-B well defined pilot signals are transmitted for a detailed determination of the EIRP values over the elevation. With the help of these pilot signals it is possible to

evaluate the frequency stability and power variations which may caused by variations of the antenna. These measurements are performed repeatedly every 6 month to check long term stability.

The other type of evaluation parameters are summarized as signal quality parameters. These parameters are derived from the base-band signal samples for periods of up to few seconds and shall characterize the instantaneous transfer characteristics distortions of the satellite with respect to its relevance for navigation performance. A theoretical analysis on the impact of satellite distortions on navigation performance parameters can be found in [1].

Here considered signal quality parameters are as first the I/Q probability density after Doppler removal, as also used for communication systems. Moreover, a set of signal quality parameters relates more to the navigation performance aspects of the signals, which are based on the correlation function. This correlation is defined with respect to ideal receiver properties in order to separate from receiver distortions according to the following:

$$CCF(\varepsilon) = \frac{\int_0^{T_p} s_{BB-PreProc}(t) \cdot s_{Ref}^*(t - \varepsilon) dt}{\sqrt{\left(\int_0^{T_p} |s_{BB-PreProc}(t)|^2 dt \right) \cdot \left(\int_0^{T_p} |s_{Ref}(t)|^2 dt \right)}}$$

with

- the pre-processed baseband signal $s_{BB-PreProc}$, ideally down-converted from the centre-frequency of interest (e.g. E5a, E5b, E5, E6 or L1) including full Doppler removal and Brick-wall-filtered to a two-sided bandwidth BW of interest,
- the reference-signal s_{Ref} , providing the ideal binary (or for CBOC quaternary) base-band receiver replica signal,
- the integration period T_p , often corresponding to the primary code-period of the reference-signal under consideration.

From this normalized correlation function, the derivation of the following main navigation relevant parameters is considered here, which are:

- correlation loss (CL)
- early-late spacing dependency of code-phase and S-curve-bias (SCB)

Correlation-Loss

For a given (distorted) signal, the correlation loss quantifies the loss in correlator output-power relative to an ideal signal. This can be formulated by

$$CL[dB] = P_{CCF}^{\text{Ideal S}_{BB}\text{-PreProz}} [dB] - P_{CCF}^{\text{SIS S}_{BB}\text{-PreProz}} [dB]$$

where

$$P_{CCF} [dB] = \max_{\text{all } \varepsilon} (20 \cdot \log_{10} (|CCF(\varepsilon)|))$$

It should be noted, that the ideal baseband signal here is the multiplexed signal including all signal-components also bandlimited with a Brickwall-filter to the band-width BW of interest.

S-Curve-Bias:

The navigation receiver obtains the (noise-less) code-delay by the zero-crossing of the code-discriminator. It turns out, that for distorted signals different code-tracking loops may have different lock-points. To quantify this effect with a reasonable compromise between parameter complexity and practical value, therefore a non-coherent power discriminator (NCELP) is considered over a wide range of early-late-spacings δ . This refers to the code-discriminator of

$$SCurve(\varepsilon, \delta) = \left| CCF\left(\varepsilon - \frac{\delta}{2}\right) \right|^2 - \left| CCF\left(\varepsilon + \frac{\delta}{2}\right) \right|^2$$

with its lock-point $\varepsilon_{\text{bias}}(\delta)$ defined by

$$SCurve(\varepsilon_{\text{bias}}(\delta), \delta) = 0.$$

Note, in case of more than one zero-crossing (for BOC-type signals), the delay closest to the delay of maximum correlation-power has to be selected. Then, the S-Curve-bias SCB is finally given by

$$SCB = \max_{\text{over all } \delta} (\varepsilon_{\text{bias}}(\delta)) - \min_{\text{over all } \delta} (\varepsilon_{\text{bias}}(\delta)),$$

considering all δ in the range $[0, \delta_{\text{max}}]$, with

$$\delta_{\text{max}} [\text{chips}] = \begin{cases} 1.5 / \left(4 \frac{m}{n} - 1\right) & \text{for a BOC}(m, n) \text{ reference Signal} \\ 1/23 & \text{for a CBOC reference Signal} \\ 1.5 & \text{for a BPSK } n \text{ reference Signal} \end{cases}$$

A more detailed description also of further signal quality parameters is given in [1].

WEILHEIM MEASUREMENT SETUP

For GIOVE signal performance measurements, DLR has installed a measurement system to the 30m dish of DLR-GSOC in Weilheim/Lichtenau. This measurement setup was completed with one rack of the BayNavTech™ Signal Experimentation Facility (BaySEF) in a cooperation between EADS Astrium and DLR.

The 30m high gain antenna at Weilheim is the main core of this verification facility. This antenna is based on a shaped Cassegrain system with elevation over azimuth mount. It is characterized by a gain value of over 50dB in the L- band and a beam-width around 0.5°. The absolute position accuracy of this antenna is 0.001° in each direction. The signals are directed from the parabolic main reflector to a hyperbolic sub-reflector with 4 meters in diameter. This sub reflector sends the signals via a waveguide and a second subreflector into a measurement cabin. One big benefit of this construction is the direct access to the installed feed in the cabin and the possibility to place the complete measurement equipment next to the feed and to avoid the use of long connection cables.



