REVIEW OF THE IMPACT OF ERS-2 PILOTING MODES ON THE SAR DOPPLER STABILITY

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ABSTRACT: ERS-2 was piloted in yaw-steering mode using three gyroscopes since the beginning of the mission until February 2000, when a new yaw-steering mode using only one gyroscope was implemented. The ERS-2 gyroscopes had experienced several problems during the mission and the new mono-gyro mode (1GP) was intended to ensure the mission continuity even in case of additional failures. In January 2001 a new test piloting mode using no gyroscopes, the Extra-Backup Mode (EBM), was implemented as a first stage of a gyro-less piloting mode. The aim of this challenging mode was to maintain the remaining gyroscopes performance only for those activities absolutely requiring them, such as some orbit manoeuvres. A more accurate version of this yaw-steering zero-gyro mode (ZGM) was operationally used since June 2001 and the performance was further improved with the implementation of the Yaw Control Monitoring mode (YCM) at the beginning of 2002. The evolution from the nominal and extremely stable three-gyro piloting mode (3GP) to the YCM has allowed to successfully continuing the ERS-2 operations despite of the gyroscopes failures. Nevertheless, this evolution has significantly affected the stability of the satellite attitude and the SAR Doppler Centroid frequency. The scope of this paper is to provide an overview of the different ERS-2 piloting modes and to assess their impact on the platform attitude, the SAR Doppler stability, the product quality and the applications performance, particularly for interferometry.

1 INTRODUCTION

Throughout is lifetime ERS-2 has suffered several problem/failures with some of the 6 available gyroscopes leading to 6 different piloting modes in order to ensure the mission continuity. This paper summarises the performance of all the piloting modes in terms of Doppler centroid frequency stability and their impact on InSAR applications. Figure 1 illustrates the succession of the ERS-2 piloting modes as well as the evolution of the orbit dead-band.

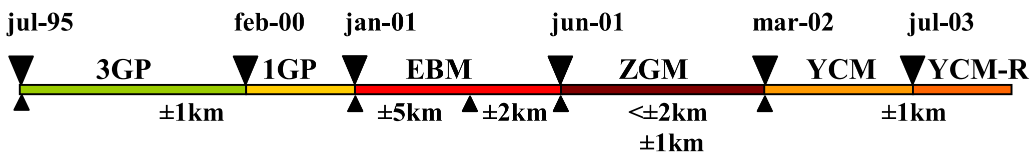

figure 1: Configuration of the ERS-2 piloting modes and corresponding orbit dead-band evolution

Section 2 presents the results obtained for both ERS-1 and ERS-2 during nominal 3GP operations. After a brief introduction to the relationship between attitude parameters and Doppler Centroid (DC) frequency in section 3, the main characteristics of the mono-gyro (1GP) piloting mode are given in section 4 as well as an assessment of the InSAR performance with 3GP data.

Due to further gyroscopes failures, ERS-2 was placed in January 2000 in Extra Backup Mode (EBM), which was the first attempt to assess the gyro-less operations. A detailed analysis of the EBM impact on attitude, DC and data quality is given in section 0. The first efficient gyro-less piloting was the ZGM, which replaced the EBM in June 2001 and which is analysed in section 6. The last piloting mode, the YCM is described in section 7 and its actual regional (YCM-R) constrain is discussed in section 8.

All those attitude control modes present different performance. In order to give a global overview figure 2 shows the evolution of the yaw angle mispointing for the 5 last years covering the end of the 3GP mode until the actual YCM-Regional (YCM-R).

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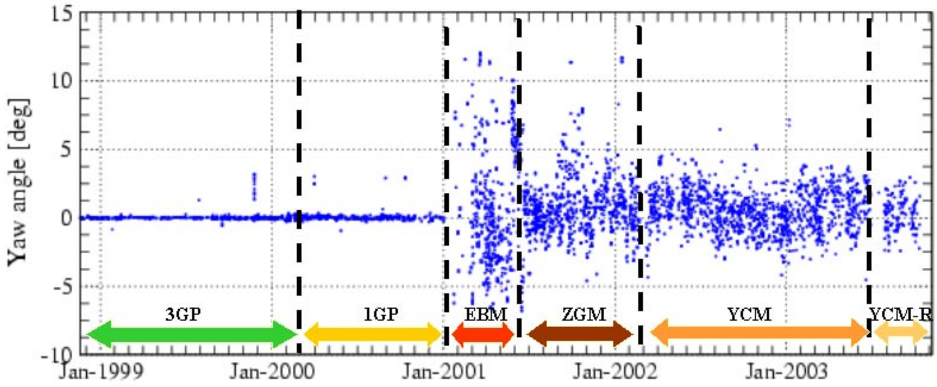


figure 2: Evolution of the yaw angle with time since January 1999 until November 2003

2 ERS-1 AND ERS-2 IN NOMINAL 3GP OPERATIONS

For both ERS-1 and ERS-2 in nominal 3GP operations, the DC frequency followed a very stable pattern around the orbit, which was a direct consequence of the high attitude stability achieved for the spacecraft. Furthermore, the yaw steering capability made possible to keep the DC frequency within the azimuth baseband (i.e. within the interval ±PRF/2) most of the orbit. The nominal variation of DC frequency along the orbit was very stable and similar for both ERS-1 and ERS-2 SAR, with ERS-2 values being around 250Hz lower than ERS-1.

