STUDY OF ARTIFICIAL AND NATURAL PSS IN THE AREA OF BEAR LAKES CALIBRATION SITE

A.I. Zakharov(1), P.A. Zherdev(2), C.G.M van ‘t Klooster(3)

(1) IRE RAS Vvedensky square, 1, 114190, Fryazino, Russia
E-mail: aizakhar@ire.rssi.ru
(2) SDB MPEI Krasnokazarmennaya str, 14, 111259 Moscow, Russia
E-mail: Jerdev@okbmei.ru
(3) ESA ESTEC Keplerlaan 1, P.O.Box 299, 2200 AG Noordwijk, Netherlands,
Email: Kees.van.t.Klooster@esa.int

ABSTRACT/RESUME

The goal of the report is an analysis of the behavior of artificial and natural permanent scatterers in the area of Bear Lakes calibration site using ERS SAR data under AO3-343 project. The area of study is calibration site in Moscow region with parabolic antennas (4.7 meters diameter of the dish), which were used over 5 years as calibration targets (artificial permanent scatterers) as well as the Moscow city territory. Our previous analysis of amplitude data has shown very impressive scattering properties and high stability of RCS for such an artificial scatterer, as the large antenna. New stage of current study is focused on long-term amplitude stability as well as phase stability of the scatterers mentioned. Of highest importance is the fact obtained from INSAR studies that such a large ground based calibration target, as antenna, does possess high phase stability (one tenth of the wavelength) in spite of the fact it is affected by pointing errors in every calibration session because of inaccurate predicted ephemeris and errors in the antenna settings. Among the other tasks planned during execution of extension of AO3 project is detection of landslides/subsidence because of technogenic processes to be solved using DINSAR technique. Having extended set of ERS SAR data including archival scenes since 1992 we were able to monitor the stability of the surface in the urban area of Moscow city on the decade time interval. Our preliminary analysis of the ERS DINSAR data shows evidence of the subsidence at the level of wavelength on some restricted areas on the south - east side of the city territory.

1 INTRODUCTION

The idea of using large antennas as calibration targets was realized in Bear Lakes test site (Moscow region, Russia) in the beginning of 1990th as a stage for preparation to Russian spaceborne remote sensing project PRIRODA. Their scattering properties were tested using ERS SAR observations of the test site mentioned. More than 30 SAR calibration sessions were conducted under AO3-343 project named "Research and development of highly efficient calibration techniques for spaceborne SAR systems on the base of ground based reflector antennas" in 1999-2000. In the year 2002 experiment was prolonged in order to continue study of long-term stability of the antennas scattering properties, ASAR calibration and intercalibration of ERS and ENVISAT.

The peculiarity of the schedule of ERS calibration observations was that in order to reduce influence of variations of antenna pattern onto measurements we have planned a series of observations in repeated tracks geometry. Two interleaved series were used – with track numbers 207 and 479.

All the calibration scenarios at the Bear Lakes test site were based on a use of 3 passive calibration targets - large parabolic antennas of 4.7 m in diameter, located at the corners of the rectangular triangle with 50 m legs. One of the targets was an antenna with a conducting disc 0.5 m in diameter, located in the focal area. It was set in practically every SAR session and served as reference target allowing to monitor possible variations of RCS because of onboard SAR instability and signal propagation media. One of the most impressing features of such a modernization is an increase of the antenna pattern till 10^6 in C-band. Another target was antenna adapted for a use by ERS ground station, being under testing at Bear Lakes test site in 1998-1999. It gave us good chance to analyze stability of regular receiving station antenna as a reference target for calibration studies. The last target was an antenna usually equipped with diffraction grid in focal area (see Fig. 1).

Because of relatively small distance between the calibration targets the ERS-2 SLCI images were used in the analysis of amplitudes of targets. The integration method of estimation the antennas RCS was used, when the signal was integrated
in the area of main lobe. Background noise signal was estimated in the area outside the impulse response function area and subtracted. Antenna pattern was taken into account as well as range spread loss of the signal.

Fig. 1. Large parabolic antenna with diffraction grid in focal area

2 RADIOMETRIC STABILITY OF ARTIFICIAL PS

Most of the results on the stability of the measurements were obtained from measurements of the RCS of antenna with disk in focal area on 1.5 years of observations in 1999-2000.

According to the RCS measurements obtained we have RCS mean value 59.03 dBm² with standard deviation 0.062. From here we made a conclusion, that the stability of our artificial PS is very high. One of the reasons of high and stable RCS of our antenna was the fact it had wide ~10° antenna pattern because of insertion of 0.5 m disc in focal area.

The prolongation of our calibration project in 2002 allowed us to get new confirmation of long term stability of our targets. On the Fig. 2 we presented prolonged series of measurements for a track 207, including observations of 2002-2003 (subdivided by a gap on the plot).

Fig. 2. RCS (dBm²) of antenna with conducting disk in focal area for the period 1999-2003 of ERS observations on the track 207 (3° angle between antenna electrical axis and look direction).

We can see here remarkably good repeatability of the measurements for the antenna with conducting disk except for the measurements in winter 2002-2003, where the numbers a 1 dB lower because of cover of the ice/snow on the antenna surface.
The situation is somewhat different for another sub-series of measurements being made at the track 479 of ERS. Unusual loss of 1 dB RCS level is typical since end of February 2000, what may be connected with problem of control the ERS attitude. Doppler data might be helpful in finding the explanation of the phenomenon.