Figure 1: 30m High Gain Antenna at Weilheim

The measurement system adapted to the 30 meter antenna includes two Low Noise Amplifiers with a total gain of almost 70dB. Several directional couplers are used for the injection of pilot signals. So it is possible to calibrate the receiving system during operation near real-time. The setup also has several signal outputs for external equipment like bit grabbers or navigation receivers. By the use of these directional couplers the signal loss and interference by internal reflections is reduced. Other main items of the receiving system are the band pass filters dedicated to the individual Galileo navigation bands. The signals are recorded using a vector signal analyser with at least 80 MHz bandwidth. For signal recording of wideband signals the analyzer is used for down conversion of the signal. A digital oscilloscope connected to the analyzer is able to record with 300MHz signal bandwidth.

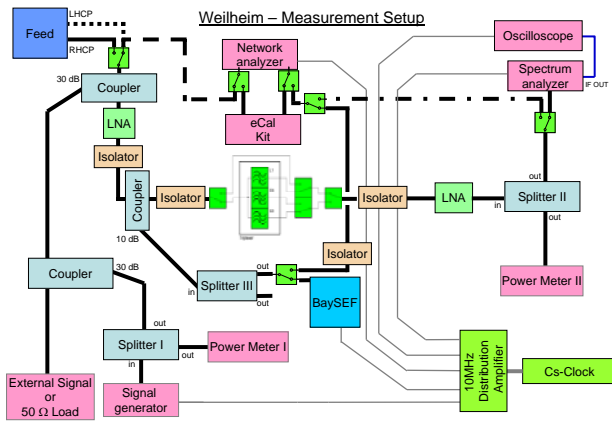


Figure 2: Measurement Setup Overview

Figure 2 shows the complete measurement setup including parts used for system calibration and a Caesium clock used as frequency standard for the measurement equipment. More detailed information about the 30m antenna and the used measurement setup can be found at [7][8].

The BaySEF rack as shown in Figure 3 is used in this setup as a high capacity multi-band bit-grabber.



Figure 3: Single BaySEF measurement system

In general, the BaySEF can be characterised as a flexible wideband GNSS receiver and signal performance evaluation platform for reception and processing of navigation signals. Main applications are the verification and monitoring of GNSS SIS and the support for application design. Key features most relevant for the signal-quality assessment of this paper are:

- Simultaneous processing (down-conversion etc.) & synchronized recording of up to 4 navigation frequency bands,
- RF 3-dB-bandwidth of more than 100 MHz in E5 and more than 50 MHz in all other bands (E5a, E5b, L2, E6, L1),
- Maximum recording capacity of 120 MByte/s per frequency band,
- Flexible decimation and quantisation,
- Recording capacity of more than 80 minutes (0.6 TByte) per frequency band (at maximum rate),
- Remote control of data-acquisition e.g. from EADS Astrium premises at Ottobrunn.

To get a more comprehensive overview on all the BaySEF capabilities, the interested reader is referred to [3, 4].

MEASUREMENT SYSTEM CALIBRATION

As the objective of the measurement setup in Weilheim is the SIS performance characterisation of satellites like GIOVE-B, all relevant distortion contributions of the measurement system need to be characterized accurately and finally removed within the parameter evaluation. To achieve a combined absolute measurement uncertainty significantly less than 1.0 dB it is essential to calibrate every part of the used system very precisely. This includes beside all RF components of the receiving system also the high gain antenna itself.

For the characterisation of the high gain antenna two values are assessed. The first one is the antenna pointing accuracy. This error contributes with a reduced maximum power value caused by the miss pointing of the antenna pattern. So the pointing offset is measured for azimuth and elevation using the geostationary satellite Artemis. The measurements show a systematic elevation offset of 0.02° and an azimuth offset of 0.03° . This offset is corrected in the antenna control. The second value is the antenna gain. For accurate measurement of the antenna gain natural sources like radio stars or artificial sources like geostationary satellites are well suited. For a characterization over the complete L-Band frequency range of interest, the radiostar Cassiopeia A is used. Cassiopeia A is one of the strongest wideband radio emitters on the northern hemisphere. The star is circumpolar and therefore usable for calibrations at every time of the year. With the help of the well-known flux density of the celestial radio sources Cass A the G/T can be measured, which is the relation between the gain of the antenna and the noise temperature of the receiving system. After a precise determination of this noise temperature the

antenna gain can be calculated. More information about the antenna calibrations can be found at [7].

For the receiving system calibration several techniques are used. The State-of-the-Art method is the use of a network analyzer. This analyzer can be calibrated remotely and connected to the receiving system by a group of dedicated switches. These precise measurements of gain and phase are performed periodical (see Figure 4). A frequency and power stabilized signal generator is used in combination with two power meters for an online gain determination during measurements. This method is used for detection of gain variations of the low noise amplifiers and passive elements of the receiving system. It is also possible to detect if one of the amplifiers is saturated and working outside specified limits.