The Doppler frequency evolution around the orbit can be characterised using both SAR images and wave products. The advantage of using wave mode products is that they are systematically acquired over almost the whole orbit. Using image products requires a long time period to collect enough data for significant analysis but it provides more accurate DC estimation. Consequently, wave mode is used on a short-term basis while image mode is used to validate the results on a long-term basis. However the DC from wave data is wrapped in azimuth baseband (ESA wave mode processor does not include a Doppler ambiguity estimator) and it can be easily compared (after unwrapping) with image mode only if the Doppler ambiguity number falls in the first left/right ambiguity.

During the 5 years of ERS-2 3GP operations, the archive was large enough to monitor the DC frequency from image mode and to compare the results with those obtained by the wave mode data. Doppler frequency values derived from both ERS-2 SAR image and wave products are in very good agreement as it can be seen in figure 3. The figure presents the near range Doppler frequency fitting extracted from wave mode products acquired during January 2000 and the one derived from a subset of SAR image data acquired during the 3GP mode. It should be noted that these two Doppler frequencies do not exactly refer to the same range position since image and wave mode have not the same swath. In effect, the near range of wave mode corresponds to almost the mid range of image mode.

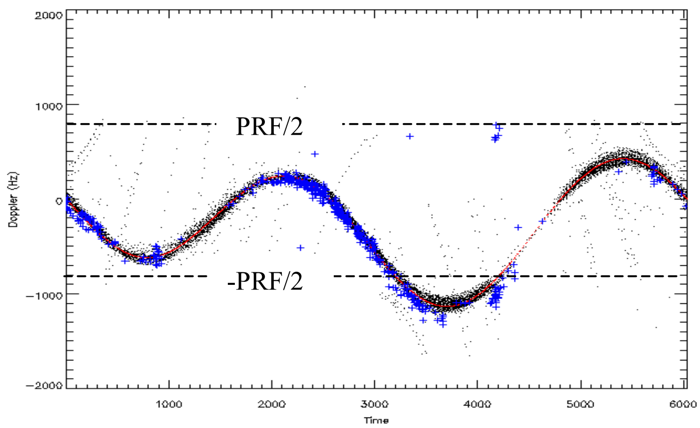


figure 3: Doppler Centroid frequency evolution around the orbit for ERS-2 in nominal 3GP mode.

Doppler Centroid from wave mode data has been used to derive an evolution model around the orbit by fitting the real DC frequency with Fourier series (red curve in figure 3). As it can be observed, the Doppler centroid is in the azimuth baseband for most of the orbit except for a short interval, approximately over the Antarctic in descending passes, where it falls on the first left ambiguity. Note that Doppler centroid values outside the expected trend correspond to SAR data acquired during manoeuvres that are usually performed in Fine Pointing Mode (FPM).

The extremely high attitude stability during nominal 3GP allowed to maintain a very stable Doppler frequency in time at the same orbit position, which combined with an orbit dead-band of ±1 Km, makes possible the exploitation of most of the ERS 3GP data archive for interferometric applications.

3 SAR ACQUISITION GEOMETRY AND DOPPLER CENTROID

Usually the Doppler Centroid frequency is estimated from the acquired SAR data. However it is also closely linked to the acquisition geometry parameters like the satellite pointing, the velocity, antenna elevation angle, the distance to the target, etc.

The platform attitude is sketched in figure 4 where the roll, yaw and pitch axes are shown. The satellite motion is positive in x-axis. The SAR antenna is looking to P target located at the zero-Doppler azimuth line relative to a null yaw and pitch. If the yaw and pitch are non-zero, a squint angle Ψ is introduced leading to a SAR pointing slightly forward or backward relative to its nominal pointing (to point P').

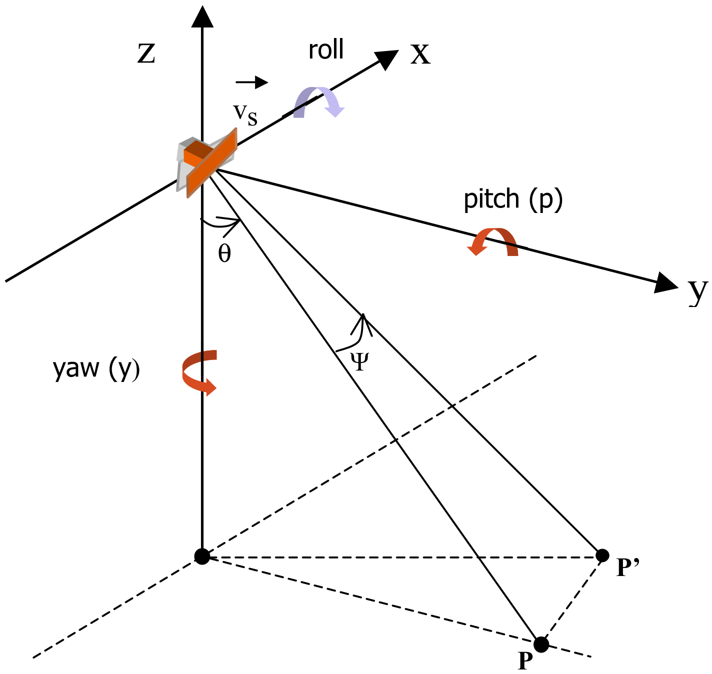


figure 4: ERS SAR acquisition geometry and attitude parameters

A non-zero squint angle Ψ leads to a DC frequency offset introduced by the imaging geometry. An estimation of the DC for circular orbits is given by:

