Study of Scattering Properties of Oil platforms in Caspian Sea as Stable Radar Scatterers according to PALSAR Data

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Abstract

An analysis of oil platforms long-term stability in Caspian Sea seen on the Japanese synthetic aperture radar PALSAR images is made. It is shown that typical radar cross section stability of oil platforms is about 0.5 dB, what is close to the parameters of specially designed calibration targets. Possibility of SARs intercalibration using the oil platforms under study is demonstrated.

1 Introduction

Radiometric stability is a key parameter of synthetic aperture radar (SAR), it provides reliable measurements of surface scattering properties and allows the long-term monitoring of the surface state dynamics. Typical practice is a conduction of radiometric calibration with a use of special stable scatterers like as corner reflectors or active calibrators (transponders). In a series of papers there was description of attempts to use natural point and extended targets for radiometric calibration [1-4]. Often the radar cross section (RCS) of such targets cannot be evaluated according to some model ideas, but ir may be estimated from measurements of accurately other calibrated sensors. Conduction of observations in similar geometry provides chance for radar systems intercalibration as well as monitoring of long-term radiometric stability. In our paper we study possibility of use new stable targets, oil platforms for SAR radiometric calibration.

2 Study area and Data Description

PALSAR — is fully polarimetric SAR system with active phased array antenna, which was working in 2006-2001. SAR operation modes included mapping at different resolutions n range and different combinations of transmit/receive polarizations for observation angles 7–50°. In a given study we use the data obtained from repeated orbits in modes FBS34.3 и FBD34.3. Observation angle in these sessions was 34.3°, range resolution in a first case was 4.68 m, in the second — 9.36 m. In the first case the signal was transmitted at H-polarization with reception of copolarized H signal, in other case signals were acquired at copolarized (H) and cross-polarized (V) polarizations.

In our earlier studies [1-4] we made an attempt to use natural point and extended scatterers for SAR radiometric calibration. At current stage of our study we analyse applicability of extended targets - 200 oil platforms in Caspian Sea for radiometric calibration

The oil platform is a huge complex structure. The size of typical platform in Oil Stones oil exploration and production area near Baku city, Azerbaijan, is 80*100 m. A picture of platform is presented in **Figure 1**. SLC SAR image of a cluster of platforms in Caspian Sea is given in **Figure 2**.

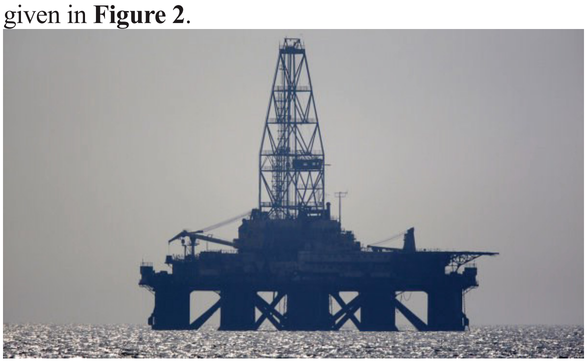

Figure 1: A picture of the oil platform in Caspian Sea.

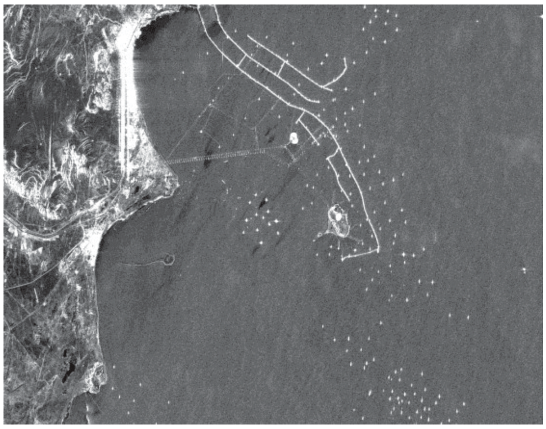

Figure 2: PALSAR image of a cluster of platforms in Caspian sea.

