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# The ERS SPTR2000 Altimetric Range Correction: Results and Validation

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# 1 INTRODUCTION

The scope of this document is to present the new SPTR2000 correction as the result of the different improvements to the Scanning Point Target Response Range Correction Algorithm.

The new SPTR algorithm initially specified by R. Francis and M. Roca in [R-1] has been accompanied during the project by the writing of a detailed software specification and the revision/upgrade of some parts of the algorithm itself. On top of this, the high level operational and pre-processing requirements have been written to integrate the new SPTR algorithm within the ESRIN PCS environment. The overall detailed description of that effort is given in [R-3] and [R-4]. In this document a very brief description is given on the main new algorithm concepts with particular highlights on the differences with the old version. The results are presented together with some elements on the validation performed within ESRIN. Information is also provided regarding the operational new SPTR correction file available to the users.

# 2 ALGORITHMS DESCRIPTION

In order to better describe the overall algorithm implemented to calculate the SPTR Altimetric Range Correction, it is useful to underline that it can be subdivided into two main parts. The first, briefly described in paragraph 2.1, evaluates the calibration measurement values using the raw data sensed in Scanning Point Target Response Calibration Mode. The second part will be presented in paragraph 2.2 and regards the Final Range Correction Evaluation using the calibration measurement values.

## *2.1 SPTR Measurements Values evaluation Algorithm*

Every day few minutes of data are sensed in the Scanning Point Target Response Calibration Ocean and Ice Modes. These data are sent in fast delivery (with less than 3 hours delay from acquisition) to ESRIN where they are processed. After a pre-processing aimed to guarantee the consistency of the data, the data undergo the real processing which consists of the following main steps:

1. Data Identification and Selection: meant to classify all the source packets with their particular mode and select only the ones needed.
2. Parameter Extraction: aimed to extract the necessary information from each selected source packet.
3. Reconstruction of the Point Target Response Shapes both in Ocean and Ice Modes. The result of this processing will be a series of data-sets each one containing a certain number of data-pairs represented by the FFT power and the relative filter position. There will be one data-set per clock stamp (RX coarse). In this section the first new feature of the algorithm can be found: when determining each sample filter position, the non linear relation between the fine time stamp (RX fine) and the filter position itself is here considered for the first time.
4. Extraction of the Open Loop Calibration pulse and evaluation of its position within the filter bank.

5. Evaluation of the Intermediate Frequency Filter Response making use of the Ice Mode Point Target Responses. In order to perform this, the central position of each PTR within the filter bank will have to be determined by means of a non-linear fitting of the PTR Shape itself with a gaussian curve.
6. Correction of the Ocean Mode Point Target Responses for the IF Filter effects using the output calculated at point 5. This is again a new element of the algorithm considering that in the previous implementation the effects of the IF Filter on the Ocean Mode PTRs were considered negligible.
7. Determination of the central position for each Ocean Mode PTR by mean of a non-linear fitting with a curve resulting from the sum of three gaussians. This is another of the new features included in the algorithm; it takes into account that in reality the Ocean Point Target Responses do not have a gaussian shape as theoretically foreseen. On the contrary some spurious signals are present giving the PTRs a shape more like a three-gaussian curve. Since we want to determine the position of the main signal and not of the spurious ones, a fitting process is recommended instead of the CoG computation, the result of which would be biased by presence of the two side lobes. At the end of this process two sets of data will be available: a set of clock stamp values (RX coarse) and their relative Ocean PTR filter bank positions. This because, as explained at point 3, each PTR is related to a single clock stamp.
8. Determination of the referential Open Loop Calibration signal position. The Ocean PTR positions, when plotted versus their relative clock stamps, should lye over a straight line representing the Chirp; in practice, because of a clock asymmetry, those values are positioned away from it. This line is determined performing a linear fitting to the points and the referential Open Loop Calibration signal position is determined evaluating the filter bank position, over the fitted line, relative to clock stamp 2496.
9. Evaluation of the SPTR measurement correction value represented by the difference between the actual Open Loop Calibration value calculated at point 4 and the referential position as determined at point 8, properly translated from filter distance to range.

