PALSAR CALIBRATION WITH DISTRIBUTED TARGETS

Alexander Zakharov, Liudmila Zakharova

Kotelnikov Institute of Radioengineering and Electronics, Russian Academy of Sciences

ABSTRACT

Radiometric stability is one of the key parameters of synthetic aperture radar (SAR), it provides reliable measurements of surface scattering properties, comparison of the measurements made in different missions, it provides basis for the long-term monitoring of the surface state. As a rule, especially designed equipment is used for the monitoring of SAR instrument state and stability during mission lifetime. In this paper we study potential of some natural extended areas for SAR radiometric calibration and intercalibration as well as control of SAR radiometric stability. Among the targets under consideration are oil platforms in Caspian Sea, dry surfaces of hot Atakama desert in Chile, Amazon rain forests and permanently cold icy covers of Antarctica.

Index Terms— SAR calibration, RCS, NRCS, PALSAR, calibration targets

1. INTRODUCTION

Use of specialized stable scatterers like as corner reflectors or active calibrators (transponders), which look like bright point targets on radar images, is typical practice in SAR radiometric calibration. Typical stability of RCS of corners with 2-2.5 m leg in Terrsar-X mission was demonstrated to be about 0.15 dB. In the PALSAR mission average stability of corners with 2-2.5 m leg involved in calibration across the world was 0.67 dB, and it was 0.17 dB for corners with 5 m leg [2]. Accurate theoretically known value of RCS is important property of corners and transponders.

Numerous bright point-like targets, formed by elements of urban and industrial infrastructure, named here as natural ones, are also supposed to be used for calibration. Among the common scattering mechanisms here are single-bounce scattering from buildings roofs, double-bounce scattering from building vertical wall + street surface, dipole scattering from linear elements of engineering constructions like as power line towers. Because of complex interaction of SAR signal with point-wise natural targets their RCS cannot be evaluated according to theoretical models. Also such targets usually do not possess sufficient stability of backscatter because of variation of their scattering properties. An alternative to point-like targets may be distributed or extended natural targets located in stable environmental conditions, which will be considered below.

An analysis of long-term stability of distributed targets was made using PALSAR and PALSAR-2 data. PALSAR is fully polarimetric SAR system with active phased array antenna, which was working in 2006-2011. 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 used the data obtained from repeated orbits in modes FBS34.3 и FBD34.3. PALSAR-2 data used here were acquired in 2014-2017 in similar observation geometry. The only type of the data, level 1.1, were used to calculate radar cross-section of the targets (RCS or σ) and normalized RCS (NRCS or σ^0).

2. OIL PLATFORMS IN CASPIAN SEA

Oil platform are huge complex structures. Size of typical platform in Oil Stones oil exploration and production area near Baku city, Azerbaijan, is about 80*100 m. 22 PALSAR images obtained at HH polarization during 4 years' observation interval were used to conduct analysis of 200 oil platforms stability. SLC SAR image of a cluster of platforms in Caspian Sea is given in Fig. 1.

The platforms RCS was integrated in a window 20*80 pixels (20 pixels in range and 80 pixels in azimuth. The RCS of one of the most stable platforms at HH polarization is 38.4 dBm^2, the scattering stability is 0.38 dB (see Fig. 2). It should be noted that sometimes the platform shapes look narrower because of twice lower SAR resolution in FBD mode of observations compared with FBS.

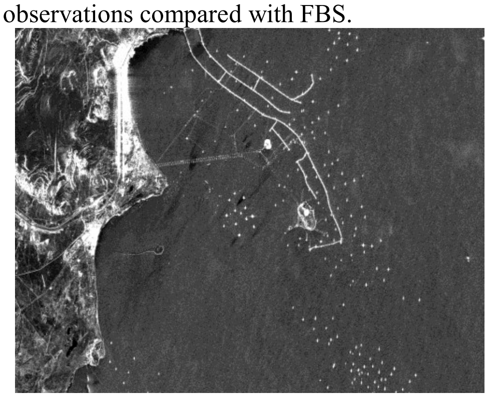

Figure 1. PALSAR image of a cluster of platforms in Caspian Sea

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.

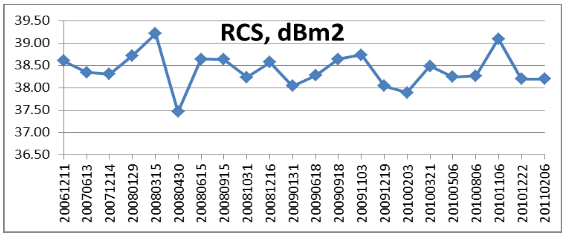

Figure 2. RCS of typical oil platform with stable backscatter at HH polarization during 4 years interval

The distribution of platforms with respect to their backscatter stability is presented in Fig. 3. We can see that about 80 platforms have the stability better than 0.6 dB both at HH polarization [1].

