NovaSAR Data Product Specifications and Format (Version 2.0)

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SAR Data Processing Division

Microwave Data Processing Group

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16.	Abstract(With Keywords)	This Document describes the data product specifications and format for NovaSAR Level-1 Scene –based data products generated from SSTL-Stripwise products and Level-2 data products generated at NRSC/ISRO.			

SARDPD/MDPG/DPA/NRSC

Version History

Date	Version	Description	Revision
20/01/2021	1.0	NovaSAR Data Products Format and Specifications	-
19/08/2021	2.0	NovaSAR Data Products Format and Specifications	1.Updation of Metadata file 2.Geolocation Accuracy Estimation 3.FAQ (Frequently Asked Questions) included .

1.0. Introduction

NovaSAR is an S-Band Imaging SAR built by Surrey Satellite Technology Limited (SSTL), UK, in collaboration with AirBus and launched by ISRO. It operates in the imaging frequency band of 3.1-3.3 GHz The satellite was launched on-board PSLV-C42 on 16 September 2018 (16:38 UTC) from SDSC (Satish Dhawan Space Center), Sriharikota.

It provides medium resolution SAR data ranging from 6m-45 m resolutions with Single,Dual,Tri and Quad-Polarization capability.It is ideal for applications like flood monitoring agricultural crop assessment forest monitoring land use mapping disaster management and maritime applications to name a few.

The NovaSAR data will be received by NRSC Antenna systems and SSTL supplied RF rack. Data is processed using SSTL- Processing systems which are integrated into IMGEOS framework for automation through workflows and products are disseminated using NRSC IMGEOS systems.

Presently, Level-1 SLC and Ground Range products are being provided by the SSTL-Image Formation Processor-IFP.For the entire imaged duration, data processing is carried out by the IFP resulting in longer strips of data.

NRSC has designed and developed scene-based imagery product generation and analysis -ready information product generation from the IFP data .These products are generated in IMGEOS for supporting and enhancing SAR remote sensing applications

This document describes the NovaSAR data product specifications and format.

2.0. SAR Sensor Specifications

The NovaSAR SAR sensor operates at the S band microwave frequency and the specifications is as tabulated below:

Table 1:NovaSAR Mission Characteristics

Parameter	Value
Imaging frequency band	S-band (3.1-3.3 GHz, wavelength of ~ 10 cm)
SAR Antenna	Microstrip patch phased array (3x1 m)

No. of phase centers	18
Peak RF power	1.8 kW
Polarizations	HH, HV, VH, VV
Imaging polarization	Single, dual, tri or quad-polar
Duty cycle	2-3 minutes per orbit (equates to single image 800 km long)
Payload data memory	544 Gbytes
AIS Antenna	2 orthogonal mounted monopole antennas per receiver
Design life for operations	7 years
Design Mass	<440 kg
Optimum orbit	580 km SSO (LTAN 10:30)
Propulsion system	Xenon
Payload data memory	2xHSDR (32 GBytes) + 2xFMMU (512 Gbytes)
Downlink rate	500 Mbps*
TT&C frequency band	S-band (2025-2110 MHz, 2200-2290 MHz)
Downlink frequency band	X-band (8.025-8.4 GHz)

3.0.NovaSAR Imaging Modes

NovaSAR is designed to image in the three basic SAR modes of Stripmap, ScanSAR and Maritime .The Stripmap provides 6m resolution, with a swath coverage of 13 km to 20 km. The look-angles and swath coverage for a typical stripmap mode is as provided in Figure 1.

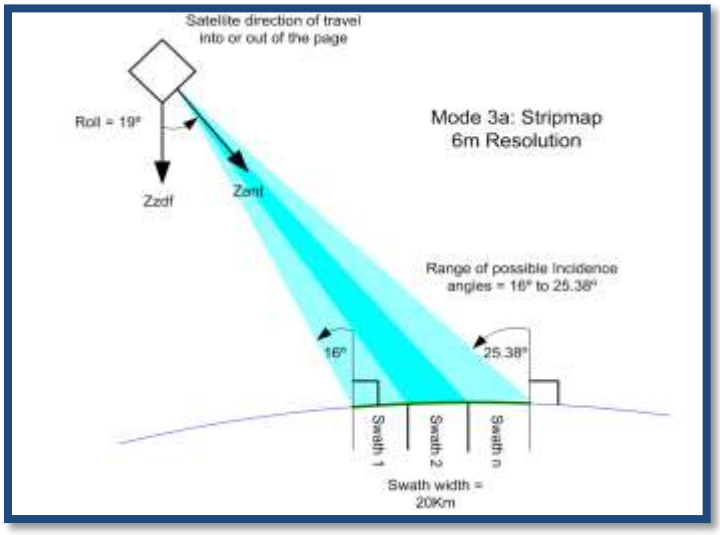


Figure 1: NovaSAR Incidence angles and swath coverage for the stripmap mode

(image courtesy of SSTL)

For the ScanSAR mode, the resolutions vary between 20m-45 m with swath coverage of 50km to 190 km.The Wide-swath coverage of nearly 400 km mode is done for the Maritime at 6m resolution.

The roll angle for the ScanSAR mode is +/-20 deg and for the strip map mode for the near beams the roll is +/-19 deg and for the far beams it's +/-26 deg. For the scansar wide beam mode, the roll angle is +/-26 deg. For the Maritime mode, the roll bias is +/-45 deg . The imaging modes with the incidence angles range at 580 km altitude with the NESZ specifications are as given in Table 2:

Table 2: Imaging Mode-wise specifications

ModeType	Ground Range Resolution	Incidence Angles (At 580 km Alti) (Deg)	No.of Swaths	Swath Width (Across track) (km)	Worst Case Sensitivity (NESZ) (dB	Worst Case Azimuth Ambiguity Ratio (DTAR)dB	Worst Case Range Ambiguity Ratio (DTAR)dB	No. Of Looks
ScanSAR (HH or VV)	20m	15.0-24.66	1	100	<-20	<-16	<-16	4 (2-Range,2 Azimuth)
ScanSAR (HH or VV)	20m	24.51-28.94	1	50	<-21	<-19	<-14	4 (2-Range,2 Azimuth)
Maritime(HH)	6mrange 13.7m azimuth	34.5-57.3	1	400	<-9.5	N/A	<-15	1 (1Range,1Azimuth)
StripMap(HH or VV)	6m	16-25.38	9	20	<-20	<-18	<-17	3 (1-Range, 3 Azimuth)