$$f_{dc} = \frac{2v_s}{\lambda}.\sin\psi \qquad (1)$$

If yaw (y) and pitch (p) are small enough and if we assume that they contribute linearly to the squint angle, Ψ could be expressed as:

$$\psi = \tan^{-1}(\tan y.\sin\theta) + \tan^{-1}(\tan p.\cos\theta) \quad (2)$$

$$\psi \approx y.\sin\theta + p.\cos\theta \quad (3)$$

and $\sin\psi \approx \psi$ for small squint angles.

with θ being the antenna elevation angle (or look angle).

The roll angle has no influence on the squint angle neither on the DC. Therefore the Doppler centroid could be expressed as:

$$f_{dc} = \frac{2v_s}{\lambda}.(y.\sin\theta + p.\cos\theta) \qquad (4)$$

As the Doppler Centroid frequency depends on the look angle θ, it can be calculated at different range positions, typically at near and far range:

$$f_{dc}(\theta_{near}) = \frac{2v_s}{\lambda}.(y.\sin\theta_{near} + p.\cos\theta_{near}) \qquad (5)$$

$$f_{dc}(\theta_{far}) = \frac{2v_s}{\lambda}.(y.\sin\theta_{far} + p.\cos\theta_{far}) \qquad (6)$$

Therefore it is possible to derive the yaw and pitch from (7) and (8) as following:

$$y = \frac{\lambda}{2V_s.\sin(\theta_{far} - \theta_{near})}.(f_{far}.\cos\theta_{near} - f_{near}.\cos\theta f_{ar}) \qquad (9)$$

$$p = -\frac{\lambda}{2V_s.\sin(\theta_{far} - \theta_{near})}.(f_{far}.\sin\theta_{near} - f_{near}.\sin\theta_{far}) \qquad (10)$$

The Doppler frequency at near range and its variation across-range are very sensitive to the yaw and pitch angles. For example, a yaw angle of 0.01° leads to near-range offset of 25Hz while the same pitch leads to an offset of 50Hz [2].

In practice, the earth motion induces a squint angle and the purpose of the YSM is to compensate it by applying a harmonic rotation mainly on yaw axis, but also in pitch and roll axis. The Doppler evolution pattern as shown in figure 3 could be considered as the residual of the YSM correction.

For an ellipsoidal orbit, the relationship between Doppler centroid and attitude parameters is more complex however the assumption of a circular orbit is enough accurate for our needs.

4 ERS-2 IN 1GP OPERATIONS

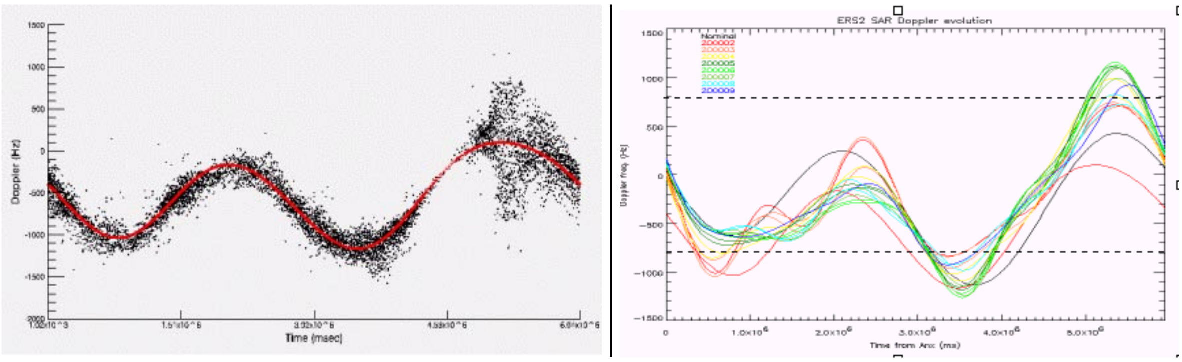
During the early part of the ERS-2 mission, some of the 6 gyroscopes have suffered several problems and failures. In order to prevent other gyro failures, a new on-board software was developed to pilot ERS-2 in YSM with a single gyroscope. In the mono-gyro piloting mode, a slight attitude degradation was expected with direct impacts on the DC frequency.

The switch to 1GP operations took place on 11 February 2000 and a short validation campaign was carried out to assess the quality of SAR data acquired in 1GP. An average of 4 minutes per day of ERS-2 SAR image mode data were planned during the 1GP validation campaign. As it was not sufficient to cover the whole orbit interval, wave mode data was used to routinely follow the DC frequency variations around the orbit.

The evolution of DC frequency after switching to 1GP operations, considering only data acquired between 11 and 16 February 2000 is shown in figure 5.a. The higher level of noise after crossing the South Pole is due to Digital Earth Sensor (DES) sun blinding effect, which is a seasonal effect occurring during this period. As usual Fourier series were used to derive a mean evolution. At the end of the validation it was decided to leave ERS-2 in 1GP operations [1,2].