## *2.2 Altimetric Range Correction evaluation Algorithm*

The final Altimetric Range SPTR correction is computed from the daily SPTR measurements, assuming that the output correction is a constant for the period in between two instrument on-board anomalies. It is there assumed that the clock asymmetry originating the range jumps is unchanged during such time interval.

Considering that the noise on the SPTR measurement values, when calculated as in par. 2.1, is high and that some outliers occur; the final range correction is evaluated applying the algorithm hereafter reported:

1. For each time interval in between two instrument anomalies all the SPTR measurement values are selected and grouped together. All the measurements taken after the last anomaly occurred are part of the same group. This is performed comparing the anomalies and the SPTR measurements time stamps including the date and time information.

2. In case no SPTR measurements are available in any period of time in between two anomalies, no final range correction will be calculated due to lack of information. The data shall be flagged.
3. For all the SPTR measurement values of each group the mean and the median deviation are evaluated.
4. The SPTR measurement values for which the deviation from the evaluated mean is higher than twice the median deviation are discarded being considered as outliers.
5. The mean and the standard deviation are then calculated again using only the remaining values. They represent respectively the final range correction and its standard deviation for the period of time related to the group under consideration.

# 3 THE NEW SPTR CORRECTION

The processing of the new ERS SPTR correction has been performed on the complete ERS-1 and ERS-2 data set, up to present. An overview of this processing output is given hereafter, along with the results of the geophysical validation performed in ESRIN. External experts from the Altimetry scientific community, who kindly accepted to support ESA in this exercise, are performing a proper validation of the new SPTR correction. This activity is on going and therefore no results is presented in this document.

## *3.1 The ERS data Processing*

In Figure 1 and Figure 2 the overall ERS-1 and ERS-2 SPTR results are presented. The SPTR measurement values are represented with black stars while the final range correction is over-plotted to them with a red line. The final range correction within the SPTR correction file is actually of opposite sign of what is reported in the plots, this because for historical reasons the SPTR measurement values have been actually calculated as the opposite of what is stated at point 8 in par. 2.1.

Observing in particular the ERS-1 plot it can be easily noticed that over certain time periods the correction is set identically equal to zero while no SPTR measurement value is available. These are examples of the case described in par. 2.2 at point 2 when the correction is artificially set to zero due to lack of information. The lack of SPTR Calibration Mode measurements during those periods is due to either:

- the SPTR calibration measurements were not planned (at the beginning of the ERS-1 mission the SPTR Calibration Mode was planned to be performed once per week, since the ERS-2 launch it was planned once every three days and since mid 1998 once per day)
- the measurements were planned but not performed by the operations. This being the case for the first couple of years after the ERS-1 launch when the importance of the SPTR Calibration Mode measurements was not yet stated and consequently the effort devoted to this subject was not at maximum.

To remark also, observing Figure 2 that the number of instrument anomalies (correlated to the correction jumps) has become much lower after mid 1997 when a patch in the on board software was up-loaded in order to prevent from the “Memory Checksum Violation” anomaly.