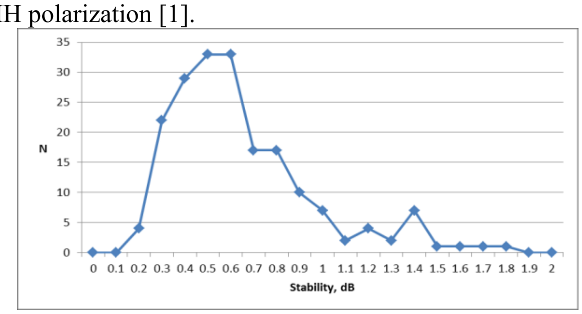

Figure 3. Distribution of 200 oil platforms with respect to scattering stability at PALSAR HH polarization

Somewhat worse results were obtained in analysis of PALSAR-2 data (see Fig. 4).

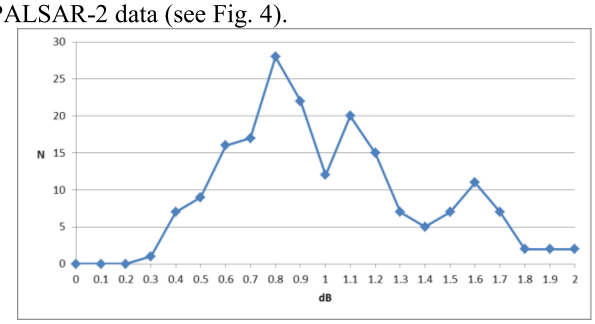

Figure 4. Distribution of 200 oil platforms with respect to scattering stability at PALSAR-2 HH polarization

Such a unique year-round 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 and radiophysical properties of metal constructions as well as water surface do not change all the year around.

The images analyzed above were obtained in similar observation geometry taking in mind satellite subsurface trace orientation and SAR signal incidence angle.

To demonstrate PALSAR – PALSAR-2 intercalibration possibility we used L-band SAR images of Oil Stones exploration and production area obtained in similar geometry conditions:

RCS of 104 potentially stable platforms (with RCS standard deviation below 0.7 dB) was measured on PALSAR and PALSAR-2 images in similar observation conditions. An agreement of RCS values for PALSAR and PALSAR-2 may be seen in Fig. 5.

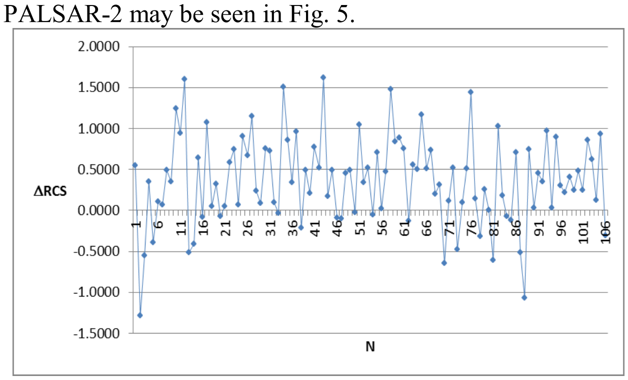

Figure 5. RCS difference between PALSAR and PALSAR-2 measurements at HH for 104 oil platforms

Oil platforms in Caspian Sea being observed in the year-round ice free conditions may be considered as acceptable targets for L-band SAR radiometric calibration and intercalibration provided the observations are made in repeated observation geometry. Similar analysis of platforms RCS stability was made with Sentinel-1 data and the results were worse because of higher effect of sea surface clutter on the signal power integrated in predefined window [4].

3. NATURAL DISTRIBUTED TARGETS

Four natural distributed targets in regions with stable environmental conditions were analyzed also from a point of view of their scattering stability. Among them are 2 areas in Antarctic, Amazon rain forest area and an area in Atakama desert in Chile. The only type of SAR data used for the analysis of backscattering stability of all the natural extended targets was L-band PALSAR data obtained in co-pol mode of observations.

Atakama desert is hot and permanently dry region in Chile, characterized by low (below 1 mm per year) level of annual precipitations and permanently positive (19-20^0 in summer and 13-14^0 in winter) air temperature. For the test area in Antofagasta province we have chosen PALSAR frame with scene center latitude -22.367^0, scene center longitude -68.812^0. SAR image is presented in Fig. 6. NRCS of scattering covers was averaged in 500*500 pixels window in a left upper corner of the image from Fig. 6. Plot of NRCS variations in 16 PALSAR observations is presented in Fig. 7. NRCS mean value here is -15.0 dB, r.m.s. is 0.52 dB. Atakama desert covers may be supposed to be also stable scatterers, what can be explained by permanently hot and dry environmental conditions here.

