Perspective Of Utilization Of The Spaceborne P-Band SAR Together With L/S-Band SAR

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Abstract

Possibilities of utilization of two frequencies SAR operating simultaneously in P-band and S or L-band are considered. Advantages of such system are shown. They are caused by improvement of data interpretation and by decrease of ionosphere influence. Tasks of surface and subsurface sensing by the complex SAR under investigation for vegetation, ice and soil covers are given.

1. Introduction

Spaceborne P-band SAR is known to be effective instrument for the solution of topical remote sensing tasks in the area of forestry, geology, oceanology, subsurface sounding in global scale and at higher level because of better penetration of a given long wavelength band. The most known and effective application area of P-band SAR is a mapping of forest covers biomass. Nowadays the airborne P-band SAR systems are widely used in Russia (IMARK system), Germany, France, Sweden, etc., for the studies of natural resources. Much attention is paid to application of P-band SAR systems in studies of soil moisture, forests biomass and moisture, crops, sea ice, snow covers. The idea of P-band spaceborne SAR construction is under discussion last 15 years. One of most known and advanced projects based on a use of P-band SAR is Biomass project, supported by ESA [1]. Similar activity is being conducted in Russia also [2]. In this experiment it is planned to place P-band SAR instrument on board ISS station. It should be noted that there is no SAR missions (except for SIR-C/X SAR), where simultaneous utilization of two or more SAR instruments operation in different frequency band was considered.

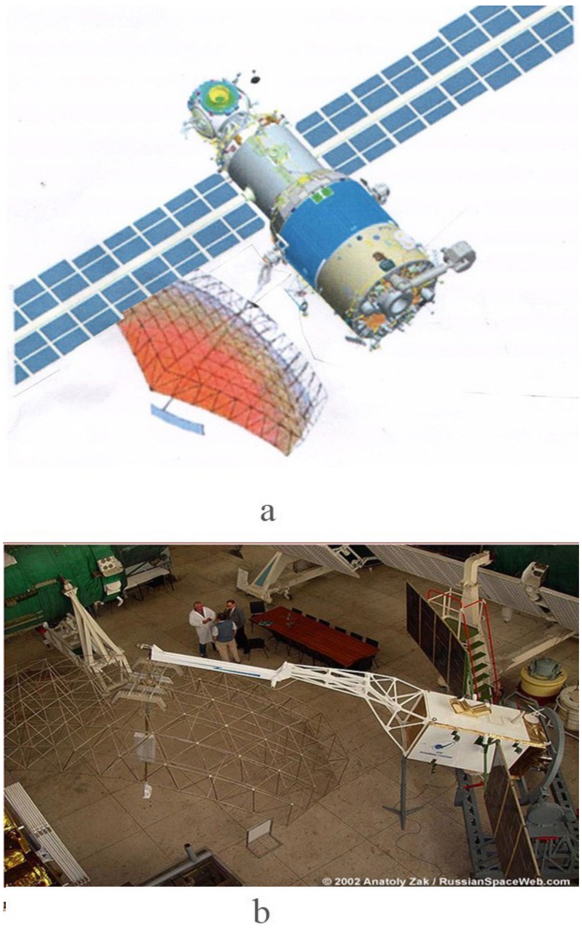

Figure 1: a) Hybrid mirror antenna for ISS SAR system; b) general view of “Condor-E” lightweight satellite with deployed SAR “Strizh” antenna in the JSC “VPK” NPO Mashinostroenia test facility

2. P-band SAR system

A specific feature of Russian project by now was a use of active phased array antenna, but now more light-weight and worked-out hybrid mirror antenna was selected. This antenna designed by Special Design Bureau of Moscow Power Engineering Institute (SDB MPEI) was destined for S-band SAR to be placed on board a small satellite “Condor-E” [3]. The antenna passed tests in space during ISS flight in a year 2013. In a **Figure 1(a)** an artist view of supposed hybrid mirror antenna on board ISS is presented. Also in the **Figure 1(b)** is presented a way of the test of this antenna.