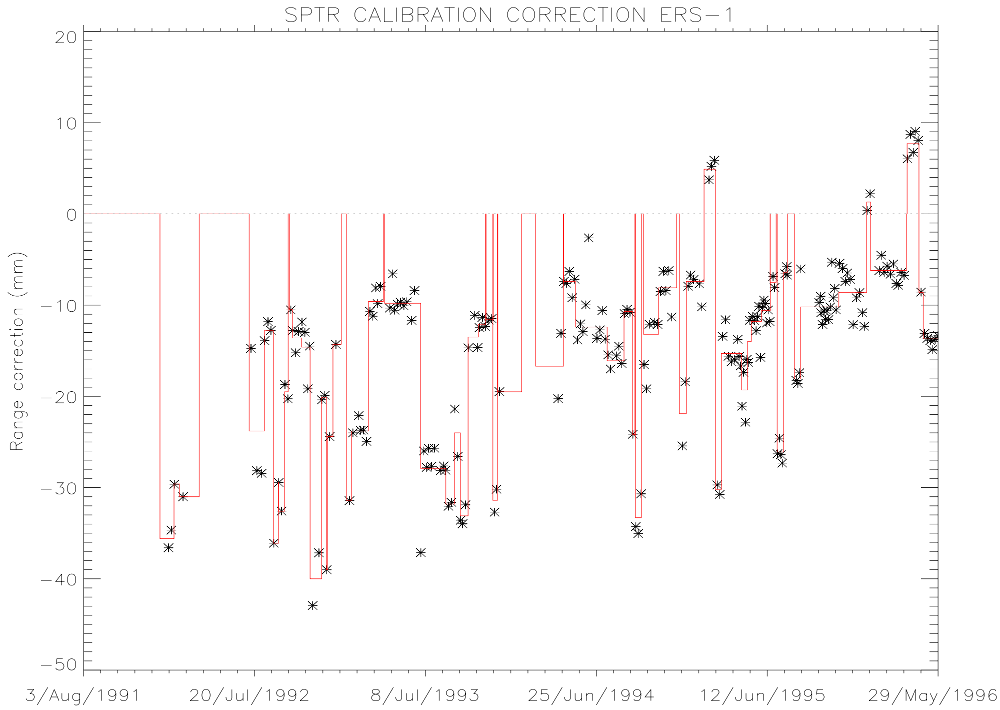


**Figure 1:** SPTR measurement values and final range correction for the whole ERS-1 mission

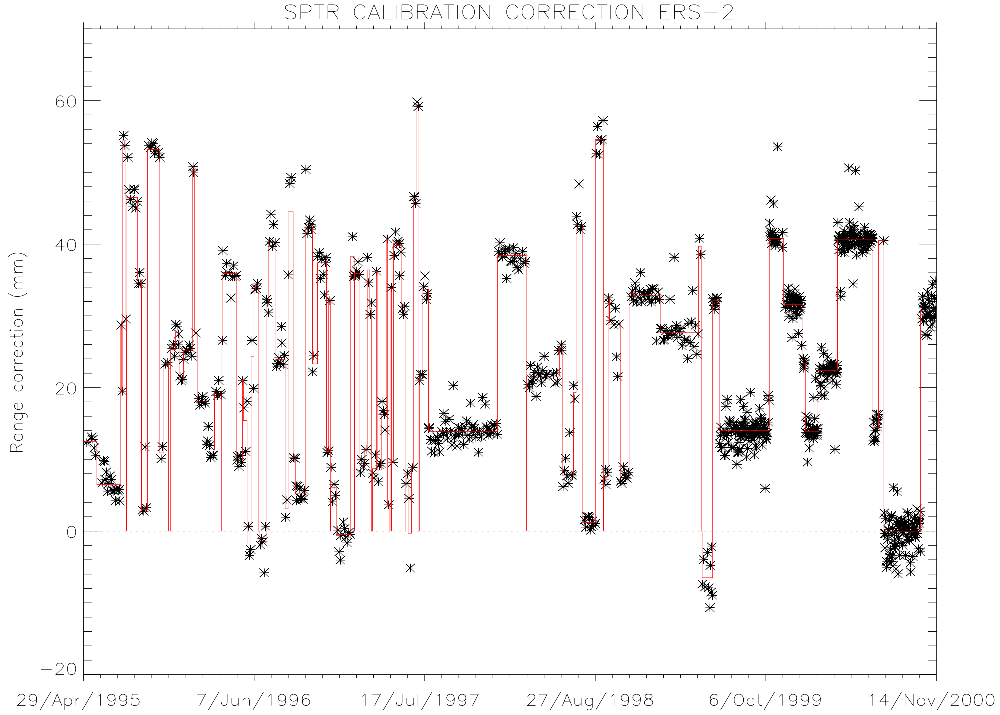


**Figure 2:** SPTR measurement values and final range correction for the whole ERS-2 mission

## 3.2 The New SPTR correction validation

A preliminary validation of the new SPTR correction has been performed within ESRIN for the ERS-1/ERS-2 tandem phase, making use of daily averaged SSH residuals provided by CLS [R-5]. This exercise was not aimed to assess any geophysical significance of the results but meant to determine the validity of the overall algorithm as described in chapter 2 and its proper implementation. However the results obtained were very satisfying. In Figure 3 and Figure 4 the results of the validation exercise are reported respectively for the new range correction results and the one evaluated with the old algorithm. In black the uncorrected daily averaged SSH residuals are plotted, in green the same values are reported after they have been corrected with the ERS-1 final range correction and in red the final result is given when both the ERS-1 and ERS-2 corrections have been applied. In the lower panel the original data and the final result are plotted after having respectively added and subtracted 100 mm for clarity.
Just observing the two plots it appears clearly that the corrected time series on Figure 3 is much more stable than the corresponding one on Figure 4. There are still some remaining evident peaks due to the occurrence of one of the following:

1. There are periods when either the ERS-1 correction or the ERS-2 correction or both are not available. As foreseen in par. 2.2 at point 2, for practical reasons we corrected the SSH residuals with corrections identically equal to zero. Peaks over those periods are caused by a lack of correction.