Now we present results of analysis of 200 oil platforms stability during 4 years based on analysis of 22 PALSAR scenes obtained at HH polarization.

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The platform RCS was integrated in 20*80 pixels window (20 pixels in range and 80 pixels in azimuth. In **Figure 3** there are 22 image fragments of the same platform and RCS values during 4 years interval in **Figure 4**. Because of unequal resolution of the image in azimuth and range the platforms shape seems to be stretched. On the images with lower resolution in range the shapes seem to be narrower.
The RCS of given platform in HH polarization is 38.4 dBm^2, the scattering stability is 0.38 dB. It should be noted that some of the platform shapes look narrower because of lower SAR resolution in a given session.

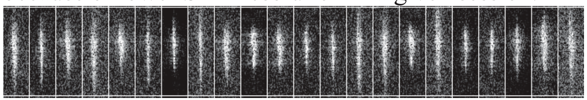

Figure 3: 22 image fragments of oil platform during 4 years interval.

3 Targets Radiometric Stability

It should be noted that the platform backscatter level is independent on the season of the year; it is the same in different meteorological conditions (wind roughness of sea surface) and different slant range resolutions. Similar results were obtained for the cross polarized data, not presented here, though the backscatter level for the platforms is 8-10 dB lower.
The distribution of platforms with respect to their backscatter stability is presented in **Figure 5**. We can see that 85 platforms have stability better than 0.5 dB and 13 platforms – better than 0.3 dB.
Such a unique all-year scattering stability of the oil platforms in the sea environment is provided, obviously, thanks to the fact the sea Oil Stones area is not covered with sea ice during the winter.

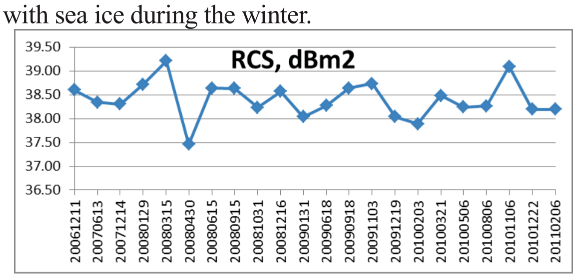

Figure 4: RCS of typical oil platform with stable backscatter during 4 years interval.

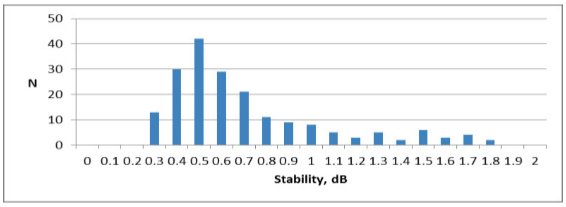

Figure 5: Distribution of platforms with respect to scattering stability.

4 Targets Polarimetric Properties

Complex structure of oil platform leads to the fact there is various types of backscattering mechanisms. To analyse types of backscatter we used ALOS PALSAR polarimetric image.
To identify scattering mechanisms in the case of coherent scatterers like as elements of platform construction it is convenient to decompose scattering matrix S:

$$S = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

and to generate Pauli vector in the next form (supposing off-diagonal elements to be the same):

$$k = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{HH} + S_{VV} \\ S_{HH} - S_{VV} \\ 2S_{HV} \end{bmatrix}$$

First element of vector k corresponds to backscatter from sphere, flat surface or trihedral (single or uneven number of reflections), second element corresponds to double bounce (multiple with even number of reflections) backscatter from dihedral with edge horizontal orientation, and third element corresponds to even bounce scattering with $\pi/4$ rotation of scatterer edge with respect to horizon.
In the **Figure 6** there are 3 images illustrating 3 components of oil platforms backscatter types: single, double-bounce and rotated dihedral type of backscatter.