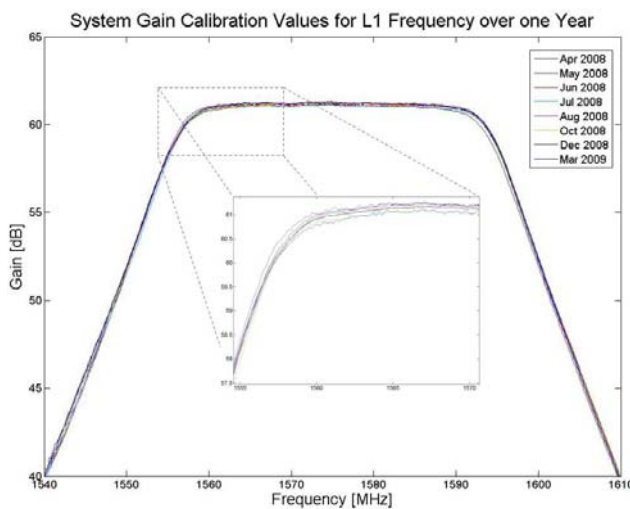


Figure 4 System Gain Calibration Values for the L1 Signal measurement path over one Year

For an online characterisation of down-converting measurement systems (from after feed until bit-grabber) the use of a wideband calibration signal is very promising. Figure 5 Schematic of Wideband Signal Calibration Setup

shows a simplified block diagram of a corresponding calibration setup. A wideband signal is generated by BPSK modulating a carrier at the desired band center frequency with a pseudorandom code sequence. Then the signal is split into two parts. While one part is sampled with a commercial digitizer to serve as a reference (in our case a Rohde & Schwarz FSQ26 vector signal analyzer), the other part is injected into the measurement setup right behind the antenna feed using a self-terminating switch. This part is used as test or calibration signal and is treated from this injection point on in the same way as the antenna signal. By this the recorded samples contain the convolution of the calibration

signal with the overall channel characteristic formed by the measurement setup including the BaySEF.

The desired inband measurement system transfer characteristic can then be extracted by means of deconvolving the BaySEF sampled calibration signal with the FSQ sampled reference signal. Once the characteristic has been determined, a compensation filter can be calculated in order to correct the unwanted but unavoidable overlaying distortions.

On the applicability of this approach two things have to be noted. First, particular attention has to be paid to the reference signal path and calibration signal injection path to not provide additional distortion contributions. Secondly, it has to be assumed, that also the FSQ might have some residual measurement distortions. Strictly speaking this means that the finally estimated transfer characteristic has to be considered always relative to the R&S FSQ.

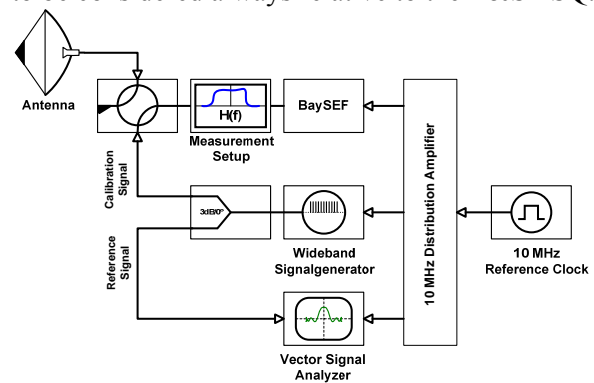


Figure 5 Schematic of Wideband Signal Calibration Setup

This approach is currently under test but was used already in the last year for BaySEF characteristic evaluation, with repeated measurements at an interval of more than two month. The results provided only small differences as shown in Figure 6 for L1, with less than 0.2 dB peak-to-peak amplitude changes, less than 1 deg phase changes and less than 2 ns changes in the group-delay characteristic within 40 MHz.

For the signal quality results shown in this paper, the NWA measurements of the RF-equipment and the BaySEF transfer characteristics derived with the use of wideband calibration signals were combined to derive the equalisation filter applied in post-processing to the recorded samples. This approach provides a quite reliable initial measurement system calibration in relative amplitude and phase.

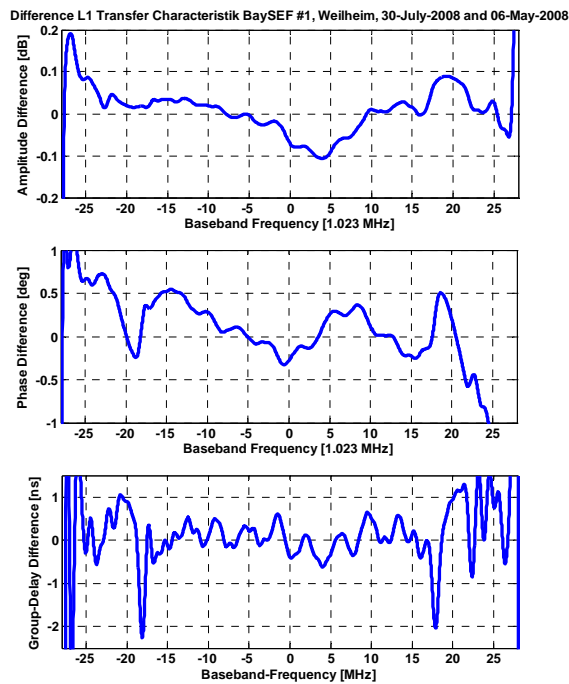


Figure 6: BaySEF transfer-changes in a 85 days interval

POWER MEASUREMENT RESULTS

During the IOT Phase of GIOVE-B CW signals for all navigation frequencies and both payloads A and B were transmitted to verify the exact signal power of the satellite over the elevation. These CW signals were recorded over the whole satellite path and absolute calibrated for EIRP determination. In Figure 7 the characteristics for the L1 EIRP measurement is plotted. This measurement was done for two CW pilot signals located at the BOC(15,2.5) main lobes. The gaps between the measurement points result from the used measurement sequences. During this time other measurement data like IQ samples or interference observations were performed and system calibrations were conducted. Figure 8 shows the power difference between the two pilot signals over time. An increasing power offset can be observed resulting by a small power drift of the right pilot signal.