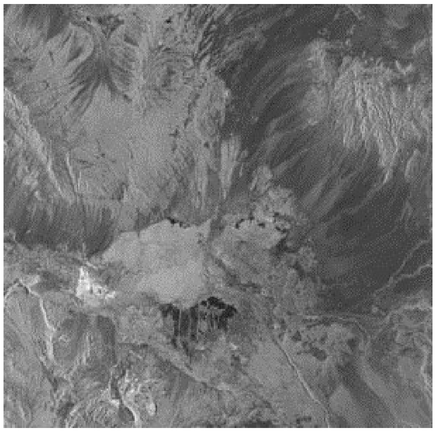

Figure 6. PALSAR image of test area in Atakama desert

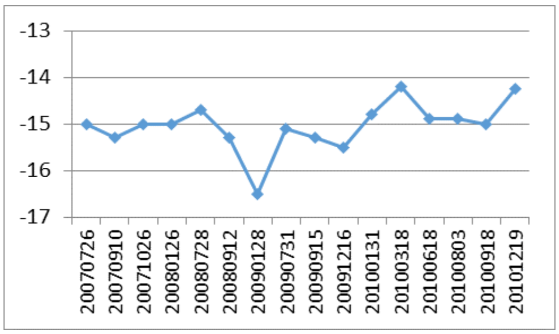

Figure 7. NRCS of test area in Atakama desert, dB

Amazon rain forest is well-known and de facto reference area for the calibration of spaceborne SAR operating in various frequency bands [5]. Thanks to permanently high humidity because of almost all the year rainy weather with 2300 mm level of annual precipitations and stable air temperature 27-28^0 the area is attractive target for SAR calibration and intercalibration. In Fig. 8 there is PALSAR image with image center coordinates 1.57^0 S, 62.543^0 W. The area imaged here is located in Rio-Negro river basin 300 km to the NW from Manaus city.

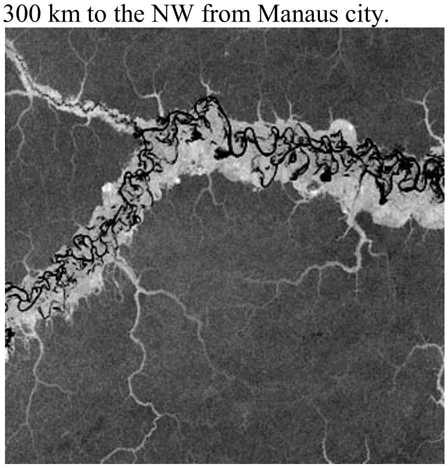

Figure 8. PALSAR image of Amazon forest test area

NRCS of scattering covers was averaged in 500*2000 pixels window in a lower left part of the image from Fig. 8. Plot of NRCS variations in 17 PALSAR observations is presented in Fig. 9. NRCS mean value here is -7.2 dB, r.m.s. is 0.22 dB, what is in agreement with [5].

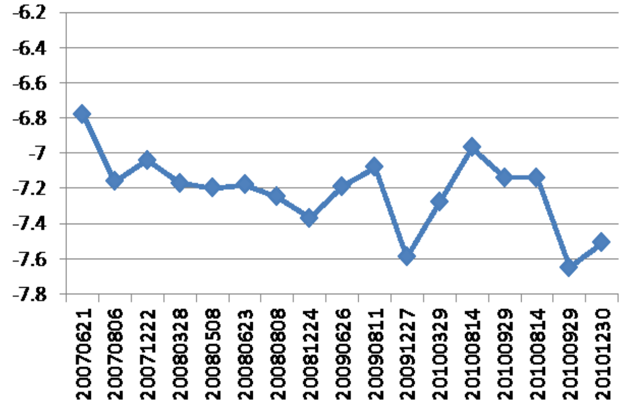

Figure 9. NRCS of Amazon forest test area, dB

First test Antarctic area discussed here is covered with PALSAR frame with scene center latitude -75.016^0, scene center longitude 118.162^0 (Dome C area). Browse frame image is presented in Fig. 10.

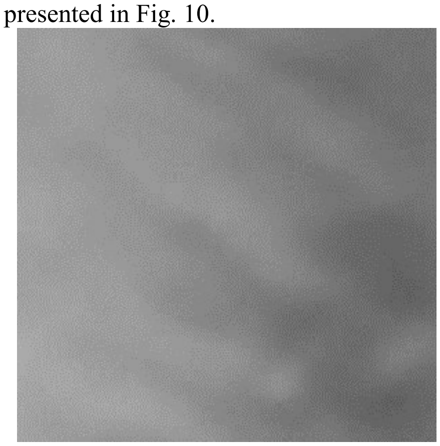

Figure 10. PALSAR image of Dom C area in Antarctic

NRCS of the test area was averaged in 500*500 pixels window in a left upper corner of the frame above. Plot of NRCS variations in 12 PALSAR observations is presented in Fig. 11. NRCS mean value is -12.7 dB, r.m.s. is 0.22 dB.

