Oil Platforms as SAR Calibration Targets in C and L bands

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Abstract

An analysis results of the PALSAR and Sentinel-1A time series of observations of oil platforms located in southern part of Caspian Sea are presented. The radar cross-section (RCS) level and RCS variations of about 200 oil platforms in "Oil Stones" oil production area were measured over 4 years interval in L-band and over 2.5 years interval in C-band. It was discovered that the platforms seem to be more stable scatterers in L-band having systematically higher radar cross-section than in C-band. The analysis results confirm the idea that the platforms may be treated as an acceptable calibration targets for the monitoring of spaceborne SAR systems radiometric stability.

1 Introduction

SAR radiometric calibration is important procedure providing reliable measurements of normalized radar cross section (NRCS) of scattering objects, which is important parameter in numerous radio physical models of sounding media. Radiometric calibration consists of a determination the number of SAR instrument and image quality parameters, including radiometric stability. Radiometric stability characterizes stability of the system transfer function, what is important in the case of data analysis in the absence of targets with known RCS value on the image. Corner reflectors or active radar calibrators are most popular especially designed instruments for the studies of SAR long-term stability. Natural point-wise objects like as elements of industrial or residential infrastructure as well as distributed objects (Amazonian rain forests, Antarctic snow/ice covers) were considered to be appropriate calibration targets last decades also [1-5]. Natural objects are supposed to be preferable targets because of their permanent availability, though absolute value of radar cross-section (RCS) may be not known from their theoretical backscattering models. In our paper we analyze the RCS stability of 200 oil platforms in southern part of Caspian Sea seen on PALSAR (L-band) and Sentinel1A (C-band) images.

2 Study area and Data Description

Twenty three radar images of oil production area "Oil stones" in northern part of Caspian Sea obtained by L-band PALSAR (Japan) and 43 images of C-band Sentinel-1A (ESA) SAR in 2006-2010 and 2014-2017, respectively, were used in the study. PALSAR images were acquires in repeated orbits interferometry scheme, from descending orbit, in FBS34.3 и FBD34.3 observation modes. Observation angle in the sessions was 34.3°, range resolution on the level L1.1 SAR images 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. PALSAR image fragment for the test area near seaboard Sangachal settlement is shown in a **Figure 1**. Long bright curves in the sea are runways connecting oil platforms seen here as bright point-like objects.

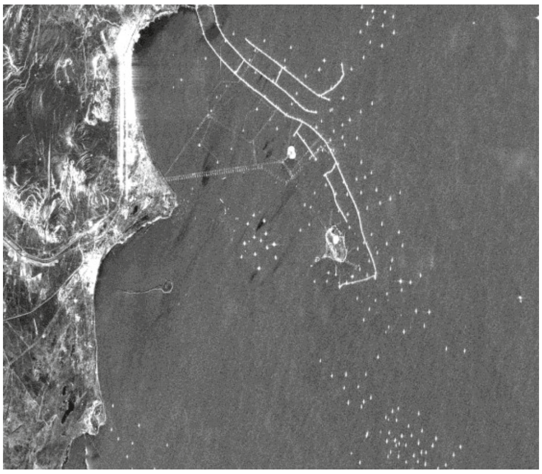

Figure 1: PALSAR image of a cluster of platforms in Caspian Sea.

Sentinel-1A SAR images were acquired from descending orbit at VV and VH polarizations in Interferometric Wide Swath mode. The resolution on the Single Look Complex images is 2.3 m in slant range and 14.1 m in azimuth. Incidence angle in the mid of

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test area including platforms is about 38^0. In this paper results of only co-polarized data analysis are presented.

PALSAR and Sentinel-1A radar images were acquired in various weather conditions and seasons of the year, but thanks to the fact there is no ice covers in the southern part of Caspian Sea during winter, the radar observation conditions are the same all the year around.

3 Data Analysis

Oil platform is a huge complex structure. Typical size of platform in the "Oil stones" oil exploration and production area is about 100*100 m. A picture of typical platform is presented in **Figure 2**.

Figure 2: A picture of the oil platform in Caspian Sea.

In **Figure 3** 22 small image fragments of the same platform from 22 PALSAR observations conducted during 4 years' time interval are presented. Due to unequal resolution on the SAR image in range and azimuth the objects of interest have elliptical shape spread in azimuth direction. The same objects are spread in range on the Sentinel-1A images because of 3-4 times coarser resolution in azimuth, than in range.