As for the antenna of regular receiving station as a reference target, we can say that narrow antenna pattern requires high pointing accuracy. Our 10 estimations of the RCS of ERS receiving station at Bear Lakes, usually being pointed to the ERS-2 satellite in 1999-2000, show mean value 55.9 dBm$^2$ and standard deviation 0.45. We can see monotonous trends in the measurements, what may be explained by antenna pointing errors. Also average RCS of receiving station is ~3 dB lower.

It should be mentioned that pointing errors of artificial PS with narrow beam width corrupt the level of radiometric and (probably) phase stability of the backscatter.

### 3 INTERFEROMETRIC STABILITY OF ARTIFICIAL PSs

One of the important tasks to be solved during implementation of the prolongation phase of the project was study of stability of antenna phase center location in the case of pointing errors. It is well known that the presence of stable
scatterers is very important for interferometric observations of the topography, especially in the repeated orbits observations scheme.

In spite of the fact of few tens of ERS observations were conducted, the number of acceptable interferometric pairs is restricted taking in mind not all the artificial scatterers were pointed to ERS in every session. Problems with ERS attitude since March 2000 preclude the use of ERS data for interferometric processing since then.

The area of our test site and its surroundings is such that high level of temporal decorrelation precludes relative measurements of antennas interferometric phase (see interferogram on fig. 5). Our analysis of the presence of natural PSs near the test site was ineffective also, so we had to measure relative phases of neighboring antennas.

From the series of observations of our calibration site available we have selected three interferometric pairs and measured the relative heights of the antennas. Antenna with conducting disk and antenna with diffraction grid constituted the calibration scenario here. We have to underline that because of small distance between the antennas (no more than 50 meters) the influence of the troposphere should be considered to be negligible. In the Table 1 we presented the details of observations and results obtained.

![Fig. 5. Examples of ERS amplitude image and interferogram for the Bear Lakes calibration site area with strong temporal decorrelation (left: image from 19991114, center: image from 20000924, right: interferogram)](image)

<table>
<thead>
<tr>
<th>Observation dates</th>
<th>Interferometric baseline Bp</th>
<th>Height variations, m, corresponding to $2\pi$ phase</th>
<th>Estimated relative altitude of antennas, m</th>
<th>Difference of phase differences, in fractions of wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>19990905-19991010</td>
<td>61</td>
<td>162</td>
<td>-2</td>
<td>0.013</td>
</tr>
<tr>
<td>19990905-20000227</td>
<td>140</td>
<td>64</td>
<td>-3</td>
<td>0.05</td>
</tr>
<tr>
<td>19991114-20000924</td>
<td>20</td>
<td>500</td>
<td></td>
<td>0.06</td>
</tr>
</tbody>
</table>

From the results presented in the Table 1 we can conclude that the calibration antennas may be considered as a targets with stable location of the backscattered signal phase center.

### 4 STABILITY OF THE MOSCOW CITY AREA FROM INTERFEROMERTIC OBSERVATIONS FROM ERS REPEATED ORBITS

Urban territories represent a huge set of natural PSs. Study of stability of their location in urban areas was chosen as an extra task for AO3-343 extension. ERS SAR observations were chosen on interval 1992-2000 in order to watch possible land subsidence because of human activities in Moscow city area.

From ERS-1/2 archive a relatively small set of data since 1992 was requested as an addition to available ERS data from 1999-2002. Suitable interferometric combinations of ERS data and perpendicular baselines are presented in Table 2. Small baselines and low topography variations allow us to interpret any phase variations as dynamics of surface/troposphere.
Various combinations of interferograms were analyzed in order to detect monotonous deviations of the phase and pairs with clear troposphere manifestations were rejected.

Probable land subsidense exists on the combination of next interferograms (see lower left corner of the image on Fig. 6): red — pair 19951105–19920927, green — pair 19951105–19970831, blue — pair 19951105–19990418.

Table 2. ERS pairs processed and interferograms generated.

<table>
<thead>
<tr>
<th>ERS pair</th>
<th>Baseline Bp, meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>19951105-19920917</td>
<td>4</td>
</tr>
<tr>
<td>19951105-19970831</td>
<td>17</td>
</tr>
<tr>
<td>19951105-19990418</td>
<td>4</td>
</tr>
<tr>
<td>19951105-20000924</td>
<td>47</td>
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<td>19991114-19920917</td>
<td>60</td>
</tr>
<tr>
<td>19991114-19990831</td>
<td>50</td>
</tr>
<tr>
<td>19991114-20000924</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 6. ERS-1 amplitude image (left) and RGB composite of 3 interferograms (right).

5 CONCLUSIONS

Parabolic antennas of Bear Lakes calibration site are stable calibration targets with mean RCS of 59 dBm2 and r.m.s. less than 0.1 dB on ~5 years time interval. Parabolic reflector antenna demonstrates stable location of the phase center for backscattered signal. Natural permanent point targets (PSs) with stable amplitude in near area of calibration antennas in the area of Bear Lakes calibration site do not show stable location of the phase center. Study of a series of interferograms for period 1992-2000 in Moscow city area by conventional INSAR technique did not reveal clear manifestation of land subsidence with spatial size above hundreds meters, though an indication of small displacements is present.

ACKNOWLEDGMENTS

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