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3. Technical features of P-band SAR antenna

Hybrid mirror antenna of SDB MPEI design selected for P-band experiment is to be deployed in space. The reflector aperture shape is hexahedron with 6 m distance between the facets. The reflector focal distance is 4 m .For dual-frequency SAR the primary feed of antenna is made in a form of three linear multi-element arrays placed in focal plane of reflector. Technical parameters of combined antenna system devoted to operation in S and P-bands are as follows (see **Table 1**). The reflector is made of lattice structure of truss rods and joints covered with scattering surface made of knitted fabric of micro wires. The reflector weight is 63.5 Kg; the sizes are 1280 mm, 744 mm, 720 mm. Power consumption is 30 W.

A use of reliable hybrid antenna along with availability of ready-to-use technology of S-band SAR production lead to the idea of simultaneous exploitation the two SAR systems sharing the same antenna on board ISS station. There is real problem of selection the second frequency band, effectively complementing P-band SAR.

Frequency band (P-band), MHz	432±30
Frequency band (P-band), MHz	3150±100
Aperture size in P-band (vert), deg	7.5
Aperture size in P-band (vert), deg	2
Antenna gain, P-band, dB	28
Antenna gain, P-band, dB	41
Pointing, vert, P-band, deg	±7
Pointing, vert, S-band, deg	±5
Beams switching, mks	5
Polarization isolation, dB	30
Pulse power, P band, W	500
Pulse power, S-band, W	600
Average power, each band, W	50

Table 1: Technical parameters of antenna system

4. Problem of secondary band selection

Taking in mind higher priority of forest studies, the second band should not be too high frequency band. At the same time, higher frequencies diversity may be more fruitful from a point of view of more tasks to be solved. The images below demonstrate the potential of multi-frequency observations for remote sensing studies. In **Figures 2** and **3** the images of various surface objects (forest, pit soils, villages, flood plains, etc.) are presented (images were obtained in ISTC Project No. #2866 "Application of multi-frequency polarimetric synthetic aperture radar at decimeter (L,P) and meter (VHF) bands for surface and subsurface sensing of soils and vegetation covers). Numbers in a **Figure 2** mark: 1 – sea surfaces with various salinity, 2 – sea swell, 3 – vortex behind the rock, 4 – river mouth.

For comparison on a **Figure 3 (c)** is presented the radar image of forest, villages flood plains obtained by SAR "Strizh" [4,5].

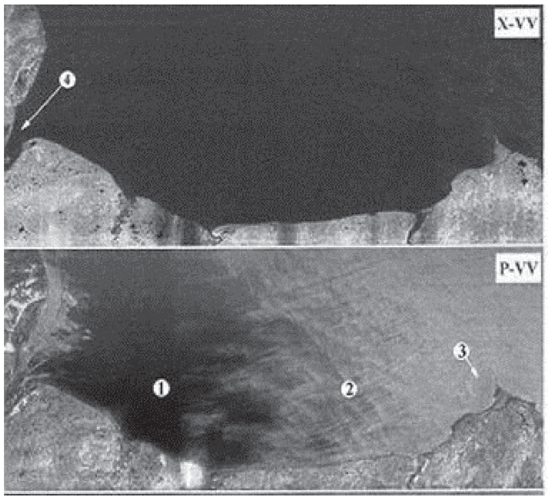
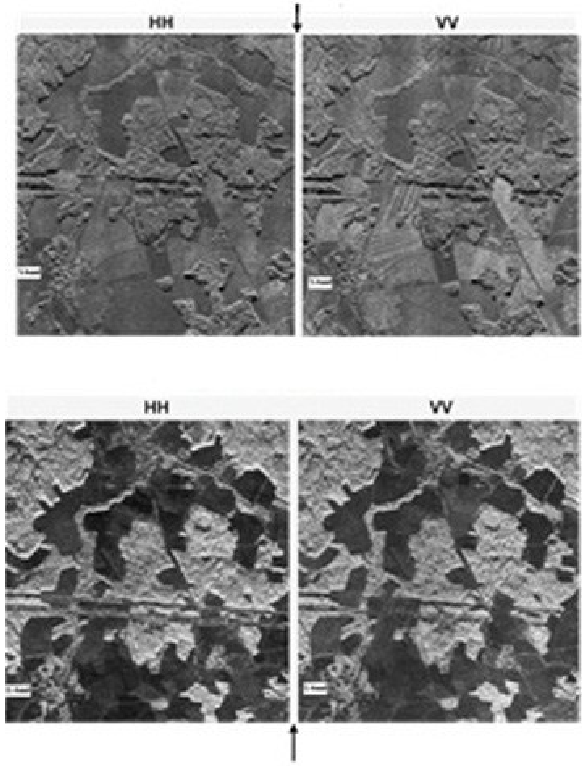