ERS-2 was operated in 1GP mode until January 2001; throughout these 11 months of operations, the characteristics of the DC frequency evolved considerably. The DC frequency standard deviation for a given orbit position was larger than in 3GP and the variation of DC frequency around the orbit followed a very different and less stable pattern. For this reason, a monitoring of the wave DC evolution around the orbit was performed routinely in 15-days basis, which appeared sufficient to follow the mean evolution of the Doppler in time [2,3]. As previously the DC frequency derived from available SAR images was used to control the results obtained with the unwrapped wave data.

The evolution of DC frequency with time can be observed in figure 5.b, where the average is performed in a monthly basis (instead of 15 days). The DC evolution from nominal 3GP is also shown as a reference (black curve). It can be observed the larger temporal variation occurs after the South Pole on ascending passes due to larger attitude instability over this geographical area (DES sun-blinding effect).



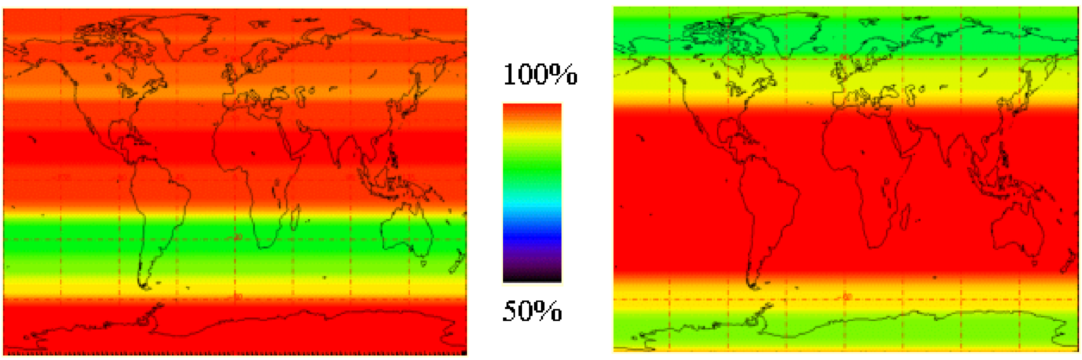
(a) Wade mode DC evolution around the orbit between 11-16 February 2000 (points) and Fourier fit (line)

(b) Temporal evolution of SAR DC frequency by Fourier fit

figure 5: Doppler Centroid Evolution in 1GP operation

The mean Doppler evolution derived from the Fourier series coefficients has been directly integrated on the ESA catalogues to support InSAR 1GP data selection. Additional information is also provided on the ESA web site and can be retrieved from http://earth.esrin.esa.it/pcs/ers/sar/doppler.

Between 11-16 February 2000 and 11-24 October 2000, ERS-2 was operated in1GP using gyroscope 6, while gyroscope 5 was used between 17 February 2000 and 10 October 2000. After the 24 October and until the start of the EBM piloting was performed using gyroscope 1 because noise was detected in gyroscope 6. No differences were found in SAR Doppler characteristics between the 1GP-5, 1GP-6 and 1GP-1 modes [2,3].



(a) Ascending passes

(b) Descending passes

figure 6: Geographical distribution of 1 GP data having a Doppler difference with the corresponding 3GP data below 500Hz comparing 3GP data

In order to assess the 1GP mode in terms of InSAR performances, the percentage of 1GP data that can be combined with 3GP data, in terms of azimuth overlap only, has been estimated. Ffigure 6 shows the geographical distribution of suitable datasets. For the whole 1GP, 88% of the data is suitable for InSAR applications when combined with ERS-2 3GP data. As it can be observed, privileged areas are slightly different between ascending and descending passes. It shall be noted that these statistics do not take into account the baseline requirement and that suitable datasets are considered here as those having an absolute Doppler difference below 500Hz.

5 ERS-2 IN EXTRA BACKUP MODE OPERATIONS

During the mono-gyro mission some anomalies s occurred with the remaining gyroscopes. Therefore in order to ensure the continuity of the mission, it was necessary to investigate the possibility of piloting the ERS-2 platform without gyroscopes.

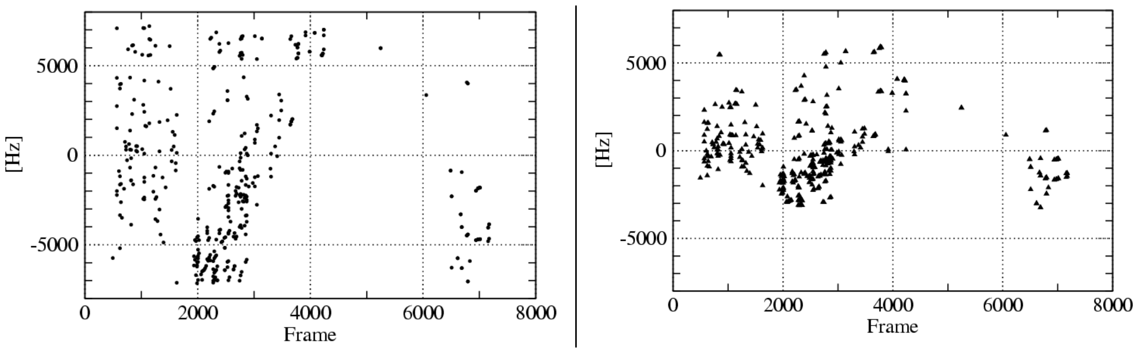
A course gyro-less piloting mode (the Extra Backup Mode), which made intensive use of the Digital Earth Sensor (DES), the Digital Sun Sensor (DSS) and the reaction wheels, was developed and up-linked on 15 January 2001 as a first attempt to pilot the satellite without any gyroscope.