In the course of a GIOVE-B re-characterization that is performed every six month a second L1 CW EIRP pass was captured at the end of February this year. By comparing this measurement to the first L1 CW EIRP in spring 2008 a slightly different characteristic can be observed. During the second CW measurement the upper band pilot (right pilot) shows now no drift over the elevation (see Figure 9) The variation of the power difference in Figure 10 is mainly caused by the lower band pilot (left pilot), which varies over the satellite pass.

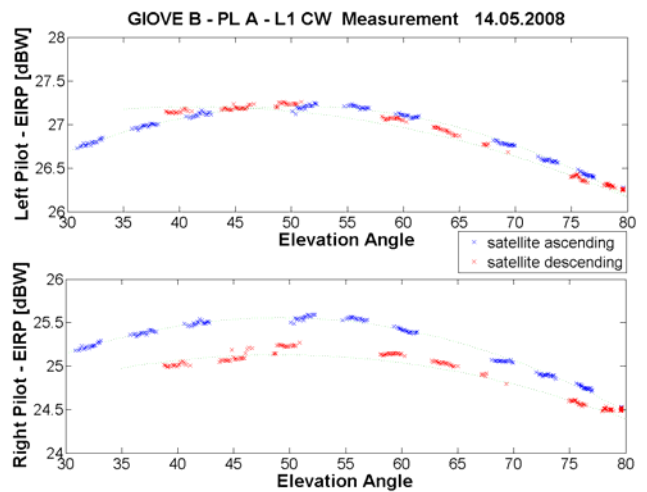


Figure 7 CW EIRP GIOVE B L1 at 14.05.2008

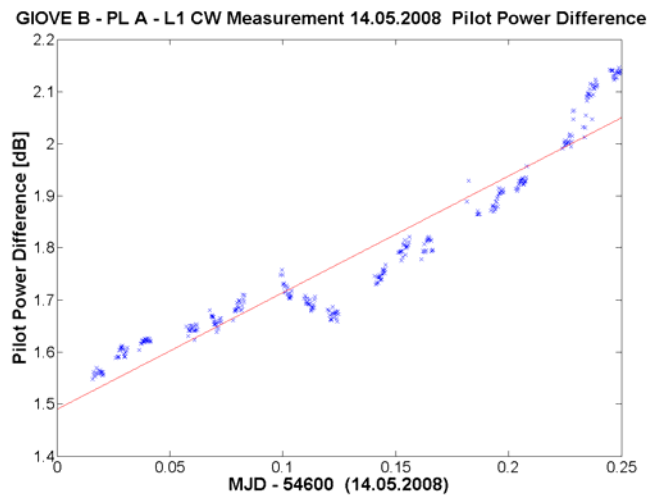


Figure 8 Pilot power difference over time 14.05.2009

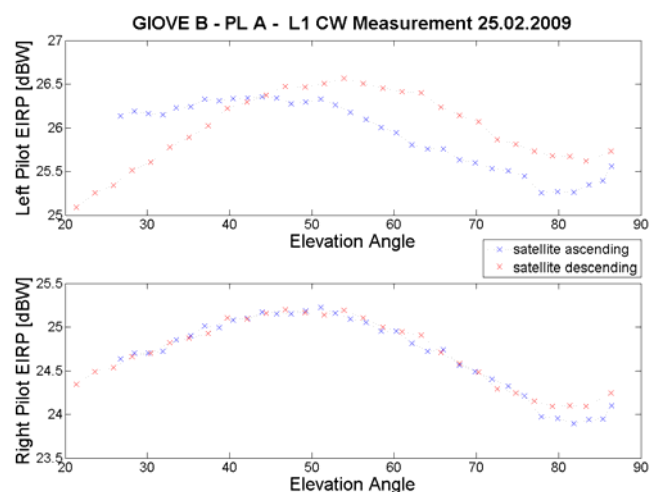


Figure 9 CW EIRP GIOVE B L1 at 25.02.2009

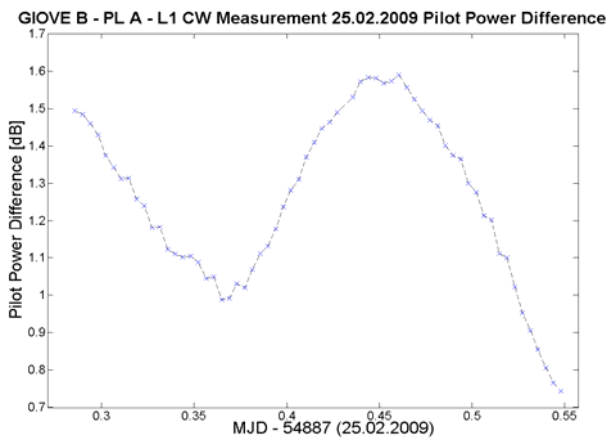


Figure 10 Pilot power difference over time 25.02.2009

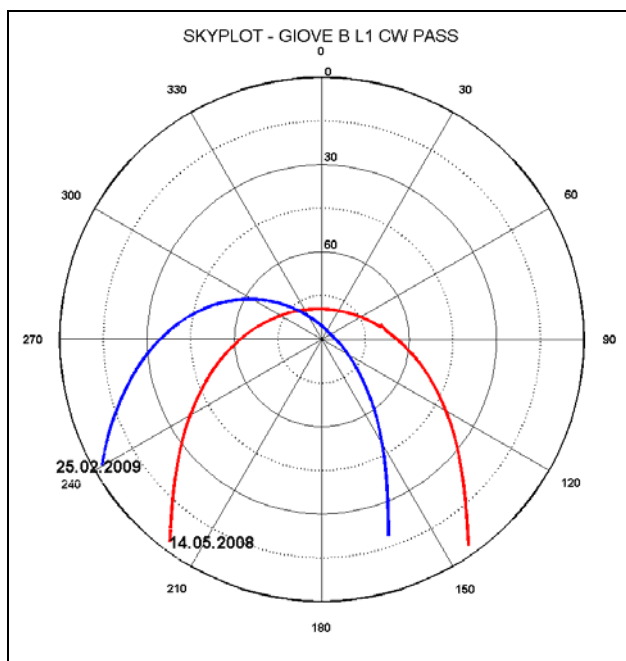


Figure 11 Skyplot of the performed GIOVE L1 CW measurements

Reviewing the skyplot of both satellite transits (Figure 11) some minor differences become visible. The second pass (blue) is passing the 30m dish nearly at 90° elevation angle. The first (red) pass only reaches around 80° . This pass is quite symmetric and could be mirrored at the 180° Azimuth axis. The maximum is reached quite in the middle of the pass. During the blue pass the maximum value is reached later. Keeping in mind that the starting orientation and also the rotation of the satellite antenna also should be different at both passes it becomes obvious that the individual cuts of the satellite antenna pattern are not directly comparable to each other. For a meaningful satellite antenna characterisation a lot more CW satellite passes are needed. Unfortunately this CW campaigns are very rare (maybe one or two passes only twice a year). So it is necessary to use also passes with the modulated

GIOVE signals over elevation including the knowledge of the exact satellite antenna orientation for a precise “long-term” characterisation of the satellite antenna.

SIGNAL QUALITY MEASUREMENT RESULTS

In this chapter some GIOVE-B L1 signal quality results are shown as obtained from BaySEF measurement data in Weilheim. Considered are results from two paths with CBOC-transmission mode:

