OIL PLATFORMS IN CASPIAN SEA AS STABLE DISTRIBUTED RADAR SCATTERERS FOR PALSAR CALIBRATION

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ABSTRACT

An analysis of oil platforms long-term stability in Caspian Sea seen on the Japanese synthetic aperture radar PALSAR and PALSAR-2 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 PALSAR and PALSAR-2 intercalibration using the oil platforms under study is demonstrated.

***Index Terms*—** Oil platform, PALSAR, RCS, SAR calibration

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 it 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 HH 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 analyze 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 Fig. 1. SLC SAR image of a cluster of platforms in Caspian Sea is given in Fig. 2.

Fig. 1. Image of the oil platform 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.

The platform RCS was integrated in 20*80 pixels window (20 pixels in range and 80 pixels in azimuth. In Fig. 3 there are 22 image fragments of the same platform and RCS values during 4 years interval in Fig. 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 sometimes the platform shapes look narrower because of lower SAR resolution in some sessions.

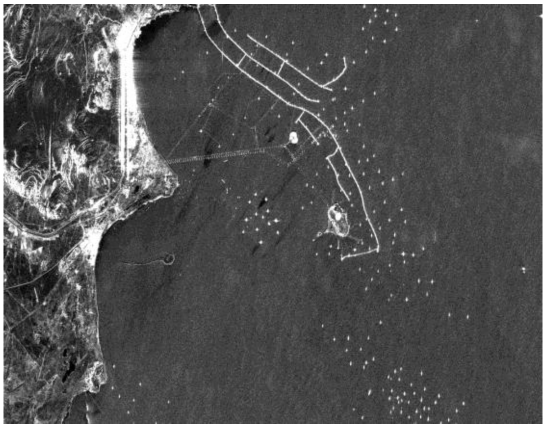

Fig. 2. PALSAR image of a cluster of platforms in Caspian Sea.

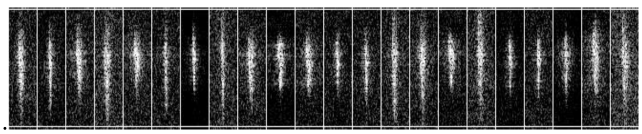

Fig. 3. 22 image fragments of the selected oil platform during 4 years interval.

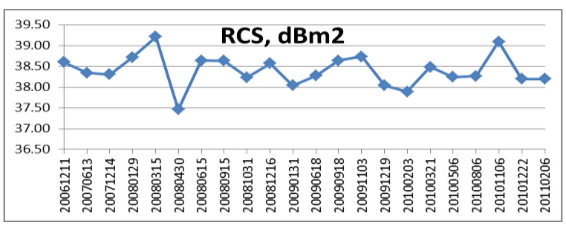

Fig. 4. RCS of typical oil platform with stable backscatter at HH polarization during 4 years interval.

3. OIL PLATFORMS 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 observed at HH and HV polarizations according to 9 FBD observations (observation dates 20070613, 20080430, 20080615, 20080915, 20090618, 20090918, 20100506, 20100806 , 20101106) is presented in Fig. 5 and Fig. 6. We can see that about 80 platforms have stability better than 0.6 dB both at HH and HV polarizations.

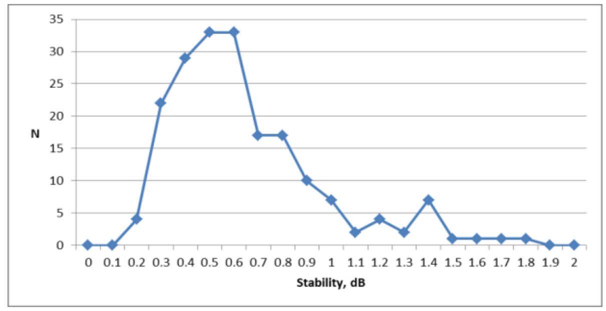

Fig. 5. Distribution of 200 oil platforms with respect to their scattering stability at PALSAR HH polarization.

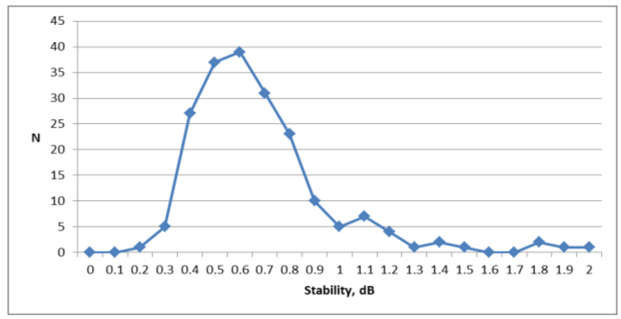

Fig. 6. Distribution of 200 oil platforms with respect to their scattering stability at PALSAR HV polarization.

Somewhat worse results were obtained using PALSAR-2 SAR data in the sessions made on 20141001, 20141210, 20150218, 20150930 and 20151209 (see Fig. 7 and 8).