2. The SSH residuals data available to us for the validation were in the form of daily averages. Considering the case when an anomaly occurred halfway a certain day, causing a jump in the final range correction, we had problems in applying the correction. It was not possible to discriminate different SSH residuals that had to be corrected with one or the other of the two corrections available for the day. For practical reasons only the first one was applied. The data corrected with the wrong range correction can bias the daily average causing a peak.

Taking into account what just explained and thus eliminating all the data falling in one of the two cases it is possible to confirm with figures what we observed before on the plots.
As reported in Table 1, column 3, the standard deviation of the corrected time series for the new range correction algorithm case is much lower than the corresponding value for the old one.

**Table:** Statistics on New Algorithm and Old Algorithm Validation results

| [mm] | Original SSH residual | | SSH res. Corrected | | SSH res. Corrected[1] | | SPTR Correction[2] | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| New Algorithm | -6.73 | 18.02 | -37.90 | 12.51 | -39.59 | 7.71 | 31.17 | 15.62 |
| Old Algorithm | -6.73 | 18.02 | -14.28 | 14.86 | -14.37 | 13.99 | 7.61 | 12.72 |

[1] The SSH daily residuals averages considered for obtaining these figures are all the ones not falling either in one or both the cases reported in par 0.
[2] Note that the sign in this column is opposite of the sign in all the other columns. This because here the correction itself is considered while the other give the SSH residuals analysis results.