StripMap(HH or VV)	6m	21.29-31.2	11	13-20	<-19	<-15	<-14	3 (1-Range,3 Azimuth)
ScanSAR Wide(HH or VV)	30m	11.29-25.93	1	150	<-21	<-19	<-15.5	4 (2-Range,2 Azimuth)
ScanSAR Wide (HH or VV)	30m	27.35-32.01	1	55	<-19.5	<-17.5	<-16	4 (2-Range,2 Azimuth)
Dual Polar(HH&VV)	20m	13.98-30.6	5	50-60	<-20	<-17	<-12	3 (3-Range,1 Azimuth)
Tri-Polar (HH&VV&HV)	30m	15-29.1	3	50-56	<-27	<-17	<-17	4 (2-Range,2 Azimuth)
Tri-Polar (HH&VV&HV)	35m	14.39-29.08	2	100km	<-26dB	<-17	<-8	1
Co+Cross Polar (HH & HV)	40m	12.95-31.18	1	195km	<-21dB	<-15	<-10	4 Co-pol(4 range ,1 azimuth), 1 Cross pol
Co+Cross Polar (HH & HV)	45m	12.95-31.18	1	195km	<-26dB	<-14	<-5	1
ScanSAR Survey	33m	11.82-30.26	1	195km	<-19.5dB	<-17	<-12	3 (3-Range,1 Azimuth)

Reference: SSTL-Airbus Products Specification

4.0 .NovaSAR Data Products

NovaSAR data products are scene-framed from the IFP strip product and processed at various levels for ease of data handling and analysis.

For the maritime mode, strip data is provided at present .Table 3 and Table 4 provide the details on the processing applied to various imaging modes.

Table 3: Levels of Processing

Level-1 SLC	Scene-Based Geo-Tagged Product (For StripMap Mode only)	Slant Range Product Format-GeoTIFF
Level-1 GND	Scene-Based Geo-Tagged Product (For StripMap Mode)	Ground Range Product Format-GeoTIFF
Level-1 SCD	Scene-Based Geo-Tagged Product (For ScanSAR Mode)	Ground Range Product Format-GeoTIFF
Level-1 Maritime	Strip-Based GeoTagged Product	Ground Range Product Format-GeoTIFF
Level-2 GeoRef	Scene-Based Geo-Referenced Product (For Stripmap and ScanSAR modes)	Map Projected Product with Sigma Naught Backscatter and Surface Water layer products Format-GeoTIFF

Table 4: Imaging Modes and Levels of Processing

Imaging mode	Processing Level	
	Level-1 Scene	Level-2 Scene
StripMap SLC	√	√
StripMap GRD	√	√
ScanSAR SCD	√	√
Maritime	*	*

* Not Applicable currently

4.1. Level-1 Scene-based Products-Specifications and Format

NovaSAR data products are provided as a complete strip for the entire imaging duration resulting with non-standard azimuth coverage by SSTL with various swaths. Such large azimuth extents consume more memory for storage coupled with higher processing time for analysis. In order to minimize the processing load and maximize the ease of data utilization from the user perspective, a standard sized product is necessary.

For a given strip of data scene-framing is carried out by suitably selecting fixed sized azimuth extent with 10% of overlap between the consecutive scenes through NovaSAR Scene making Software-SMS.It is designed to generate standardized Level-1 products are geo-tagged and provided in the GeoTiff format in WGS-84 datumfor the SLC, GRD and SCD products .

The Geographic Tie-points and the Azimuth time stamping is modified with respect to the scene-extent. The Lat/Lon points for the scene-centre and the scene-corners are provided .A Quick Look image in jpeg format for each daughter scene is provided, in addition to the imagery files in tiff format and the modified Meta data in xml format.

4.2. Level-2 Scene- Based Products-Specifications and Format

The Level-2 product is the Bundled Geo-referenced product containing scene-based geo-referenced imagery along with Geo-referenced Sigma –Naught Backscatter and Surface Water Layer products as Analysis-Ready data-ARD.

The sigma naught backscatter is derived using the radar equation as:

$$\sigma_0=10*\log10(DN*DN/K)+10*\log10(\sin(i_{pixel})/\sin(i_{centre}) \quad (1)$$

where σ_0->Sigma Naught backscatter at each pixel

DN->Digital number in the imagery

K->Calibration Constant

i->Incidence Angle .

The surface water-layer products are generated for the co and cross pol channels using backscatter thresholds.

The products are in the WGS84 datum and Universal Transverse Mercator-UTM projection .The sigma naught backscatter products and Surface Water Layer Products are generated along with the imagery files in the tiff format. A quick-look image in jpeg format along with the modified meta data, relevant to Level-2 are also provided.

The Sigma Naught Reference Values as per AirBus is provided in Annexure 2.

It is to be noted that the corrections due to topographic variations shall be implemented subsequently on the Level-2 products with Local – incidence Angle and layover maps and derived Information Products.