The AOCS configuration for EBM was then 3 gyroscopes for Orbit Control Manoeuvres (OCM), one for safe mode and zero for attitude control.

The EBM validation campaign began on 15 January 2001 and it was due to end on 19 January. However since one of the gyroscope failed during the campaign, it was decided to fully dedicate the remaining gyroscopes to OCM and safe mode. ERS-2 mission was forced to continue in EBM operations for safety reasons until June 2001.

In order to limit the number of manoeuvres in EBM (and therefore reduce the use of the gyroscopes as much as possible), the orbit dead-band was increased to ±5km in January 2001. In April 2001, the dead-band was reduced to ±2 Km (c.f ±1 Km in 3GP and 1GP).

With EBM, the variation of Doppler Centroid frequency along the orbit was much faster than for the previous mode, showing very often a complete different evolution from one orbit to the next. This rapid variation made impossible the derivation of Doppler evolution models with a validity of several days (which was implemented during the 1GP period). The large Doppler differences from orbit to orbit (at the same relative orbit position, i.e. same frame) can be observed in figure 7.a and b. The Doppler Centroid frequency during this period can reach values up to ±30 KHz at near range and variation across range of up to 6 KHz (c.f. 100-200 Hz in 3GP mode).

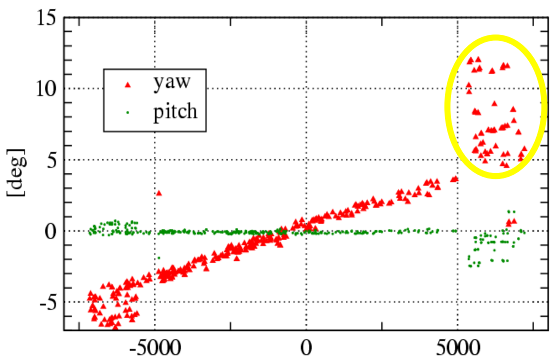


(a) DC frequency at near range along the orbit

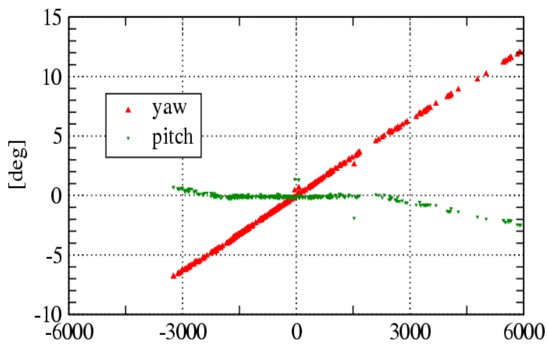
(b) DC frequency difference (far-near) along the orbit

figure 7: Image mode Doppler centroid frequency characteristics during EBM

figure 8.a and b show the yaw and pitch behaviour versus the Doppler centroid and versus its variation across range. As it can be observed, the platform mispointing is mainly due to the yaw angle with values of up to 12º (c.f. 0.2º in 3GP). Indeed a variation of 1º in yaw is equivalent to a variation of 1250 Hz in the Doppler Centroid frequency. The pitch is limited to smaller values but has still a significant impact. The different behaviour of the yaw in figure 8.a and b (yaw follows a straight line when plotted versus the Doppler variation in range while yaw values appear stretched when plotted versus the Doppler Frequency at near range) is due to the fact that the Doppler Centroid frequency at near range for data sets with high yaw (above 4º) has not been correctly estimated by the ESA ERS SAR processor (VMP). The true Doppler Frequency for the datasets marked in yellow is indeed between 5000 Hz and 15000 Hz.



(a) Yaw and pitch evolution versus DC frequency at near range



(b) Yaw and pitch evolution versus DC difference (far -near) range

figure 8: Yaw and pitch characteristics during EBM

When the true Doppler frequency is correctly estimated, resulting products do not present any radiometric calibration or geometric degradation although they might be displaced in azimuth up to 30km (4.5sec) with respect to the nominal frame. This is not a localisation error since the coordinates annotated are consistent with the scene content but a displacement due to the antenna squint angle. Products with high Doppler centroid frequencies will also appear slightly shorter in azimuth [3].

The VMP is able to correctly estimate the Doppler ambiguity number for true Doppler frequencies within ±5000 Hz and, as mentioned above, those products can be regarded as nominal. However, for true Doppler frequencies outside the ±5000 Hz range, the VMP could wrongly estimate the Doppler ambiguity number and products would appear defocused and mislocated in azimuth.

For this reason only products with Doppler centroid frequencies within ±4500Hz are routinely distributed to the users and products outside this range are analysed before delivery. This dedicated quality control uses the linear relationship between yaw and Doppler Centroid frequency where data with a wrong ambiguity number appears like outliers as it can be seen in figure 8.a.