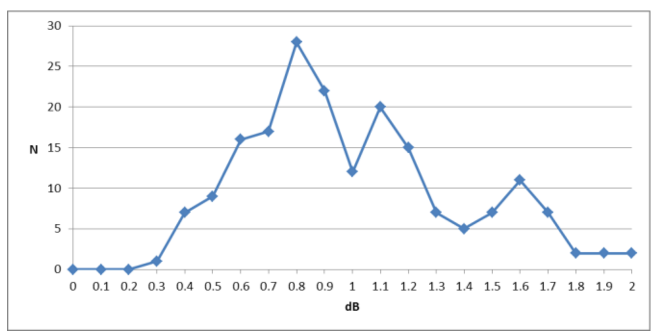

Fig. 7. Distribution of 200 oil platforms with respect to their scattering stability at PALSAR-2 HH polarization.

Such a unique all-year scattering stability of the oil platforms in the sea environment is provided, obviously, thanks to the fact the Oil Stones area in Caspian Sea is not covered with sea ice during the winter.

At the same time, we may suppose lower radiometric stability of PALSAR-2 RCS measurements (see Fig. 7 and 8). Histograms maximum there displaced 0.3 dB compared with PALSAR histograms in Fig. 5 and 6.

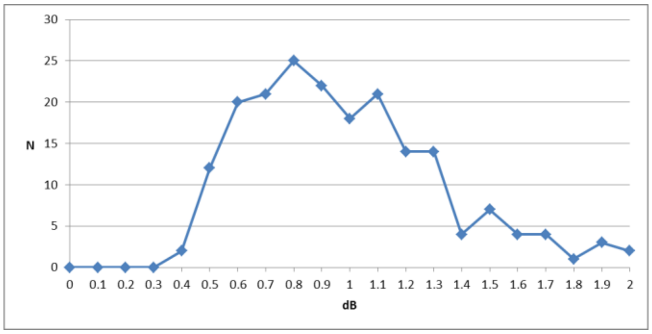

Fig. 8. Distribution of 200 oil platforms with respect to their scattering stability at PALSAR-2 HV polarization.

The images analyzed above were obtained in similar observation conditions taking in mind satellite subsurface trace orientation and SAR signal incidence angle. In order to look for the platforms RCS variations with respect to geometry of observations we processed a set of 4 PALSAR-2 images of the same area obtained on descending orbits. As it was supposed, the platforms RCS on descending orbit is different from that measured on ascending orbit, though the level of RCS stability is similar.

4. OIL PLATFORMS POLARIMETRIC PROPERTIES

Complex structure of oil platform leads to the fact there is various types of backscattering mechanisms. To analyze types of backscatter we used PALSAR-2 image obtained in polarimetric mode.

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 Fig. 9 there are 3 images illustrating 3 components of oil platforms backscatter: single, double-bounce and rotated dihedral type of backscatter.

Sea surface on the left image looks brighter because of dominating surface scattering type. The platforms are better seen in the center 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.

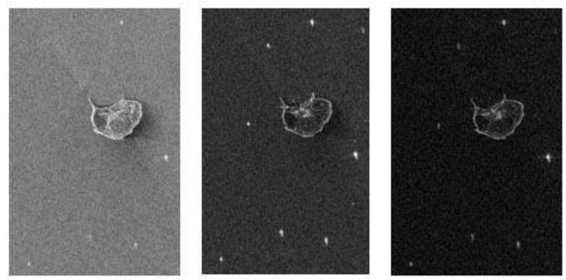

Fig. 9. Images of oil platforms in the case of single (left) double-bounce (center) and dipole (right) types of SAR signal backscatter.

5. PALSAR – PALSAR-2 INTERCALIBRATION

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 3 PALSAR-2 images. The difference between mean RCS values for PALSAR and PALSAR-2 Respective results are presented in Fig. 10. 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.

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 show also 0.4-1 dB underestimation compared with theoretical values and PALSAR observations of the same corners in Buryatia region made in 2006-2007.

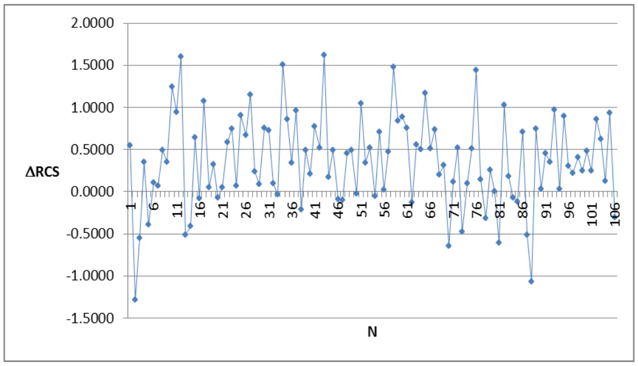

Fig. 10. RCS difference between PALSAR and PALSAR-2 average measurements at HH polarization for 104 oil platforms.

6. CONCLUSION

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 using ALOS PALSAR images show yearly backscattering stability better than 0.6 dB with typical RCS 38 dBm^2. The platforms RCS was stable during years 2006-2011. At the same time PALSAR-2 SAR images obtained in 2014-2015 show 0.2-0.3 dB worse stability. The platforms RCS difference between PALSAR data and PALSAR-2 data is about 0.4 dB, what means underestimation of PALSAR-2 RCS measurements

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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