The resolutions/Swath Coverage, Incidence Angle Range and scene sizes areas shown as under:

Table 5: Scene -sizes as per the imaging mode

	NOVASAR-S Imaging modes				
S. No	**Mode**	**Ground range resolution | Swath width (across track)**	**Incidence angles**	**Standard Level 1/Level-2 Slice Range XAzimuth Extent(KM)**	**Approximate Data Volumes*(Level-1)**
1.	1a ScanSAR	20m | 100 km	15.8-25.38°	100X100	100-150 MB
2.	1b ScanSAR	20m | 50 km	25-29.4°	50X50	50-100 MB
3.	2 Maritime	6m range 13.7m azimuth | 400 km	34.5-57.3°	As per Acquisition Extent in Azimuth	2-6 GB
4.	3a Stripmap	6m | 20 km	16-25.38°	20X20	120-170 MB
5.	3b Stripmap	6m | 13-20 km	21.83-31.2°	13-20X20	100-160 MB
6.	4a ScanSAR Wide	30m | 140 km	14-27.39°	140X140	200-400 MB
7.	4b ScanSAR Wide	30m | 55 km	27.35-32.01°	55X55	50-200 MB
8.	ScanSAr_40 Co-Pol+ Cross Pol	40m | 195 km	13.00-31.14°	195X195	200-400 MB
9.	Stripmap_6 Single Pol	6m | 18-25 km	13.10-31.22°	18-25X25	100-200 MB
10.	Stripmap_6x20 Cross-Pol	6m | 20 km	13.10-31.22°	20X20	120-170 MB
11.	ScanSAR_20 CoPol+Cross Pol	20m | 20-30km	13.00-31.22°	20-30X30	100-200 MB
12.	ScanSAR_30 Single-Pol	30m | 195 KM	13.0-31.137°	195X195	200-400 MB

**For Level 2 products, the data volumes is nearly 4 x (Level-1 Scene Product Volume).*

Both the Level-1 and Level-2 products are supported for viewing using generic Image-viewing software /COTS packages.

4.3. Scene-Based Product Details

The Product details are described in the table as below:

Table 6: NovaSAR Product Details

Product Type(Scene-framed)	Imaging Mode	Polarizations	Product Contains
Level-1 – SLC (Single look complex)	Stripmap Only	Single/Dual	Scene-framed image strip with imagery files-for each polarization, Quick-Look images and metadata.
Level-1 – GRD (Ground Range detected)	Stripmap –GRD ScanSAR/Maritime –SCD GRD- Ground range detected SCD-ScanSAR detected	Single/Dual/Tripol	Scene-framed image strip with imagery files-for each polarization, Quick-Look images and metadata.
Level-2 - Bundled	Stripmap/ScanSAR/*Maritime	Single/Dual/Tripol	Geo-referenced Imagery files, Geo-referenced Sigma Naught files and Geo-Referenced Surface Water Layer files for each polarization, along with Incidence Angle file and metadata.

The product file-naming and input/output matrix convention are as in Table 7.

Table 7:Scene-Based Products- Input/Output Matrix

Process Name	Input in IMGEOS-SAN	Output in IMGEOS-SAN	Remarks
Level-1 Scene-Based	Level-1 Work-order : NVS_* _01	Scene-Based Output products in the output path 1.SCNNVS_*_01_01 2.SCNNVS_* _01_02 ..... 3.SCNNVS_* _01_0N 4.Modified Meta File 5.QuickLook image	Scene-based products where N is the total number of scenes generated from the strip. Eg.:metadata.xml Eg.:QLP.jpg
Level-2 Scene-Based	Level-2 Work Order ID : YYXXXXXX	Output Work order ID:WOID in the prescribed output path with the following entries: 1.Geo-Referenced Imageries for various Imaging modes 2.Sigma Naught Products in GeoTIFF format 3.Water Layer Products in GeoTiff Format 4. Modified Meta File. 5. Quick-look file	E.g.: image_HH.tif image_VV.tif E.g.: Georefsigma_HH.tif Georefsigma_VV.tif E.g.: Novaswl_HH.tif Novaswl_VV.tif E.g.: metadata.xml WOID.log

Using the Impulse Response Function analysis,the PSLR for the stripmap mode is found to be -20.8 dBin Azimuth and -20.7 dB in elevation for the stripmap mode.

5.0 Geolocation Accuracy

The spatial and radiometric quality parameters are monitored since the commisioning phase and subsequently in the IMGEOS inception phase .The location accuracy as observed for various modes is as tabulated in Table 8:

Table 8:Geolocation Parameters

DOP	Mode	Lat/Lon	RMSE (Az) m	RMSE (Rng) m
3/3/2020	20m ScanSAR HH	32.5/90.8	153S	693 E
3/3/2020	20m ScanSAR HV	32.5/90.8	165S	675E
2/9/2019	30m ScanSAR HH,HV,VV	22.7/78.4	709N	216E
11/3/2020	6m StripMap	24.8/82.5	184N	762W

The system level geolocation accuracies are found to be high in the strip data as the geolocation is based on the Ellipsoid Model but is improved post terrain correction where true height is incorporated for the geolocation

6.0 Level-1 and Level-2 Data Product Volumes

For a given imaging mode ,the Level-1 scene volume for each imaged polarization is found to vary between 30 MB to 400 MB .

The corresponding Level 2 Imagery volume would be nearly 60 MB to 600 MB. The Sigma Naught Backscatter product would be 120 MB to 1200 MB .The Surface Water Layer would be 30MB to 300MB in volume.

7.0. Metadata File

The Metadata File logically records the full information on radar data acquisition, image generation and image characteristics. It enables full interpretation of the Image Product File. Along with the imageries, the updated meta information is provided as metadata.xml .This includes the scene–related information along with the Information Product related fields based on the processing level of product.

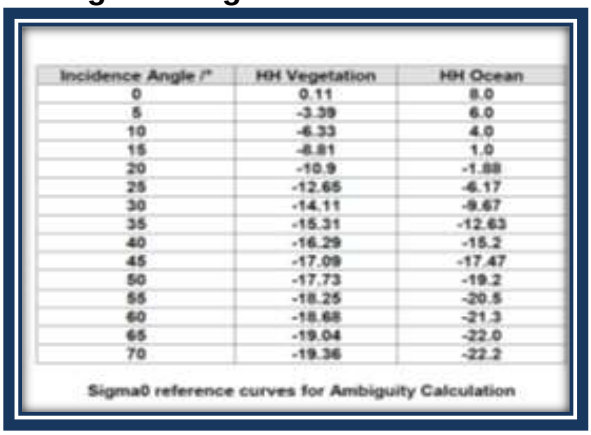
The sigma naught reference values are presented in Annexure 1.The Meta data file format is provided in Annexure -2. The Level-1 and Level-2 sample metadata .xml is provided in Annexure -3 and Annexure -4.