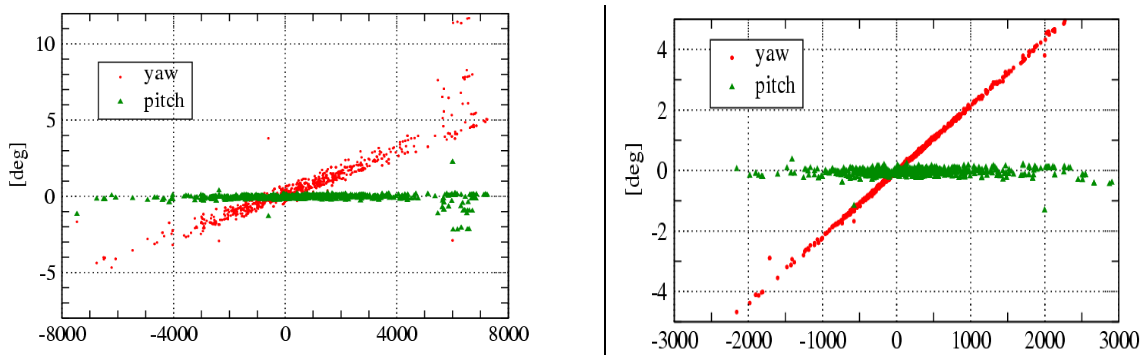
Due to the variability and the unpredictable nature of the EBM attitude, retrieval of Doppler Centroid frequencies during this period (to support InSAR data selection) has not been possible. The DC difference between pairs of products will be very large in most of the cases, limiting the overlap between the azimuth spectra and reducing the InSAR performances or preventing the use of the data for InSAR applications. Considering the very high DC frequency variation, the lack of auxiliary information and the large orbit dead-band during this period, the use EBM data for InSAR applications is not recommended.

6 ERS-2 IN ZERO GYRO PILOTING MODE

During the 6 months of EBM operations a software patch was developed to improve the attitude and orbit control performances of ERS-2. In June 2001 this new AOCS software was uploaded leading to the first efficient gyro-less mode called Zero Gyro Mode (ZGM).

The first benefit of ZGM was on the OCM performances. In effect, the orbit dead-band was brought back to the nominal range of ±1 Km for descending passes in 50ºN, 30ºN/ 50ºS, 30ºS, and ±2 Km elsewhere.

The second benefit was as expected on the attitude control stability. As shown in figure 9, the antenna mispointing was considerably decreased comparing to EBM. The yaw angle is henceforth mainly constrained between ±5° and the outliers related to the Doppler ambiguity errors have been significantly reduced. The remaining cases are related to manoeuvres and to the impact of external effects on the attitude stability (ZGM is particularly sensitive to the solar activity).



(a) Yaw and pitch evolution versus DC frequency at near range

(b) Yaw and pitch evolution versus DC difference (far -near) range

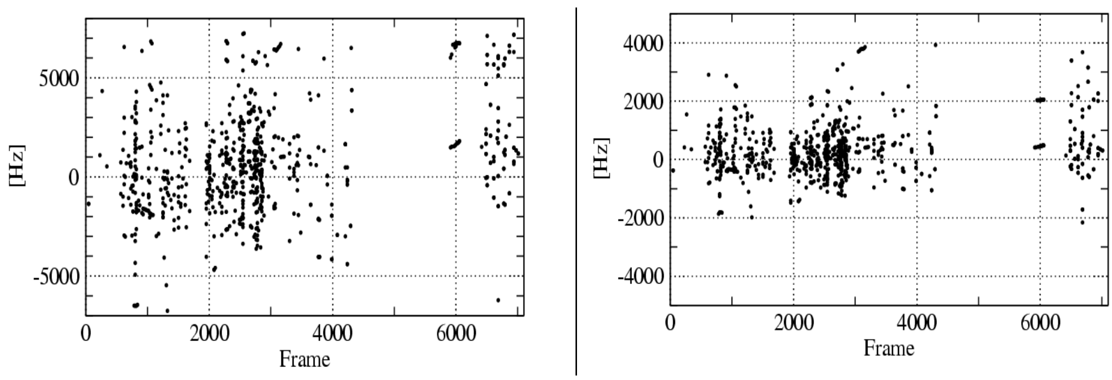
figure 9: Yaw and pitch characteristics during ZGM

The Doppler Centroid frequency evolution was still very unstable from orbit to orbit, preventing the derivation of orbital Doppler models (as performed for the 1GP operations) even for short periods of time. Therefore a new procedure was developed to monitor the Doppler evolution during the ZGM period and to assess the ZGM performance in terms of attitude stability. The new strategy combined the Doppler unwrapping of global wave mode data with the absolute Doppler frequency from few image mode data sets with some knowledge of the yaw & pitch behaviour. The main steps in the procedure are provided below:

1. Wave Doppler unwrapping
2. Unwrapping refinement using the pitch derived from the wrapped wave Doppler
3. Solving the ambiguity number using the absolute DC derived from the image mode
4. Filling the gaps in the DC around the orbit obtained in step 3 (these gaps correspond to segments were no wave mode data was acquired)

At the end of the process, an absolute Doppler evolution around the orbit is obtained with an accuracy of ±500 Hz. This information is updated once per cycle and it is then used to populate the ESA catalogues. It is also directly on line at http://earth.esrin.esa.it/pcs/ers/sar/doppler.