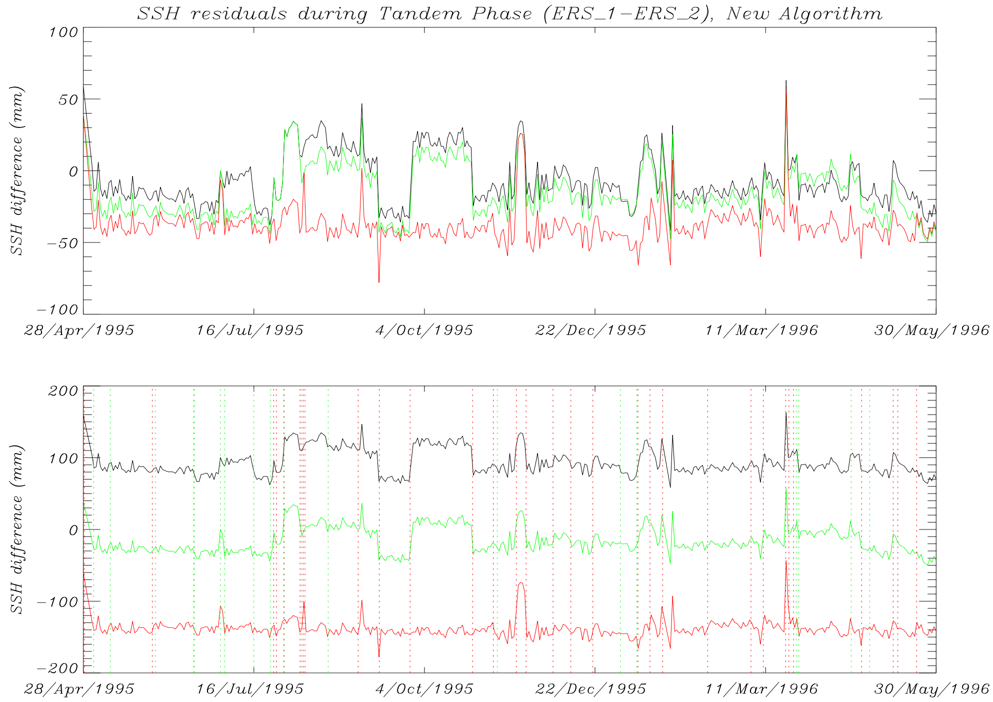


**Figure 3:** SSH difference (ERS_1-ERS_2) during Tandem Phase. Validation results for new range correction algorithm.

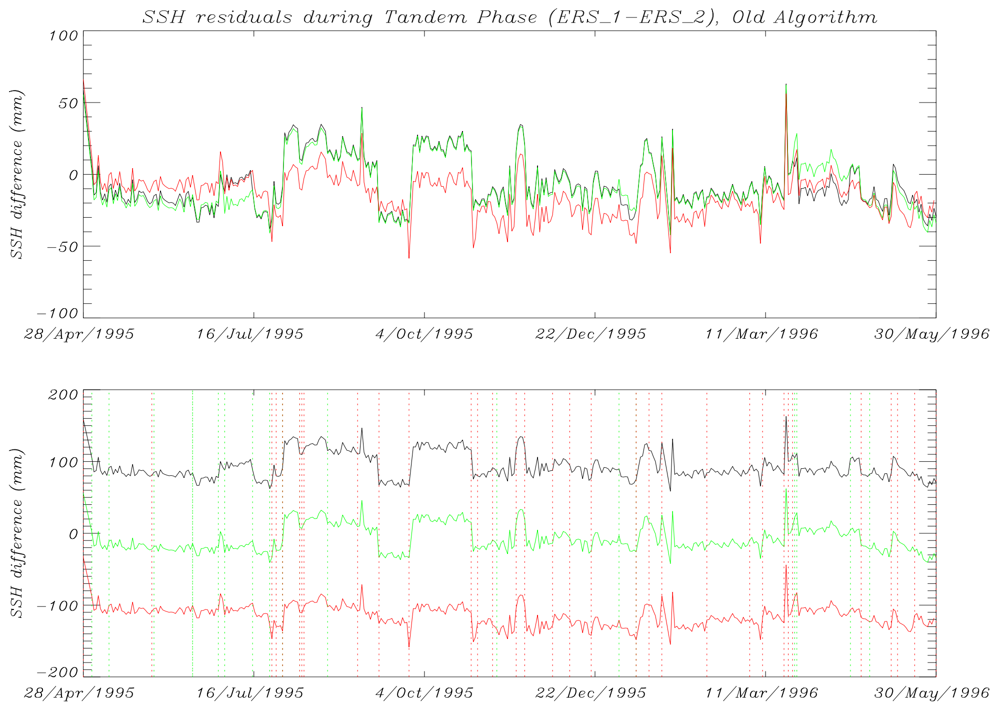


**Figure 4:** SSH difference (ERS_1-ERS_2) during Tandem Phase. Validation results for new range correction algorithm.

## *3.3 Discussion on the New SPTR correction Validation*

When comparing Figure 3 and Figure 4 it easily becomes evident that the SSH residuals time series corrected with the new algorithm results exhibits a higher negative bias with respect to the old algorithm corrected one. This is confirmed by the figures reported in column 4 of Table 1 stating that the overall new correction applied (ERS-1 final range correction – ERS-2 final range correction) causes a bias of about 3 cm while the bias produced by the old one was of few millimetres.