Figure 2: Radar images of Barents sea obtained simultaneously at wavelength of X=4 cm (VV polarization), P =68 cm (VV polarization)

When comparing L and S band signals we have to take in mind better potential resolution because of larger frequency band allocated (up to 200 MHz) and lower signal distortion in ionosphere in S band. For that reason S-band might be more attractive secondary band for P-band SAR system.

In the figures below we present for qualitative comparison a number of radar images obtained over different landscapes in various frequency bands and at different polarizations.



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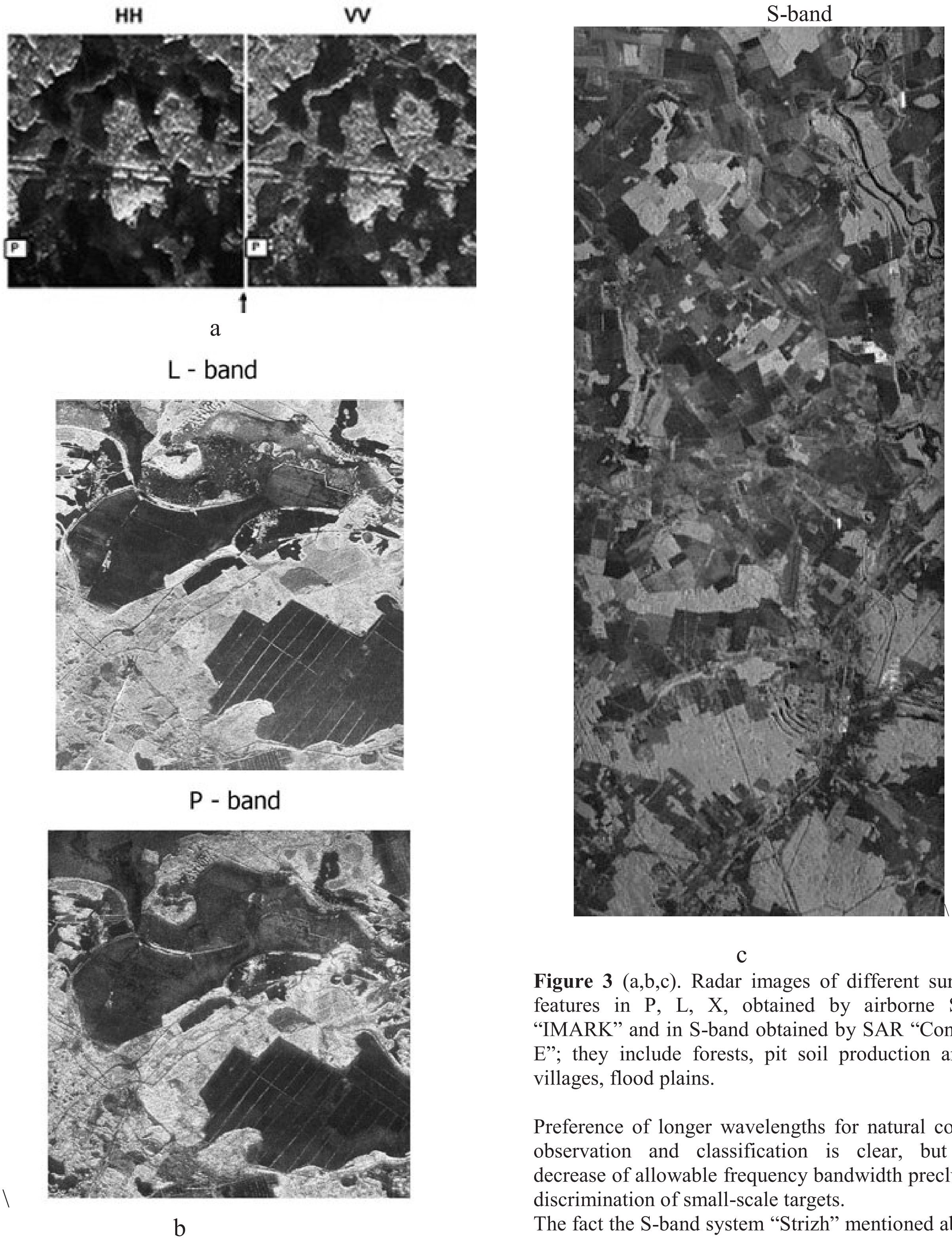