7.0. References

1. ISRO NovaSAR Ground Segment ICD- NV K V - #0324588
2. Scene-based Level-1 and Level-2 Products Generation for NovaSAR-NRSC-DPA-MDPG-SAR-DPD-Dec2020-TR-0001740-V1.0
3. Preliminary Analysis on NovaSAR Data Products Received from SSTL- NRSC-DPPA&WAA-MAY-2019-TR-1287-V1.0.
4. Software Requirements Document of NRSC Elements for NovaSAR -NRSC-DPA-DEC-2019-TR-0001403-V1.0
5. Software Design Document of NRSC Software Elements FOR NOVASAR: NRSC-DPA-DEC-2019-TR-0001404-V1.0
6. Concept of operations of NovaSAR in IMGEOS-Dec 2019
7.0320909_NovaSAR Mode performance and incidence angle tables
8.0342129_NovaSAR Products

Annexure-1

* Sigma Naught Reference Values



Incidence Angle /°	HH Vegetation	HH Ocean
0	0.11	8.0
5	-3.39	6.0
10	-6.33	4.0
15	-8.81	1.0
20	-10.9	-1.88
25	-12.65	-6.17
30	-14.11	-9.67
35	-15.31	-12.63
40	-16.29	-15.2
45	-17.09	-17.47
50	-17.73	-19.2
55	-18.25	-20.5
60	-18.68	-21.3
65	-19.04	-22.0
70	-19.36	-22.2

Sigma0 reference curves for Ambiguity Calculation

*** Values are as provided in the initial phase.**
The updated values shall be appended subsequently

Annexure 2

Meta Data File Format

Metadata files are ASCII text files in XML (Extensible Markup Language) format. XML is a self-descriptive format.

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
Primary Grouping = **Product**					
ProductName	*text_string*		Name of the parent product		e.g.NovaSAR_01_14008_grd_180125_121508_HH_1
ProductID	*integer_value*				
SceneID	*integer_value*		Scene number		
Strip ID	*integer_value*		Strip Number		
Primary Grouping = **Source_Attributes**					
Satellite	*text_string*			eg 'NovaSAR1'	
Sensor	*text_string*			eg 'SAR'	
InputDataSetID	*text_string*		File name of processed echo data file		
InputDataSetFacilityID	*text_string*		Name of ground station facility that received echo data.	eg 'SSTL'	

ModeID	*integer_value*		The ID of the instrument mode used.		
OperationalMode	*integer_value*		SAR Operational Mode		
OperationalSwath	*integer_value*		SAR Operational Swath		
Operational Mode Name	*text_string*		Indicates the imaging mode with resolution, polarization and swath coverage details		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
AcquisitionID	*integer_value*		Acquisition ID		
ModeMnemonic	*text_string*				A usually 3 char mnemonic for the Image Product
RawDataStartTime	*text_string (YY-MM-DD HH:MM:SS.ssss)*		Start time of acquisition raw data used to generate scene.		
Polarisations	*text_array*		List of Polarisation types used	VV, HH, HV, VH	
NumberofSwaths	*integer_value*		Number of range sub swaths used to form image		set to 1 for Strip-map modes
PulsesReceivedPerDwell*	*integer_value*		The number of PRI packets of valid raw data used in each subswath burst.		*Output only in ScanSAR& Maritime Modes See Note 1
NumberOfPulseIntervalsPerDwell*	*integer_value*		The number of PRI in each subswath burst.		*Output only in ScanSAR& Maritime Modes See Note 1

Rank	*integer_value*		Rank of received echoie the number of complete PRI between transmission of pulse and pulse reception		See Note 1
ReceiveGain	*float_value*	dB	Receiver relative gain		See Note 1

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
RadarCentreFrequency	*float_value*	Hz	Radar Centre Frequency		
PulseRepetitionFrequency	*float_value*	Hz	Pulse Repetition Frequency		See Note 1
PulseLength	*float_value*	sec	Duration of transmit pulse for each sub swath.		See Note 1
ChirpBandwidth	*float_value*	Hz	Bandwidth of transmit pulse for each sub swath.		See Note 1
AntennaPointing	*text_string*		Antenna pointing direction	'LEFT' or 'RIGHT'	
YawSteeringFlag	*text_string*		Defines whether platform is steered to orient antenna in zero Doppler direction	'TRUE' or 'FALSE'	
EchoSamplingRate	*float_value*		Number of raw echo data complex samples per second.		See Note 1
RawBitsPerSample	*float_value*		Equivalent number of bits per I/Q sample	2.5, 3, 3.5, 4, 4.5, 5,12	See Note 1
SamplesPerEchoLine	*integer_value*		Number of raw echo data complex samples per pulse.		See Note 1
InternalRefNoise	*float_value*	counts	RMS of Internal Noise pixels.		See Note 1,3
ExternalRefNoise	*float_value*	counts	RMS of External Noise pixels.		See Note 1,3
Bias_I	*float_value*	counts	Mean value of real part of digitised echo data		See Note 3
Bias_Q	*float_value*	counts	Mean value of imaginary part of digitised echo data		See Note 3

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
StandardDeviation_I	*float_value*	counts	Standard Deviation of real part of digitised echo data samples		See Note 3
StandardDeviation_Q	*float_value*	counts	Standard Deviation of imaginary part of digitised echo data samples		See Note 3
GainImbalance	*float_value*	dB	Ratio of the mean power of the real part of the digitised echo data to the mean power of the imaginary part of the echo data		
PhaseOrthogonality	*float_value*	degrees	Deviation from quadrature of real and imaginary parts of echo data		A positive value indicates that there is less than 90 degrees between real and imaginary parts
FractionOfPacketsWithError	*integer_value*		Fraction of raw data packets used to form image that were detected as containing errors.		Total packet errors is sum of Data Error 1 plus Data Error 2 plus Data Error 3
DataError_MissingPackets	*integer_value*		Number of Missing Packets in processed echo data		