The explanation for this can be identified from both instrument and method characteristics:

- the different shape of the Point Target Responses of ERS-1 and ERS-2 and the different ways they are dealt between the new and the old algorithms.
- The old technique used to determine the PTR positions within the filter bank (Centre of Gravity) generated two final range corrections, for ERS-1 and ERS-2, closer to each other than what is obtained by applying the new algorithm (Fitting) (ref. Par. 2.1 point 7). In Figure 5 and Figure 6 the differences in PTR shapes for ERS-1 and ERS-1 and the relative positions evaluated with the two algorithms are shown.

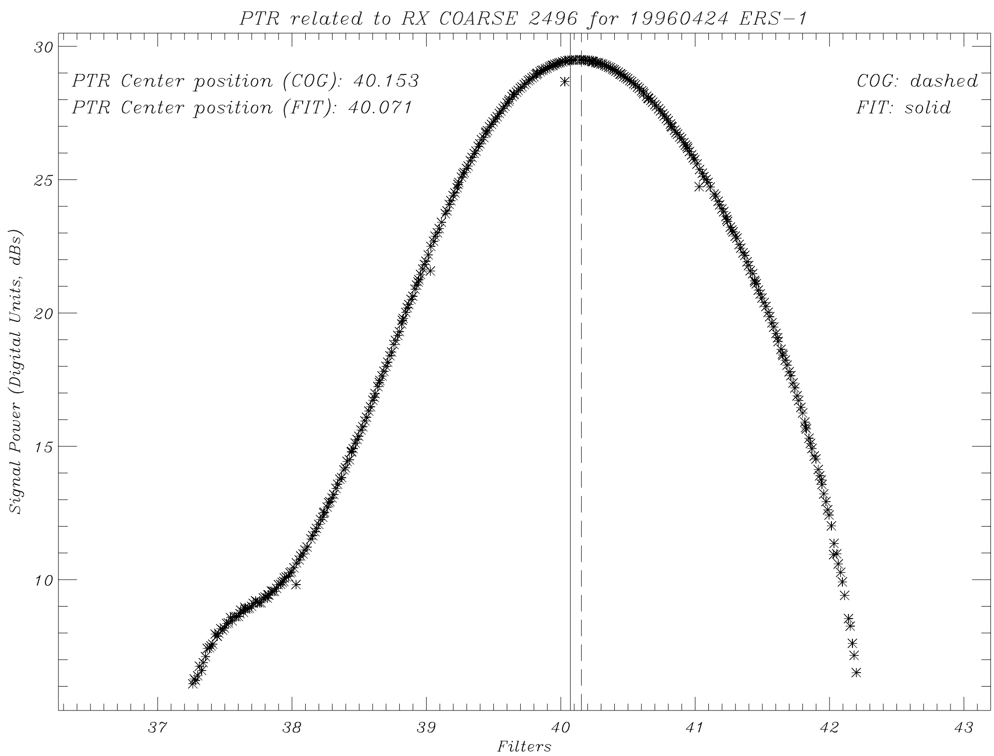


**Figure 5:** Point Target Response and positions for ERS-1

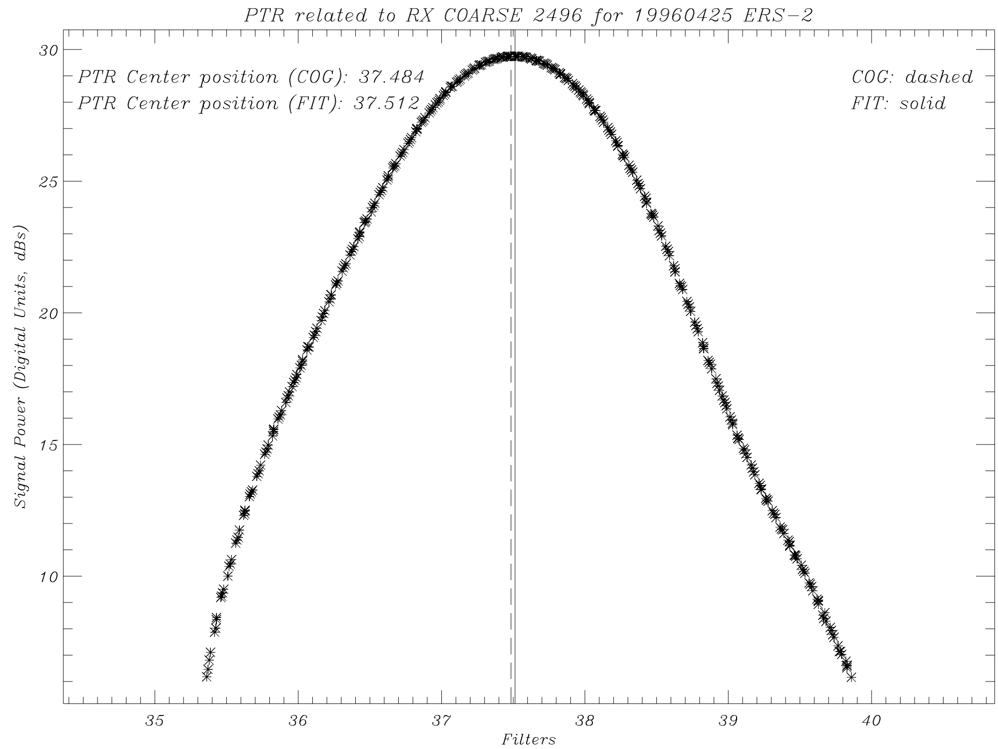


**Figure 6:** Point Target Response and positions for ERS-2

# 4 CORRECTION FILE IN OPERATIONAL MODE

In this chapter few practical information are given regarding the way and the timing in which the final range correction is made available to the users. Remember that the correction provided is to be ***added*** to the altimetric range measurements of all ERS data products.

## *4.1 Correction File Format*

The range correction values are made available in an ASCII file consisting of a series of records in the following format:

a7, x, a8, 4x, d6.1, 4x, d6.1, 5x, i6, 5x, a1

while hereafter the description of the fields content is reported:
yymmdd hh:mm:ss correction (mm) correction stdev (mm) number of elements flag

Example:

```
950429 11:14:45   -12.5   0.5    4   0
950531 04:42:29    -6.5   0.8   12   0
```