- 09.05.2008, few days after the signal transmission being switched on
- 29.09.2008, a path with about 1 hour eclipse period.

The type of L1-signal can be seen from the I/Q-sample probability distribution. Such a scatter plot is shown in Figure 12, derived from about 50 ms signal-samples. Other I/Q-plot results as measured by ESA in Chilbolton are given in [6]. Note, for this and all following evaluations, the signal-samples had to be Doppler-compensated first.

The overlay with the eight phase-points of the ideal constant envelope signal allows clear identification of the interplexed CBOC signal. Due to band-limitation, distortions and noise-jitter, the individual phase-states have been blown up, and transition traces become visible. Also the symmetry of phase-states becomes slightly deformed. How far this affects measurable navigation performance is not directly obvious.

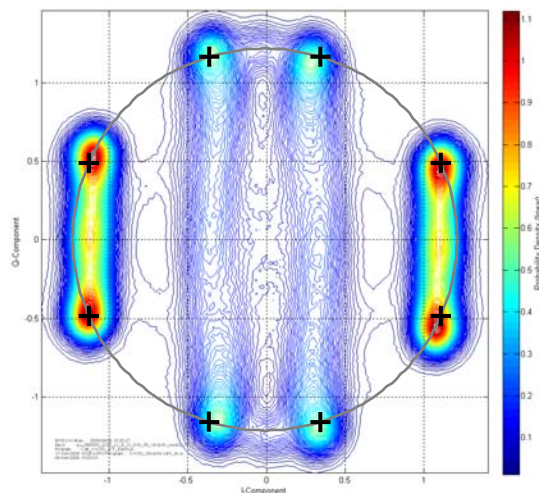


Figure 12: Scatter-plot of GIOVE-B L1-CBOC (lower plot), together with black crosses at ideal base-band signal phase-states.

Therefore we have first a look to the correlation function shapes of the L1 signal components CBOC in Figure 13 and BOCc(15,2.5) in Figure 14 as obtained by averaging over about 0.5 seconds. But before, a general statement: For all following

evaluation results the L1 signals have been Brick-wall band-limited to 40.92 MHz ($= 40 \times 1.023$ MHz), which was the performance bandwidth of interest, and upsampled to rates of 575 MHz.

The differences in shapes are not due to distortions but due to different sign of BOC(6,1) sub-carrier in B- and C-channel. A direct visibility assessment of these shapes offer not too much conclusions, despite of its imaginary-parts, which should not be but are due to signal distortions. Note, the imaginary part is here already 10 times amplified in order to stress its presence.

For the shape of the BOCc(15,2.5) correlation-function also a small asymmetry in the real-part is visible when comparing to the ideal band-limited auto-correlation-function. This signal distortion effect might be relevant, leading to a certain chance for false lock in acquisition and tracking.