DataError_CRC	*integer_value*		Number of Cyclic Redundancy Check errors in processed echo data		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
DataError_PRI_type	*integer_value*		Number of wrong PRI Type errors in processed echo data		
OrbitDataFile	*text_string*		Name of file containing orbit data.		
PassDirection	*text_string*			'ASCENDING' or 'DESCENDING'	Direction of satellite pass at the start of the image
OrbitDataSource	*text_string*		Origin of the orbit data file used	'GPS DATA' or 'TLE FILE'	
NumberOfStateVectorSets	*integer_value*		Number of state vectors used in the given scene.		
For each state vector set....					
Time	*text_string (YY-MM-DD HH:MM:SS.sssss)*		GPS Position Timestamp		e.g. 2018-01-25 12:15:09.77851
xPosition	*float_value*	m	GPS Position		
yPosition	*float_value*	m	GPS Position		
zPosition	*float_value*	m	GPS Position		
xVelocity	*float_value*	m/s	GPS		

			Velocity		
yVelocity	*float_value*	m/s	GPS Velocity		
zVelocity	*float_value*	m/s	GPS Velocity		
...end of state vector set details					
AttitudeDataSource	*text_string*		'GPS' or 'MODEL'		Roll/Pitch/Yaw all set to zero if set to 'MODEL' Always 'GPS' for NovaSAR
PlatformRoll	*float_value*	deg	Payload roll angle		Roll Attitude Parameter value at zero Doppler time of mid-image. Relative to Zero Doppler Frame (ZDF)
PlatformPitch	*float_value*	deg	Payload pitch angle		Pitch Attitude Parameter value at zero Doppler time of mid-image. Relative to ZDF
PlatformYaw	*float_value*	deg	Payload yaw angle		Yaw Attitude Parameter value at zero Doppler time of mid-image. Relative to ZDF
PlatformRollRate	*float_value*	deg/sec	Payload roll angle rate		Roll rate Parameter value, assumed constant over the acquisition
PlatformPitchRate	*float_value*	deg/sec	Payload pitch angle rate		Pitch rate Parameter value, assumed constant over the acquisition
PlatformYawRate	*float_value*	deg/sec	Payload yaw angle rate		Yaw rate Parameter value, assumed constant over the acquisition

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
ProductType	*text_string*		Product Type	"slc" Stripmap, Single Look Complex, Slant Range "srd" Stripmap, Multilook Detected, Slant Range "grd" Stripmap, Multilook Detected, Ground Range "scd" ScanSAR, Multilook Detected, Ground Range and "Bundled", Georeferenced along with Analysis ReadyData	
ProcessingFacility	*text_string*			e.g.NRSC/ISRO	
ProcessingLevel	*text_string*		Indicates Level of Processing	L1 L2	
ProcessingTime	*text_string (YYMMDD_HHMM)*		Time of processing to this image product by IFP.		
SoftwareVersion	*text_string*		Version of IFP software used.		
AlgorithmUsed	*text_string*		Selected Processing Algorithm	RM' or 'RD – Interpolator' or 'RD – Fourier Shift' or 'RD – Chirp Scale'	RM: Range Migration RD: Range Doppler
ExtendedChirpScaling	*text_string*			'TRUE' or 'FALSE'	Set 'TRUE' in ScanSAR or Maritime modes
wK_Flag	*text_string*	N/A	Whether a component of the matched filter in the range/Doppler frequency domain has been applied.	'TRUE' or 'FALSE'	
RadiometricScaling	*text_string*	N/A		'None' 'Sigma0' 'Beta0' 'Gamma0'	No radiometric scaling applied rcs per unit area on Earth

					Ellipsoid rcs per unit area in the plane of the look direction rcs per unit area in the plane perpendicular to look direction

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
RadiometricSmoothingPerformed	*text_string*	N/A	Indicates whether smoothing has been performed to merge neighbouringScanSAR image blocks (in range and azimuth)	'TRUE' or 'FALSE'	Output in ScanSAR only
DopplerSource	*text_string*	N/A		Always 'ORBIT & ATTITUDE'	
ZeroDopplerTimeFirstLine	*text_string (YY-MM-DD HH:MM:SS.sssss)*		The time at which the radar viewed the location of first image line in direction of closest approach.		
ZeroDopplerTimeLastLine	*text_string (YY-MM-DD HH:MM:SS.sssss)*		The time at which the radar viewed the location of last image line in direction of closest approach.		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
SWST	*float_value*	seconds	Time between start of a transmit pulse and start of the receive window in which the ground return from that pulse is received. (for the indicated subswath)		See Note 1, 3
NumberOfRangeLooks	*integer_value*	N/A	Number of Range Looks processed		Looks are defined in frequency and may overlap.
RangeLookBandwidth	*float_value*	Hz	Range Bandwidth per Look		
TotalProcessedRangeBandwidth	*float_value*	Hz	Total Bandwidth spanned by all of the range looks.		Will be less than sum of look bandwidths if looks overlap.
NumberOfAzimuthLooks	*integer_value*	N/A	Number of azimuth Looks processed		In ScanSAR modes looks are defined in time domain.
AzimuthLookBandwidth	*float_value*	Hz	Azimuth Bandwidth per Look		

TotalProcessedAzimuthBandwidth	*float_value*	Hz	Total Bandwidth spanned by all of the azimuth looks.		Will be less than sum of look bandwidths if looks overlap. For ScanSAR is the sum of a look bandwidth plus the range of look centre frequency over imaged ground extent for subswath burst.