Figure 3 (a,b,c). Radar images of different surface features in P, L, X, obtained by airborne SAR "IMARK" and in S-band obtained by SAR "Condor-E"; they include forests, pit soil production areas, villages, flood plains.

Preference of longer wavelengths for natural covers observation and classification is clear, but the decrease of allowable frequency bandwidth precludes discrimination of small-scale targets.

The fact the S-band system "Strizh" mentioned above was utilizing the same reflector antenna we planned earlier for spaceborne P-band SAR to be placed on board ISS makes the idea of simultaneous use of two SAR systems to be very probable.

5. Expected Results

An international experience of spaceborne SARs exploitation shows that significant amount of remote sensing tasks might be solved more efficiently using SAR data obtained in various frequency bands because of different penetrating capability of signals into sounding media and sensitivity to surface roughness. Joint utilization of S and P band data is an attractive combination because of essential difference of the signals interaction with sounding media as well as propagation media in atmosphere.

Remote sensing tasks frequently propose underlying covers sounding with subsurface penetration. P and S band data are preferable for vegetation studies. Because of distinction in signals penetration depths it is possible to study height profile of forest, to study forest biomass in more detail and to measure thickness of vegetation layer by means of interferometry technique.

In the area of **vegetation covers studies** such as forests it is possible to conduct forests classification more efficiently and to measure vegetation biomass because of better penetration of P-band signals under the tree crown and sensitivity to signal backscatter from large branches and trunks. At the same time, it is possible to study soil state under the forest covers, moisture extent, detection of forest floods, while S band signals provide sensitivity to penetration from crowns and smaller branches.

An estimation of **soils state** in economic activity, such as moisture, it is may be evaluated more efficiently in P-band because of lower influence of vegetation and higher penetration depth in subsurface sounding, though the landscapes classification according to their small-scale roughness (at wavelength scale) is preferable in S-band, where almost all the surface types are rough in different extent.

In **geology** it is possible to observe geological structures under the sediments and vegetation in P band. For the same reason this frequency band is preferable for studies of arid and desert areas.

In **hydrology** longer wavelengths are preferable in studies of wet underlying surface layers because of lower influence of surface roughness and sensitivity to larger depth of surface layer. Water reservoirs may be delineated more reliably because of lower influence of wind ripples on the water surface. At the same time, the maps of large-scale waves separated from wind ripples are observable better in P-band. Studies of flood zones covered with forests are more efficient in P-band because of better radio waves penetration through the forest layer.

In **glaciology** P-band provides better opportunities for studies of structure of ice covers of shallow fresh-ice water reservoirs because of better signal penetration through the ice layer and interaction with bottom topography, yet S-band data are preferable for sea ice covers classification because of coincidence of wave length and scales of ice roughness. Studies of ice glaciers and glaciers structures under the snow covers as well as permafrost soils are preferable in P-band also.

In the interferometric scheme of surface mapping from satellite repeated orbits the P-band provides lower sensitivity of measurements to temporal decorrelation of backscattered signals, especially in the case of long time intervals between observations, when observations at shorter wavelengths are practically impossible.

In studies of the **atmosphere** impact the use of S and P bands will allow studies of destructive influence of ionosphere on the process of radar images synthesis and search for algorithms of compensation of the radar images defocusing, Faraday rotation of linearly polarized signal polarization plane orientation as well as unwanted phase shifts corrupting interferometric measurements of surface topography.

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