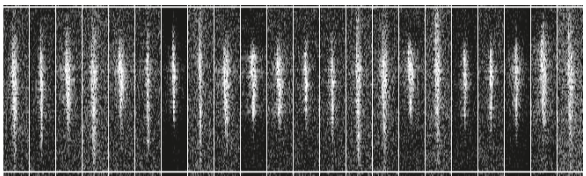

Figure 3: 22 PALSAR image fragments of oil platform during 4 years interval.

Data numbers of each PALSAR and Sentinel-1A pixel were converted to pixels RCS using respective absolute calibration constants and pixels square. The RCS of such extended targets as oil platforms was integrated in a 20*80 pixels window on the PALSAR images and in a 30*30 pixels window on the Sentinel-1A images. RCS mean and root-mean-square (r.m.s.) values for each platform were calculated on 22 PALSAR images and 43 Sentinel-1A images. Mean RCS for 190 oil platforms in each frequency band is presented in **Figure 4**, the histograms of r.m.s. values, describing platforms backscattering stability, are given in **Figures 5** and **6**. In spite of the fact the backscatter of the open sea increases sometimes significantly with growth of wind stress, as it is seen in some fragments in **Figure 3**, we did not find any impact of the sea surface roughness variations on the platforms integral RCS. We have to mention that the stability of platforms at cross-pol in L-band is not presented here, but is almost the same as at co-pol mode.

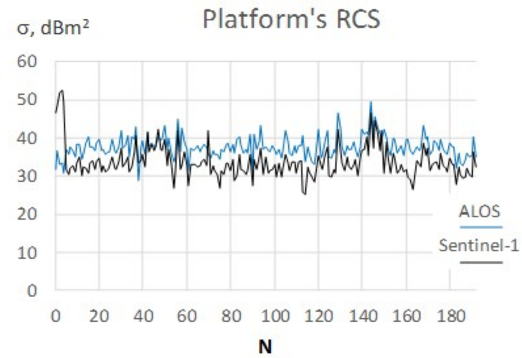

Figure 4: Mean RCS of 190 platforms in L (blue) and C-band (black).

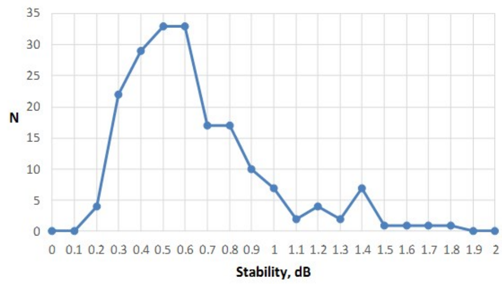

Figure 5: Platforms backscattering stability in L-band.

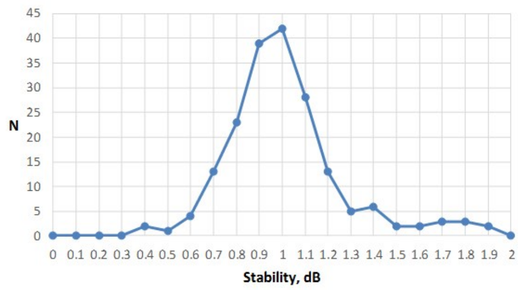

Figure 6: Platforms backscattering stability in C-band.

In **Figures 7** and **8** below there are scatter plots describing distribution of platforms scattering stability across the integral RCS in L and C bands.

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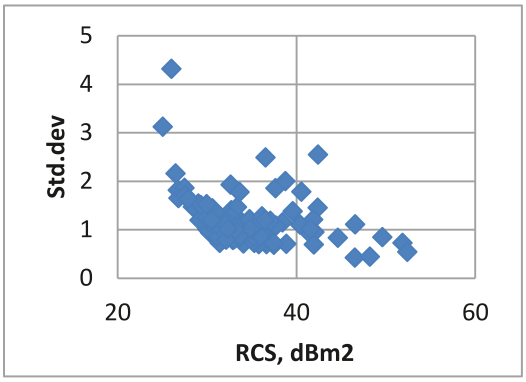

Figure 7: Platforms stability scatter plot in C-band.

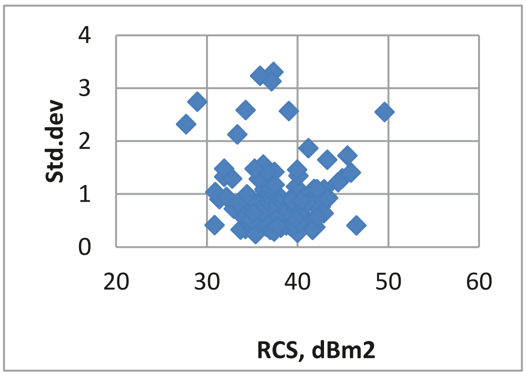

Figure 8: Platforms stability scatter plot in L-band.