The ZGM has significantly improved the attitude performances comparing to EBM operations. The detailed analysis of the ZGM absolute Doppler Centroid frequency shows that 90% of the data is constrained in the range of ±4500 Hz and its variation across range has been decreased to ±2000 Hz as illustrated in figure 10 with all image mode data available at ESRIN for the ZGM operations.



(a) DC frequency at near range along the orbit

(b) DC frequency difference (far-near) along the orbit

figure 10: Image mode Doppler centroid frequency characteristics during ZGM

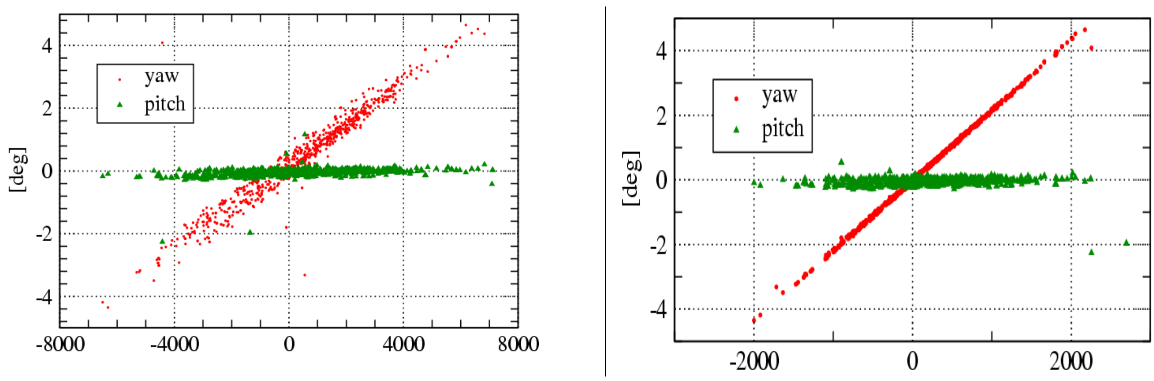
In addition, the new on-board s/w has made possible to increase the frequency of orbital manoeuvres with respect to the EBM period and the orbit dead-band (maximum baseline) has been reduced to the nominal range of ±1 Km for part of the orbit and to ±2 Km for the remaining orbital interval.

7 ERS-2 IN YAW CONTROL MONITORING

In order to further improve the performances of the gyro-less piloting mode, a new piloting mode, the Yaw Control Monitoring (YCM), was implemented as an evolution of the ZGM. Operations in YCM started in March 2003. The main feature of the new mode is the use of the mean yaw per orbit to adjust the satellite yaw in the following orbit. The mean yaw per orbit is routinely derived at ESRIN in Near-Real-Time (NRT) from wave mode data and sent to ESOC for tuning the attitude of the next orbit if necessary.

YCM has shown immediate improvements comparing to ZGM. As shown in figure 11, the mispointing has been reduced by 1°, mainly constraining the yaw within ±4°. As a consequence, the DC is constrained within ±4500 Hz for the 95% of the data and its variation across range between ±1500 Hz, ensuring nominal radiometric and geometric data quality.

In addition, with the YCM operations, the orbit dead-band has been returned back to the nominal range of ±1 Km over the whole orbit.



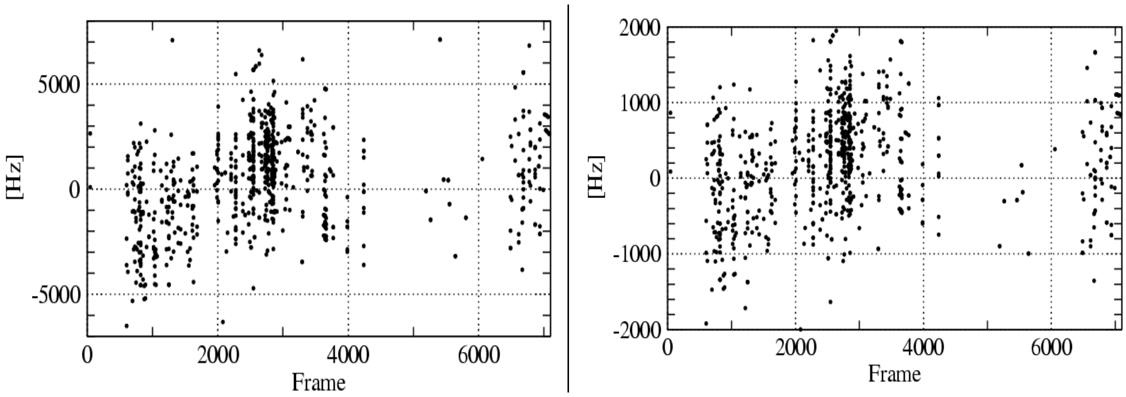
(a) Yaw, pitch versus near range DC frequency **(b) Yaw, pitch evolution versus DC difference (far -near) range**

figure 11: yaw and pitch characteristics during YCM

Despite of the improvements in the attitude stability, as it can be observed in figure 12.a, the DC is still highly variable from orbit to orbit and the DC at the same orbit position (i.e. same frame) may change beyond the requirements for InSAR applications. For the same reason, it is not possible to define a Doppler model around the orbit valid for a certain period of time and therefore, retrieval of Doppler Centroid information is performed following the same strategy as in ZGM (see section 6).