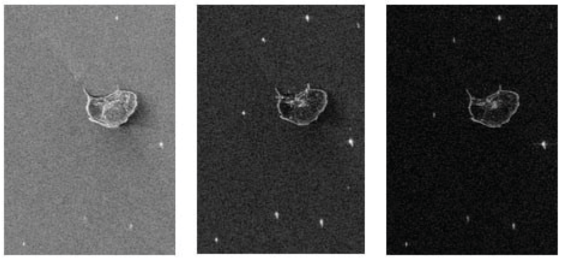

Figure 6: Images of oil platforms in the case of single (left) double-bounce (centre) and dipole (right) types of SAR signal backscatter.

Sea surface on the left image looks brighter because of dominating surface scattering type. The platforms are better seen in the centre image. The images visual comparison shows that double-bounce type of backscatter from oil platforms (oil platform - sea surface – back to radar) is dominating component usually, consequently the state of sea surface during SAR observation should be taken into account.

5 Intercalibration with Platforms

To demonstrate intercalibration possibility we used L-band SAR images of Oil Stones exploration and production area obtained in similar geometry conditions: PALSAR FBD (observation dates 20070613, 20080430, 20080615, 20080915, 20090618, 20090918, 20100506, 20100806, 20101106) and PALSAR-2 (observation dates 20141001, 20141210, 20150218).

RCS of 104 potentially stable platforms (with standard deviation below 0.7 dB) was measured on 9 PALSAR and on 3 PALSAR-2 images. The difference between mean RCS values for PALSAR and PALSAR-2 Respective results are presented in **Figure 7**. Mean value for PALSAR and PALSAR-2 RCSs differences here is 0.37 with standard deviation 0.54. According to that we may state 0.37 dB underestimation of PALSAR-2 RCS measurements.

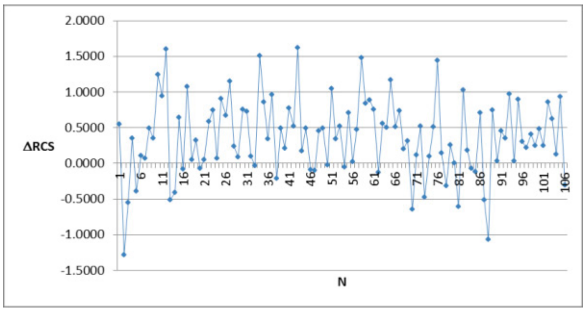

Figure.7: RCS difference between PALSAR and PALSAR-2 average measurements for 104 oil platforms.

During PALSAR-2 CAL-VAL activity we conducted calibration experiments with 2 corner reflectors (2 meters leg) deployed in Baikal Lake coastal area (Boyarsk settlement, Buryatia region). Direct measurements of corners RCS on PALSAR-2 images shows also 0.4-1 dB underestimation compared with theoretical values and PALSAR observations made in 2006-2007.

As can be seen, in spite of the fact surface resolution of the sensors mentioned is different; the RCS of the antennas is almost the same. We can make a supposition about some inaccuracy of PALSAR-2 calibration constant error, which lead to the fact PALSAR-2 RCSs become ~0.4 dB lower.

6 Conclusions

Oil platforms in Caspian Sea were discovered to be prospective type of monitoring the spaceborne SAR stability – among the 200 platforms investigated about 80 platforms show yearly backscattering stability better than 0.5 dB with typical RCS 38 dBm^2. The platforms RCS was stable during years 2006-2011.

Double bounce backscattering (platform – sea- back to radar) is dominating type of backscatter, consequently, the state of sea surface is one of important factors determining the platform backscattering stability.

Scattering properties of sea surface in the area of Oil Stones exploration area, near Baku city, Azerbaijan, usually is not corrupted by ice covers. At the same time the mirror-like scattering of sea in PALSAR observation geometry is not so sensitive to sea wind roughness. For that reason the platforms backscatter is stable all the year around in various wind conditions.

The oil platforms in Caspian Sea may be considered as good tool for SAR radiometric calibration and intercalibration provided the observations are made in repeated observation geometry.

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