4 Analysis Results

Stability of the platform backscatter is dependent both on its scattering properties stability as well as stability of SAR transfer factor. Wide peak on PALSAR histogram (from 0.3 dB to 0.9 dB) allows us to make a conclusion about an existence of a large number of platforms with high, though slightly different stability level. According to [6], PALSAR radiometric stability measured in observations of corner reflectors with 37 dBm^2 RCS is 0.4 dB. In the case of corners with 30 dBm^2 RCS, PALSAR radiometric stability level is 0.6 dB [7]. Consequently, we may state that according to our experiment with platforms having 35-40 dBm^2 RCS the stability of their backscatter is worse than stability of PALSAR system transfer factor. According to **Figure 8**, there is no obvious dependence of stability form platform backscattering level.

Lower stability (~1 dB) of platforms RCS in C-band and narrow histogram pike lead to the conclusion about dominating role of Sentinel-1A transfer factor instability. It is in agreement with 1 dB Sentinel-1A stability figure from [8], but significantly less than 0.5 dB from [9]. For that reason we cannot be sure that the platforms themselves have the backscattering stability in C-band better than 1 dB. According to **Figure 7**, there is a decrease of RCS stability with RCS decrease below 30 dBm^2.

According to plots in Figure 4, platforms RCS in C-band (typical level 30-35 dBm^2) is 4-5 dB lower than in L-band (typical level 35-40 dBm^2). According to radio physical model of simple scatterers like as plate or corner reflector, its RCS should be ~12 dB higher in C-band than in L-band. Probable explanation of the fact platforms RCS has lower value in C-band is presented in **Figure 9.**

One of typical scattering constructions is dihedral corner reflector with angle Δ of non-orthogonality. In the case of orthogonal plates an incoming ray AB would propagate along the line CE after double reflection in points B and C. Otherwise it will travel along DF line in slightly different direction. Narrow scattering plate beam width (shown in red) is a reason of the decrease of signal strength being measured from the direction CE.

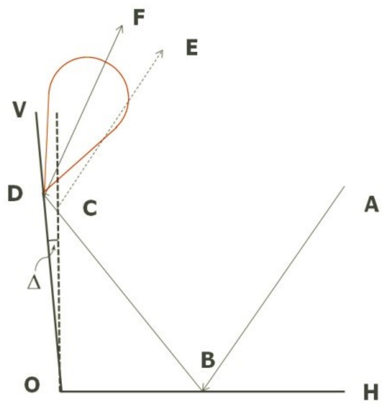

Figure 9: Impact of corner plates non-orthogonality.

The decrease of the corner RCS as a function of the angle Δ compared with maximal RCS σ_{max} is as follows [10]:

$$\frac{\sigma(\Delta)}{\sigma_{max}} = \frac{\sin^2\left(\frac{\pi a \Delta \sqrt{2}}{\lambda}\left(1-0.5|\Delta|\right)\right)}{\left(\frac{\pi a \Delta \sqrt{2}}{\lambda}\right)^2},$$

where σ(Δ) is orthogonality- dependent corner RCS, α - dihedral plate length, λ - signal wavelength.

Non-orthogonality or non-flatness of the platform extended elements is more pronounced at higher frequencies; it violates in-phase backscatter within the image pixel and reduces scattering structure RCS.

5 Conclusion

The estimations of Caspian Sea oil platforms mean and r.m.s. RCS values on PALSAR and Sentinel-1A images

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allow us to consider them as acceptable objects for the monitoring of the spaceborne SAR radiometric stability in both C and L-bands. The platforms in Caspian Sea may be considered as stable calibration targets with reasonably high RCS both in L and C bands. Comparatively low stability in C-band may not be explained by properties of the Centinel-1A SAR system.

Double bounce scattering of signal involving sea surface scatter is relatively high, for that reason all the year ice free conditions here are very important. Also, an analysis of RCS time series in both frequency bands did not reveal any effect of wind stress or seasonal observation conditions onto platforms RCS stability.

Oil platforms may be considered as stable calibration targets for radiometric calibration and intercalibration in the case of the repeated geometry of SAR observations.

Acknowledgments

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