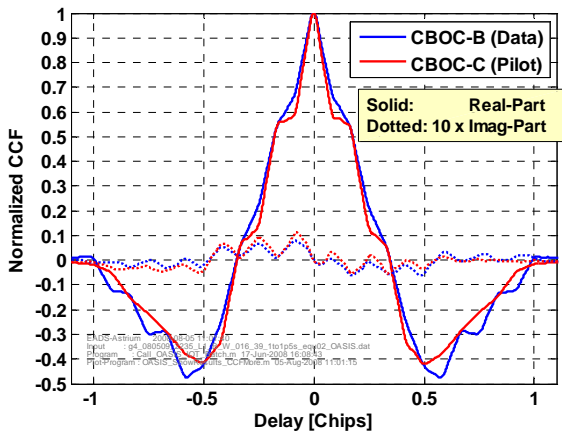


Figure 13: GIOVE-B L1-CBOC correlation function shape.

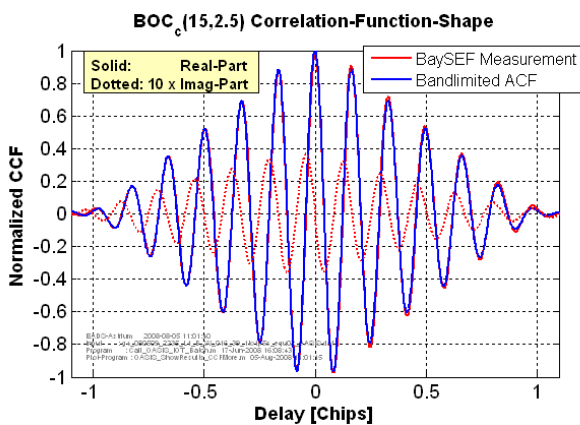


Figure 14: GIOVE-B L1-BOCc(15,2.5) correlation function shape

More quantitative evaluations provide the performance parameters of correlation-loss and lock-point bias-behaviour.

Example results on the correlation power evaluation for GIOVE-B CBOC-B are shown in Figure 15, with the red curve showing the correlation-power of succeeding code-periods, relative to the total signal (which includes also the CBOC-C, and BOCc(15,2.5) signal components). The strong jitter of more than 0.1 dB is due to code-cross-correlations as it is also obtained for the ideal signal reconstruction of the multiplexed baseband-signal, when exactly synchronizing and accounting for the exact codes (the blue curve in Figure 15). The correlation-loss is obtained by taking the difference, with a much lower variation of maximum 0.02 dB. This is not due to residual noise (which is much smaller) but due to residual distortion differences of the four code-cross correlation values of the GIOVE-B codes as annotated by the four different colored dots in the figure. The negative loss means a corresponding gain of usable signal power of CBOC-B relative to the undistorted case. This is due to power re-distribution of the signal-components relative to each other. The wide-band signal-component BOCc(15,2.5) is stronger band-limited (by the distortion), relative to the narrow-band CBOC-signal component, which effectively gains relative power by this.

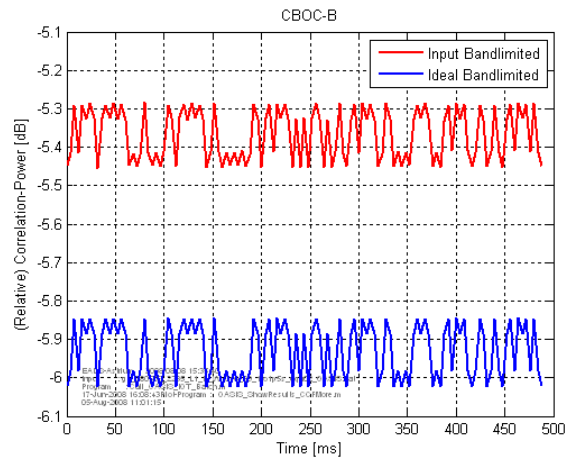


Figure 15: GIOVE-B example correlation-power evaluation result for CBOC-B.

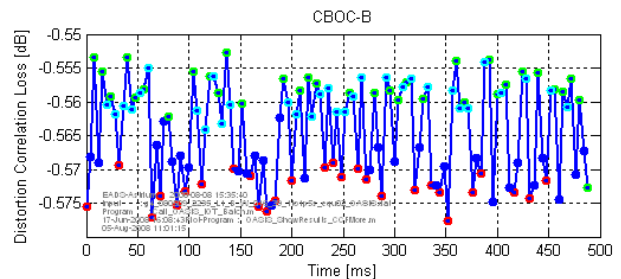


Figure 16: GIOVE-B example distortion correlation-loss evaluation result for CBOC-B.

As next, we consider the lock-point bias of a non-coherent power discriminator in dependency of early-late-spacing (over the relevant range) for the

CBOC-C signal in Figure 17, evaluated for about 60 succeeding code-periods. Again, different colors indicate different code-cross-correlation values, showing only a relatively small corresponding dependency. This becomes more obvious, when evaluating the peak-to-peak variation of this lock-point bias, which is the so called S-curve bias. Over this short period of 0.5 seconds, a quite stable value is obtained with only 25 ps standard-deviation mainly due to residual code-cross-correlation effects and residual noise.