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
IRFWindow	*text_string*	N/A	Type of window function applied to data, in frequency domain, to reduce IRF sidelobe levels.	'None' or 'Taylor' or 'Hanning' or 'Kaiser'	
WindowParam1	*float_value*	N/A	Parameter 1 value for IRF window	Weight parameter.	Taylor: Number of sidelobes of desired

					peak sidelobe level
WindowParam2*	*float_value*		Parameter 2 value for IRF window	Nominal level first sidelobes.	*Output for Taylor weight only
SlantRangeNearEdge	*float_value*	metres	Distance from radar to ground in zero Doppler look direction at near swath edge		
PlatformHeight	*float_value*	metres	Nominal platform height above reference ellipsoid		
DopplerCentroid	*float_array*	Hz	Offset of centre of processed Doppler bandwidth from zero.		At pre-defined positions across swath (0.2,0.5& 0.8 of swath in Slant Range). Note this may not be the received Doppler centroid.
IRF_3dBWidth	*float_value*	m	Replica auto-correlation 3 dB width		
IRF_PSLR	*float_value*	dB	Replica auto-correlation Peak Sidelobe level ratio, PSLR		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
IRF_ISLR	*float_value*	dB	Replica auto-correlation Integrated Sidelobe Level Ratio, ISLR		
ChirpAmp Coeffs	*float_array*	N/A	Coefficients of polynomial fit to amplitude component of deramped replica, in amplitude/ sample^n.	First sample in line is sample no. 0.	Output only when repFiltmethod = 3 or 4 Array length = repFiltOrd + 1 Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$ where x is replica sample number. Evaluated polynomial gives linear amplitude. See Note
ChirpPhaseCoeffs	*float_array*	N/A	Coefficients of polynomial fit to phase component of deramped replica, in degrees/sample^n.	First sample in line is sample no. 0.	Output only when repFiltmethod = 3 or 4 Array length = repFiltOrd + 1

Parameter	ParameterFormat Description	Units	Meaning	Permissible Values	Comment
					Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$ where x is replica

					sample number . Evaluated polynomial gives phase in degrees See Note
ChirpDirection	*text_string*	N/A	Slope of Transmitted RF Pulse Frequency Modulation	'UPCHIRP', 'DOWNCHIRP' or 'ALTERNATE'	
GroundToSlantRangeCoefficients*	*float_array*	N/A	Coefficients of polynomial fit to the "Ground to Slant Range" transform applied. Fixed along all image slices.	In (slant range in m)/(pixel no.)^n where first pixel in line is pixel no. 0.	*output for ground range products only. Array length = srtgrOrd + 1 Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x$ … $+A_nx^n$ where x is pixel number in the line where the first pixel

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
					in the line has x=0. Evaluated polynomial gives Slant Range in metres.
IncAngleCoeffs	*float_array*		Polynomial coefficients for incidence angle at pixel position.	In deg/(pixel no.)^n where first pixel in line is pixel no. 0.	at mid-imageValues output in order A_0, A_1, … A_n for fitPolynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$where x is pixel number in the line where the first pixel in the line has x=0. Evaluated polynomial gives incidence angle in degrees.
DepAngleCoeffs	*float_array*		Polynomial coefficients for depression angle	In deg/(pixel no.)^n where first pixel in line is pixel no. 0.	at mid-image Values output in order A_0, A_1, … A_n for fit Polynomial to be evaluated $A_0 + A_1x \ldots + A_nx^n$ where x is pixel number in the line where the first pixel in the line has x=0.

NearRange Incidence Angle	*Float*		Incidence angle at Near Range		
Center IncidenceAngle	*Float*		Center Incidence Angle		
FarRange IncidenceAngle	*Float*		Incidence angle at Far Range		
RangeSwath	*Int*		Swath Width (In km)		

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
					Evaluated polynomial gives depression angle in degrees.
Projection	text_string	N/A	Indicates the coordinate reference system for location on earth. The projection used here is the Universal Transverse Mercater.	Eg .:UTM	For L2 only
TerrainHeightUsed	*float_value*	metres	Assumed mean scene height used in geolocation calculations		For L2 only
FalseEasting	*Float value*	metres			For L2 only
FalseNorthing	*Float value*	metres			For L2 only
StandardParallel	*Float value*	metres			For L2 only
DEMCorrection	*String*		Applied /NotApplied		For L2 only
ProductFormat	*text_string*	N/A	Image File Format	'GeoTIFF' or 'Big GeoTIFF'	
OutputMediaInterleaving	*text_string*	N/A	Describes interleaving of real and complex parts of samples for	'LINE_INTERLEAVED' or 'PIXEL_INTERLEAVED'	

			complex products.		
DataType	*text_string*	N/A		‘COMPLEX’ or ‘MAGNITUDE_DETECTED’ or ‘Geo-Referenced’	
BitsPerSample	*integer_value*	N/A	Number of bits contained in each image pixel component value	8 or 16 or 32	
NumberofSamplesPerLine	*integer_value*	N/A	Number of pixels per line of image.		
NumberOfLinesInImage	*integer_value*		Number of lines in scene		
SampledPixelSpacing	*float_value*	metres	Distance between pixels in across-track (range) direction		metres
SampledLineSpacing	*float_value*	metres	Distance between pixels in along-track direction		metres
LineTimeOrdering	*text_string*	N/A	Time ordering of lines in along-track direction	‘INCREASING’ or ‘DECREASING’	
PixelTimeOrdering	*text_string*	N/A	Time ordering of lines in across-track direction	‘INCREASING’ or ‘DECREASING’	

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
RangeResolution	*float_value*	N/A	Nominal range resolution		metres
AzimuthResolution	*float_value*	N/A	Nominal azimuth resolution		metres

PixelMeanI	*float_value*		Mean value of scene pixel I values		Mean of real part of pixel values for complex images
PixelMeanQ	*float_value*		Mean value of image pixel Q values		Mean of complex part of pixel values for complex images
PixelStandardDeviationI	*float_value*		Standard Deviation of scene pixel I values		Standard Deviation of real part of pixel values for complex images
PixelStandardDeviationQ	*float_value*		Standard Deviation of scene pixel Q values		Standard Deviation of complex part of pixel values for complex images
Equiv_Number_of_Looks	*float_value*		Number of independent looks that would give same scattering cross section variance for a uniform distributed scene as the look arrangement used by IFP.		
CalibrationConstant	*float_value*		Radiometric calibration constant		The radiometric scattering cross section, σ_0, β_0 or λ_0, is the (pixel value)^2/ CalibrationConstant
CalibrationStatus	*float_value*	N/A	Status of mission radiometric calibration.	Uncalibrated Preliminary	