As for 1GP, the percentage of ZGM/YCM data that could be combined with 3GP has been assessed. Considering the DC instability, the threshold on azimuth spectra overlap has been increased to 800Hz and the baseline requirement is (as before) not taken into account. Unlike 1GP, no geographically privileged areas are observed and only 7% of the data could be used for InSAR applications between ZGM/YCM and 3GP modes.

YCM achieved the best attitude and DC frequency stability since the gyro-less operations. Although suitable ZGM-3GP and YCM-3GP InSAR pairs exist, it remains difficult to identify them. In order to support the identification of suitable data, the retrieved DC frequency along the orbit (following the strategy defined in section 6) is made available to the users.



(a) DC frequency at near range along the orbit **(b) DC difference (far-near) along the orbit**

figure 12: image mode Doppler centroid frequency characteristics during YCM

8 ERS-2 IN YCM-REGIONAL OPERATIONS

On 22 June 2003 a failure occurred on the second ERS-2 tape recorder, which was definitively declared unavailable. The ERS-2 tape recorders were used to record on board the ERS-2 Low Rate mission (including SAR Wave mode), which was then dump in the visibility of ESA ground stations. Clearly, the failure of the 2nd tape recorder has interrupted the global ERS-2 low rate mission and low rate data is now only available within the visibility of ESA stations and some National and Foreign Ground stations. Using the network of ground stations, ERS-2 low rate data is now available over Europe, the North Atlantic Ocean, the Arctic and the western part of North America and Canada.

As the ERS-2 High Rate mission didn't use the tape recorders, the SAR Image mode operations are not affected by the failure. Nevertheless, due to the lack of global wave data, the strategy used during ZGM and YCM to derive the DC frequency around the orbit cannot be applied anymore and retrieval of this information becomes extremely difficult. A new strategy to support InSAR users is however under analysis.

Furthermore, the lack of global wave mode data means also that the strategy used during YCM for adjusting the satellite attitude based the yaw information from previous wave mode orbit shall be reconsidered, as it cannot be applied in the same manner. It will be attempted to modify the previous strategy using wave mode data acquired over a small orbit segment in Kiruna visibility. The goal will be now to maintain the same or better attitude stability than during YCM operations, at least over Europe.

9 CONCLUSION

This paper has presented the evolution of the ERS-2 attitude and DC frequency stability throughout the mission lifetime and has assessed the impact of the different piloting modes on data quality and InSAR applications.

It has been shown that except a slight degradation of the DC frequency in time and over specific geographical areas, the performance of the mono-gyro mode is very close to the 3GP mode. The slow variation of DC in time during 1GP operations made possible to derive a model for the DC evolution around the orbit (valid for a limited period of time) and therefore to easily estimate the DC frequency at any orbit position. The resulting DC information is integrated on the ESA data catalogues and it is directly accessible online in order to support the InSAR data selection.

The attitude stability was considerably degraded with the start of EBM operations, the first attempt to pilot without the help of the gyroscopes, which had a significant impact on data quality and InSAR performance. Image quality is not degraded for products with DC within ±4500Hz, but actual DC frequency values range up to ±30 KHz and varies rapidly from one orbit to the next. This rapid and unforeseen variation makes unfeasible the retrieval of a DC frequency around the orbit. **These products are currently distributed others are systematically controlled before shipment**. In case of very high DC frequency, EBM imagery may also be displaced with respect to the expect scene location due to the large antenna squint angle. EBM data presents severe limitations for InSAR applications due to the very high and unstable DC frequency, to the impossibility to provide any Doppler information and to the increase of orbit dead-band during this period. For these reasons, use of EBM applications for InSAR applications is not recommended.

The first improvements in the gyro-less operations arrived with ZGM. During ZGM, the attitude and the DC frequency were still very unstable but the maximum mispointing was significantly reduced. As a result, the DC frequency for 90% of the ZGM data is within the range of ±4500 Hz, ensuring nominal data quality and increasing the percentage of suitable data for interferometric applications. Since the DC frequency is still variable from one orbit to another, a new strategy to derive the DC around the orbit was implemented. The information is, as for the 1GP period, available on line and on the ESA data catalogues to support the identification of suitable InSAR ZGM data.

Since the start of the gyro-less operations the attitude performance has been progressively improved, first with the ZGM and then with the YCM, which provided the best attitude stability since January 2001. As a further improvement, the orbit dead-band was back to the nominal range of ±1 Km over the entire orbit. During YCM, the DC frequency is within the range of ±4500 Hz for 95% of the data. However due to the attitude variability from one orbit to another, the strategy for Doppler monitoring is the same as for ZGM.

With the failure of the second tape recorder in June 2003, the ERS-2 Low Rate mission was partially lost. This had an important impact in the YCM operations, since global wave mode data (used to monitor the DC evolution) was not available anymore. Currently, wave mode data is only available over specific areas (Europe and North Atlantic) and therefore the strategy for YCM has been modified to use data acquired North of Europe for the attitude monitoring. The very first results of the YCM-R do not indicate any significant degradation in the attitude and DC stability.

10 REFERENCES

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