The correction reported is to be ***added*** to the data from the date (with time) associated to it, until the following one. Each date represents the time-stamp when a Radar Altimeter on-board instrument anomaly occurred. Together with the correction, the correction standard deviation is reported as well as the number of individual measurements used to compute the correction. The last field is a flag indicating if the correction reported is valid (flag equal to 0) or not (flag equal to 1). The meaning of the flag is related to the fact that over some periods no range correction could be available (ref. Par. 2.2 point 2); in this case the correction reported identically is equal to zero and so is the flag.
Studies are on going to estimate a correction when actually no SPTR calibration measurement or SPTR correction is available (this represents less than 5% of the ERS data set) between 2 sensor on-board anomalies. They are based on the correlation between the correction itself and some temperatures inside the instrument. Those studies are still at the level of investigation and no meaningful correction is yet available.

## *4.2 File Availability*

The new SPTR altimetric range correction files as described in par. 4.1 are downloadable on the following new HTML address:

http://pcswww.esrin.esa.it (Within the Radar Altimeter Section)

The file is updated once per week on Wednesday and contains all the information up to the previous day. On the same web site it will be possible to find any news or further information on the subject.

# 5 REFERENCES

[R-1] ER-TN-ESA-RA-150, *SPTR Algorithm Specification, Draft 4,* R. Francis, M. Roca, 28 October 1999
[R-2] *Identification and Correction of Clock Asymmetry in the ERS-1 and ERS-2 Radar Altimeters*, R. Francis, A. Martini, M. Roca, P. Féménias, S. Mingot, ERS-ENVISAT Symposium, 16-20 October 2000, Gothenburg, Sweden.
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