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
				Relative Calibrated	
ImageNoiseRangePixelPositions	*integer_value*		Across swath pixel positions at which Image Noise values are provided		

ImageNoiseValue	*float_value*	pixel counts ^2	Noise contribution to image		Variance of noise contribution to image.
ImageMapcorners (UL,UR,LR,LL)	*Float*	metres	Map corners of the image in easting ,northing		Image corners
ImageLat/lon (UL,UR,LR,LL)	*Float*	Decimal degree	Image corners in geodetic		Image Corners
ProductMapCorners (UL,UR,LR,LL)	*Float*	metres	Product corners of the image (easting ,northing)		Product corners
ProductLat/Lon (UL,UR,LR,LL)	*Float*	Decimal degree	Product corners in geodetic		Product Corners
L2_SoftwareVersion	*decimal*	-	Version ID		-
SceneNoData	*Binary*	0 or 1	0 - for nominal 1- for data loss		Quality Flag
Primary Grouping = **geographicInformation**					
EllipsoidName	*text_string*	N/A	Nameof Reference Ellipsoid Model		eg 'WGS84'
SemiMajorAxis	*float_value*	metres	Semi-major axis of reference ellispoid		
SemiMinorAxis	*float_value*	metres	Semi-minor axis of reference ellipsoid		
NumberOfRangeTiepoints	*Integer_value*	N/A	Number of across track tie points provided in scene		
NumberOfAzimuthTiepoints	*Integer_value*	N/A	Number of along track tie point positions provided in scene		

For each tiepoint....					
Line	*float_value*	N/A	Line number of tie point	First line in image	

Parameter	Parameter Format Description	Units	Meaning	Permissible Values	Comment
			(along-track direction)	is line no. 0.	
Pixel	*float_value*	N/A	pixel number of tie point (across-track direction)	First pixel in line is pixel no. 0.	
Latitude	*float_value*	degrees	Latitude of tie point		
Longitude	*float_value*	degrees	Longitude of tie point		
Height	*float_value*	metres	Height of tie point above reference ellipsoid		
For each tiepoint....					
SceneCenterLon	*float_value*	degrees			
SceneCenterLat	*float_value*	degrees			
SceneULLon	*float_value*	degrees			
SceneULLat	*float_value*	degrees			
SceneURLon	*float_value*	degrees			
SceneURLat	*float_value*	degrees			
SceneLRLon	*float_value*	degrees			
SceneLRLat	*float_value*	degrees			
SceneLLLon	*float_value*	degrees			
SceneLLLat	*float_value*	degrees			

Annexure 3

Sample metadata Level-1

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    <Product_ID>13</Product_ID>
    <Product_Code>ST0000NTD</Product_Code>
    <Workorder_ID>21306795611115</Workorder_ID>
    <Scene_ID>15</Scene_ID>
    <Strip_ID>1</Strip_ID>
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    <Sensor>SAR</Sensor>
    <InputDataSetID>NV_01_006356</InputDataSetID>
    <InputDataSetFacilityID>SSTL</InputDataSetFacilityID>
    <ModeID>4014</ModeID>
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    <OperationalSwath>13</OperationalSwath>
    <OperationalModeName>6m_Stripmap_HH_G5</OperationalModeName>
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    <ModeMnemonic>6m GRD</ModeMnemonic>
    <RawDataStartTime>2021-08-04 17:02:49.512275</RawDataStartTime>
    <Polarisations>HH </Polarisations>
    <NumberofSwaths>1</NumberofSwaths>
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    <ReceiveGain Subswath="S1" units="dB">-12.42</ReceiveGain>
    <RadarCentreFrequency units="Hz">3.2E+09</RadarCentreFrequency>
    <PulseRepetitionFrequency Subswath="S1"
units="Hz">5903.19</PulseRepetitionFrequency>
    <PulseLength Subswath="S1" units="seconds">4.1711E-05</PulseLength>
    <ChirpBandwidth Subswath="S1" units="Hz">5.9649E+07</ChirpBandwidth>
    <AntennaPointing>Right</AntennaPointing>
    <YawSteeringFlag>TRUE</YawSteeringFlag>
    <ScanInReceiveFlag>FALSE</ScanInReceiveFlag>
    <EchoSamplingRate Subswath="S1" units="Hz">6.54545E+07</EchoSamplingRate>
    <RawBitsPerSample Pol="HH" Subswath="S1">4 Bit</RawBitsPerSample>
    <SamplesPerEchoLine Subswath="S1"
units="samples">5198</SamplesPerEchoLine>
    <InternalRefNoise Subswath="S1">1.38</InternalRefNoise>
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    <ExternalRefNoise Subswath="S1">9.22</ExternalRefNoise>
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    <StandardDeviation_Q Pol="HH">10.921</StandardDeviation_Q>
    <GainImbalance Pol="HH" units="dB">-0.304</GainImbalance>
    <PhaseOrthogonality Pol="HH" units="degrees">0.086</PhaseOrthogonality>
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02</PacketErrorsDetectedperpacket>
    <DataError_MissingPackets>0</DataError_MissingPackets>
    <DataError_CRC>0</DataError_CRC>
    <DataError_PRI_type>0</DataError_PRI_type>
    <DataError_Interferer_Present>6904</DataError_Interferer_Present>
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  <OrbitData>
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5430.xml</OrbitDataFile>
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    <StateVector>
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      <yPosition units="m">6200503.3</yPosition>
      <zPosition units="m">3155695.1</zPosition>
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      <yVelocity units="m/s">3318.8944</yVelocity>
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    <PlatformYaw units="degrees">-0.01</PlatformYaw>
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17:02:53.237344</ZeroDopplerTimeLastLine>
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units="Hz">5.9621E+07</RangeLookBandwidth>
    <TotalProcessedRangeBandwidth Subswath="S1"
units="Hz">5.9621E+07</TotalProcessedRangeBandwidth>
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units="Hz">1237.8</AzimuthLookBandwidth>
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    <PlatformHeight units="m">5.899348e+05</PlatformHeight>
    <DopplerCentroid units="Hz">-383.5 0.0025005 -9.9823E-07 1.2985E-10
</DopplerCentroid>
    <IRF_3dBWidth Pol="HH" Subswath="S1" units="m">2.57</IRF_3dBWidth>
    <IRF_PSLR Pol="HH" Subswath="S1" units="dB">-23.26</IRF_PSLR>
    <IRF_ISLR Pol="HH" Subswath="S1" units="dB">-15.72</IRF_ISLR>
    <ChirpAmpCoeffs Pol="HH" Subswath="S1">928.5 3.56 -0.057848 0.00047148 -
2.1567E-06 5.9787E-09 -1.0178E-11 9.5338E-15 -9.6619E-19 -1.0569E-20 1.6474E-
23 -1.4115E-26 8.0081E-30 -3.1353E-33 8.424E-37 -1.4883E-40 1.5608E-44 -
7.3706E-49 </ChirpAmpCoeffs>
    <ChirpPhaseCoeffs Pol="HH" Subswath="S1">-0.14044 0.0011622 -2.634E-05
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22 -8.8376E-26 5.4491E-29 -2.5005E-32 8.4109E-36 -2.0127E-39 3.2426E-43 -
3.1517E-47 1.3959E-51 </ChirpPhaseCoeffs>
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    <GroundToSlantRangeCoefficients>644526.6 1.064502 4.413747E-06 -
8.091985E-12 1.888164E-16 -1.586706E-20 </GroundToSlantRangeCoefficients>
    <IncAngleCoeffs>25.2 0.00022355 -3.6941E-10 8.5018E-15 -1.654E-18
1.0714E-22 </IncAngleCoeffs>
    <DepAngleCoeffs>67.081 -0.0002011 3.6752E-10 -7.6075E-15 1.4875E-18 -
9.6397E-23 </DepAngleCoeffs>
    <NearRangeIncidenceAngle units="degrees">25.2</NearRangeIncidenceAngle>
    <CenterIncidenceAngle units="degrees">25.77</CenterIncidenceAngle>
    <FarRangeIncidenceAngle units="degrees">26.34</FarRangeIncidenceAngle>
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    <SampledLineSpacing units="m">2.50</SampledLineSpacing>
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    <PixelTimeOrdering>INCREASING</PixelTimeOrdering>
    <RangeResolution units="m">5.92</RangeResolution>
    <AzimuthResolution units="m">6.04</AzimuthResolution>
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    <PixelStandardDeviation
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    <CalibrationConstant>1E+05</CalibrationConstant>
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</ImageNoiseRangePixelPositions>
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938.61 </ImageNoiseValue>
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    <NumberOfAzimuthTiepoints>1</NumberOfAzimuthTiepoints>
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    <SceneLRLon>84.62192892737902</SceneLRLon>
    <SceneLRLat>27.52050559536289</SceneLRLat>
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</metadata>
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Annexure 4