It has to be noted, that all evaluation results include not only the satellite distortions but also receiver contributions. In fact, the order of measurement system calibration uncertainty and instability for these results (see e.g. Figure 6) is expected to provide here still relevant contributions. Accurate measurement system calibration is therefore one of the most critical issues for exact signal quality assessment of satellite transfer characteristics and its impact on navigation performance.

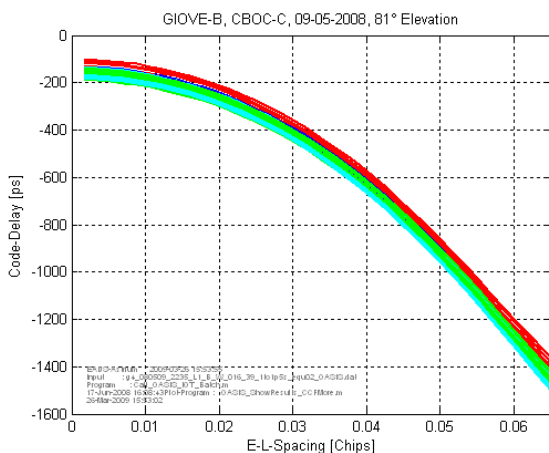


Figure 17: Lock-point-bias in dependency of early-late-spacing for GIOVE-B CBOC-C

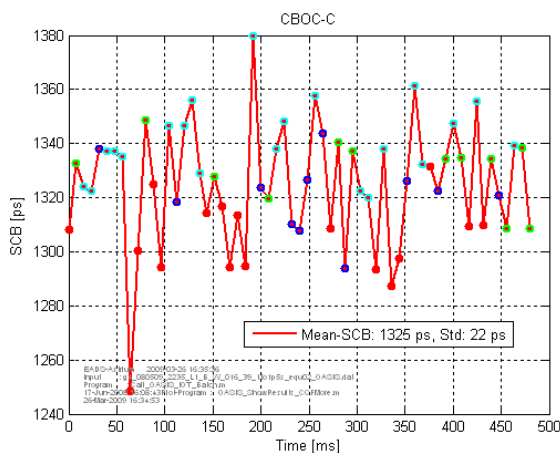


Figure 18: Measured S-Curve-Bias for GIOVE-B CBOC-C at 09.05.2008

Beyond the signal quality assessment of individual snapshot measurements also its variation over observation direction and over time is of major relevance. Therefore, these evaluations have been performed for many snapshots of two single pathes in almost 5 month distance. The pathes and measurement points mapped to the directions as seen from a satellite antenna fixed coordinate system are shown in Figure 19.

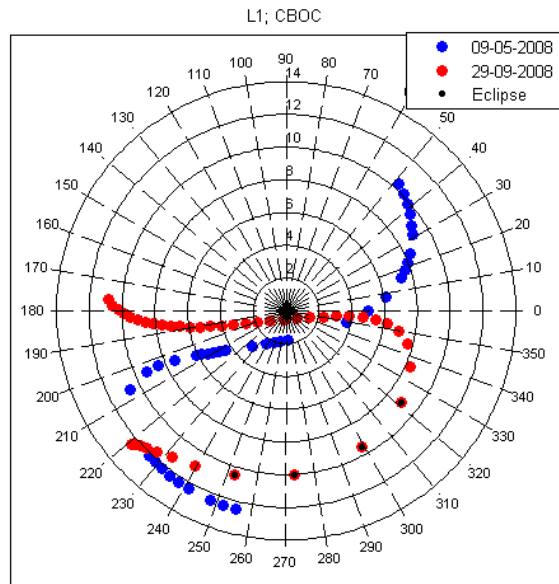


Figure 19: GIOVE-B measurement points of BaySEF transformed in satellite antenna coordinates (off-axis-angle, antenna-azimuth-angle)

In Figure 20 and Figure 21, the results on correlation-loss and S-curve bias are shown for both dates mapped in dependency of the satellite antenna off-axis angle. For a monotonic x-axis, a sign was added to this angle here, with negative values for the ascending part of the path and positive values for the descending path as seen from Weilheim.

The correlation-loss results at both dates vary about ± 0.1 dB around 0.7 dB for BOCc(15,2.5), around -0.5 dB for CBOC-C and around -0.55 dB for CBOC-B. Also the measured S-curve-bias results are in the same range at both dates, which is about $\pm 100 - 200$ ps around 1200 ps for CBOC-B and CBOC-C and ± 2 ps around 23 ps for BOCc(15,2.5). Furthermore these plots show smooth variations over the antenna off-axis-angle, obviously also with some azimuth dependency due to the different shapes at both dates. Remarkable is also the similar relative shape of correlation-loss and S-curve-bias curves.

Even if measurement system instability may also contribute, most parts of corresponding variations are supposed to be due to the direction dependency of the satellite antenna pattern. See also the similarity of results from both dates at the one end of high off-axis angles corresponding also to similar azimuth angles. Such variations were expected and are already known from respective EIRP measurements [7, 8].

These results indicate, that also for full characterisation of signal-quality, further well calibrated measurements over several paths would be required.

Within the measurement path of 29.09.2008, few measurement points were taken during eclipse, when the satellite was shadowed by the earth. Corresponding results marked by black points in the figures show almost no impact of the eclipse on correlation loss and S-curve-bias during the eclipse period. Further measurements and evaluations would be required to finally confirm, that the stronger changes afterwards are not affected by the eclipse.