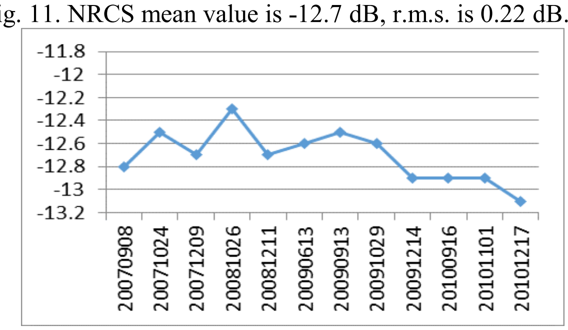

Figure 11. NRCS of Dome C area, Antarctic region, dB

The most attractive is probably Vostok Lake located in high latitudes of Antarctica – on the flat ice surface of the Lake covered with 4 km ice layer there is no any manifestation of the bottom topography. As in the case with Dome C, extremal weather conditions with 18 mm annual precipitations and air temperature -65^0 in winter and -35^0 in summer are common. PALSAR image with scene center latitude -77.5^0 S, scene center longitude 105.5^0 E. is shown in Fig. 12. The topography of coastal hills is seen in the upper left corner. White line between the hills is the road of sledge-track trains connecting Vostok station with Molodezhnaya station on the Antarctic coast.

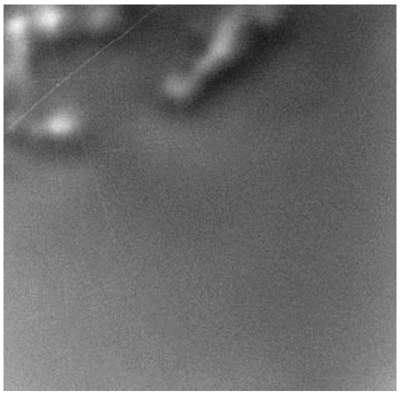

Figure 12. PALSAR image Vostok Lake surface

NRCS of the test area was averaged in 500*500 pixels window in a left lower corner of the frame above. Plot of NRCS variations in 15 PALSAR observations is presented in Fig. 13. NRCS mean value is -17.7 dB, r.m.s. is 0.19 dB. The decrease of NRCS in range in all the scenes being analyzed reaches 1.2 dB and may be approximated by $\cos^4\theta$.

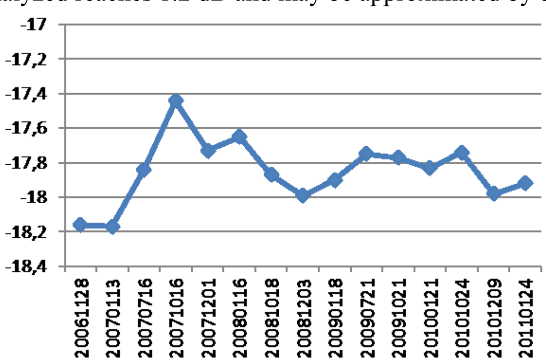

Figure 13. NRCS of Vostok Lake surface, dB

According to polarimetric decomposition of the only polarimetric PALSAR data acquired on 20090614 shows total domination of surface-like type of backscatter with moderate entropy. There is 1.5 dB excess of VV backscatter over HH. Co-pol phase difference equals to 20^0, what may be explained by presence of thin ice cylinders in snow covers, similar to observations in [6].

Antarctic covers in general demonstrate outstanding temporal stability of NRCS, though there is usually 2-3 dB spatial variation of NRCS across the PALSAR standard image frame 60*60 km in size. Main reason of the Antarctic covers scattering stability at high latitudes is permanently cold temperatures, below -20^0 ÷-60^0 C.

6. CONCLUSION

Oil platforms in Caspian Sea were discovered to be prospective type of distributed targets for monitoring the spaceborne SAR stability – among the 200 platforms investigated about 80 platforms according to ALOS PALSAR data show yearly backscattering stability better than 0.6 dB with typical RCS 38 dBm^2. A number of natural distributed objects on the Earth surface have been investigated in order to identify surfaces with stable scattering properties. Among the analyzed are oil platforms of the Caspian Sea and 4 territories in the Antarctica and South America. In general, the stability of the scattering properties of the natural objects under discussion is similar to the stability of artificial targets - corner reflectors. Lake Vostok in the Antarctica demonstrates highest level of stability - the year-round stability is 0.19 dB on the 3.5 years interval. Distributed natural objects can be recommended as objects for intercalibration and monitoring the stability of the spaceborne radars..

7. ACKNOWLEDGMENTS

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8. REFERENCES

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