Sample Meta Data File Format –Level 2

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    <Product_ID>27</Product_ID>
<Product_Code>STUC00ETD</Product_Code>
<Workorder_ID>213697311</Workorder_ID>
    <Scene_ID>2</Scene_ID>
    <Strip_ID>1</Strip_ID>
  </Product>
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    <Satellite>NovaSAR_01</Satellite>
    <Sensor>SAR</Sensor>
    <InputDataSetID>NV_01_005A97</InputDataSetID>
    <InputDataSetFacilityID>SSTL</InputDataSetFacilityID>
    <ModeID>8008</ModeID>
    <OperationalMode>13</OperationalMode>
    <OperationalSwath>1</OperationalSwath>
    <OperationalModeName>35m_3Pol_ScanSAR_100km_VVHHHV</OperationalModeName>
    <AcquisitionID>23191</AcquisitionID>
    <ModeMnemonic>35m SCD</ModeMnemonic>
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    <PulsesReceivedPerDwell Subswath="S4">664</PulsesReceivedPerDwell>
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17 2.7941E-20 -3.6265E-23 3.4881E-26 -2.4095E-29 1.1298E-32 -3.2199E-36
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18 -1.6792E-20 3.1907E-23 -4.5366E-26 4.7493E-29 -3.5505E-32 1.7926E-35 -
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Frequently asked Questions

1.What are the Transmit/Receive polarizations offered by Novasar?

The Tx/Rx Polarizations offered are as follows:

1.1. Single HH,Single VV,
1.2. Co-Cross-HH&HV ,VV&VH
1.3.Co-Pol –HH&VV
1.4.Tripol-HH,VV&HV

2. Is NOVASAR Fully Polarimetric?

No.Tripol data HH,HV and VV is available for ScanSAR data in Detected (SCD) format with intensity only . Only stripmap data is provided in Single Look Complex(SLC) and Ground Range (GRD)

3. What is the difference between Level-1 and Level-2 Products provided to the user?

Level-1 Products are scene–framed imagery in GEOTIFF format in the ground range in Geodetic Lat/Lon Projection.A quick look jpeg file along with the modified meta data file are also provided.

The level-2 products are bundled Analysis Ready Data (ARD) with Geo-referenced product containing scene-based imagery along with Sigma–Naught Backscatter(dB scale)and Surface Water Layer products for each polarization channel .The incidence angle map is also provided .The products are generated in the GeoTiff format . The products are in the WGS84 datum and Universal Transverse Mercator-UTM projection. A quick-look image in .jpg along with the modified meta data is also provided.

4. Are the data products speckle filtered?

No external filters for speckle removal are applied on the Level-1 and Level-2 Products in order to maintain the data sample integrity and the users might opt for application- specific Speckle filtering techniques.

5. What is the type of scaling applied to the Sigma Naught products?

The Sigma Naught is provided in the decibel (dB) notation . The values are low for specular surfaces like still water bodies and high for bright scattering targets .

6. Are the products Terrain Corrected?

Currently, the data products are Ellipsoid-Corrected with mean height consideration.However, Terrain Correction is being implemented using External DEM Data along with

Layover/Shadow masking and Local Incidence Angle generation.This shall be given in the upcoming versions.