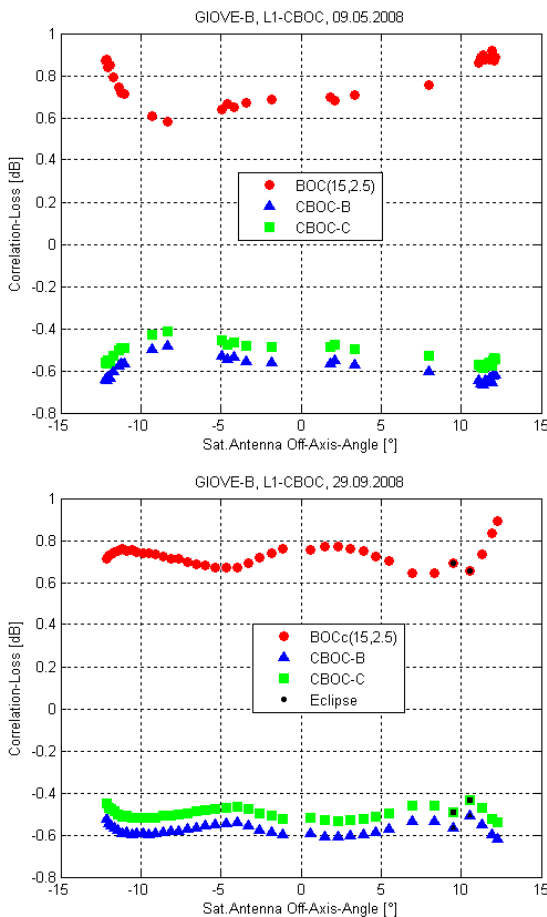


Figure 20: GIOVE-B BaySEF correlation-loss evaluation results

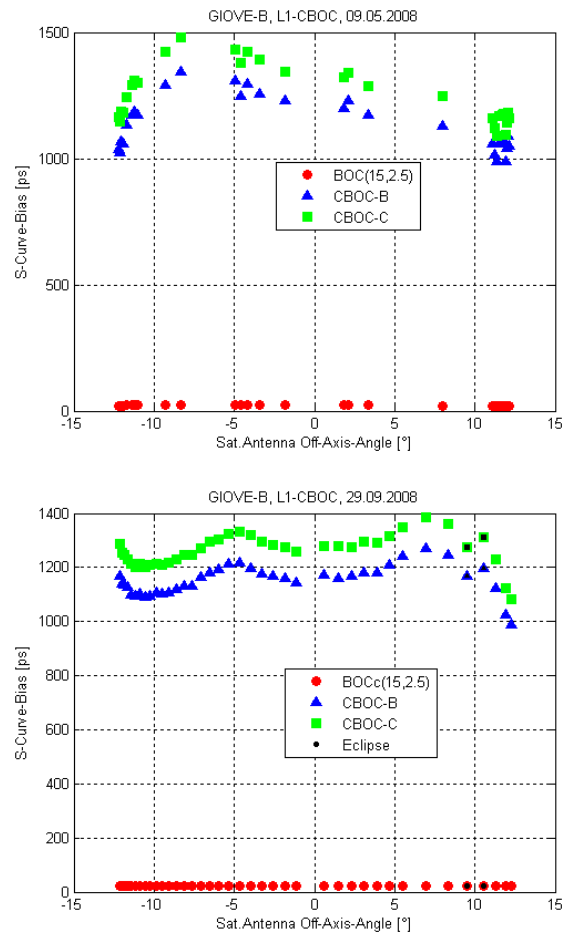


Figure 21: GIOVE-B BaySEF S-Curve-Bias evaluation results

CONCLUSIONS

This paper describes some GIOVE-B SIS performance characterisations performed in cooperation between DLR and EADS-Astrium during the last year. These characterisations are based on an appropriate measurement setup installed at the Weilheim 30m high gain antenna. Major evaluation parameters concentrate on absolute power / EIRP, on spectral evaluations and on signal quality parameters like correlation loss and S-curve-bias. Crucial for corresponding satellite characterisations is a very accurate measurement system calibration in absolute power, relative amplitude and phase over frequency. For this purpose, several calibration approaches have been adopted and are still under optimisation. Based on that, results are shown not only from the initial phase of the GIOVE-B in-orbit testing, but also from measurements performed several months later.

The similarity of corresponding measurement results indicates a perfect long-term stability of the considered characteristics. Also it has been demonstrated, that an eclipse period seems not to impact signal quality in a relevant manner.

As expected and already known from previous publications [1][7][8] the satellite provides some directional variations in its EIRP characteristics which naturally also impacts signal quality.

Moderate variations have been obtained within the considered few paths, but for a full characterisation, measurements and evaluations of several more paths would be required in future.

Due to the respectively required long-term spread of measurements, the measurement system calibration stability is of central importance. This demands for effective and automatic re-calibration procedures as with the proposed wide-band signal calibration approach currently under optimisation.

For a full EIRP characterisation over several paths, this also implies to concentrate on measurements with modulated signal transmission.

With the GIOVE-B measurements and evaluations, DLR and EADS Astrium gained considerable experience in accurate characterisation of the navigation signals transmitted from the in orbit satellite which can be useful also for future satellite validation campaigns.

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