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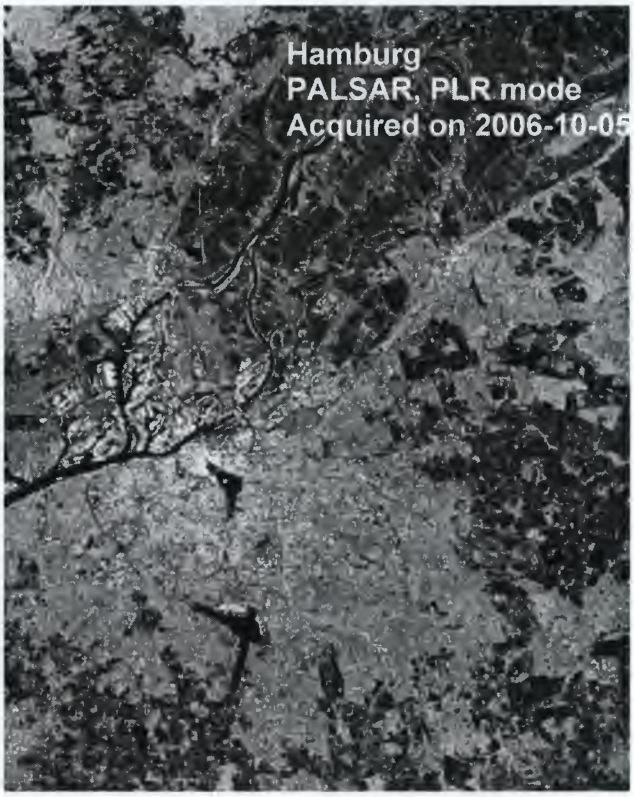
INFORMATION ON ALOS PALSAR PRODUCTS FOR ADEN USERS



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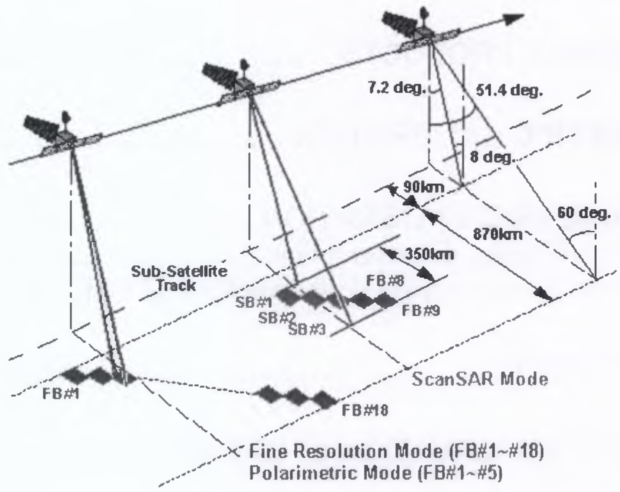
1 INTRODUCTION

The Advanced Land Observing Satellite (ALOS), launched on 24 January 2005, is a joint project between JAXA and the Japan Resources Observation System Organization (JAROS). ALOS has three remote-sensing instruments: the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping, the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) for precise land coverage observation, and the Phased Array type L-band Synthetic Aperture Radar (PALSAR) for day-and-night and all-weather land observation.

Information on ALOS is available on the JAXA web site:
http://www.eorc.jaxa.jp/ALOS/about/about_index.htm

PALSAR is an L-band SAR with an active antenna providing beam steering capabilities in elevation, with flexible viewing geometry:



The scope of this note is to provide summary information on PALSAR products to ADEN users.

Information provided in this note is aligned with version I of PALSAR product format specifications.

For any additional information, please contact ESA HelpDEsk at: EOHeLP@esa.int

2 REFERENCES

R-1 The ALOS PALSAR Observation strategy, A. Rosenqvist, M. Shimada, M. Watanabe, K. Yamauchi

R-2 ALOS PALSAR: Technical outline and mission concepts, A. Rosenqvist, M. Shimada, M. Watanabe, 4th International Symposium on Retrieval of Bio-and Geophysical parameters from SAR Data for Land Applications, 16-19 November 2004, Austria

R-3 PALSAR Calibration and Validation, M. Shimada, M. Watanabe, A. Rosenqvist, T. Tadono, IGARSS 2005

R-4 Calibration and Validation of PALSAR, M. Shimada, M. Watanabe, A. Rosenqvist, T. Tadono, 2nd ALOS Cal/Val and Science Team Meeting, 8-9 Nov. 2004

R-5 ALOS PALSAR L1 Product format Specification version I, http://www.eorc.jaxa.jp/ALOS/doc/format.htm

R-6 ALOS home page, http://www.eorc.jaxa.jp/ALOS/index.htm

3 ABBREVIATIONS AND ACRONYMS

This section controls the definition of all abbreviations and acronyms used within this document. Special attention has been paid to adopt abbreviations, acronyms and their definitions from international standards as ISO, ANSI or ECSS.

ADEN	ALOS Data European Node
ALOS	Advanced Land Observing Satellite
DSN	PALSAR Fine Beam Single polarization mode
FBS	PALSAR Fine Beam Single polarization mode
FBD	PALSAR Fine Beam Single polarization mode
JAXA	Japan Aerospace Exploration Agency
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PLR	PALSAR Polarimetric mode
SAR	Synthetic Aperture Radar
WB1	PALSAR ScanSAR short bursts mode
WB2	PALSAR ScanSAR long bursts mode

4 PALSAR MODES

PALSAR can operate in 5 different science data modes. The main characteristics for the different modes are summarised in the following table:

PALSAR ACQUISITION MODES					
	FINE BEAM SINGLE POLARISATION (FBS)	FINE BEAM DOUBLE POLARISATION(FBD)	DIRECT DOWNLINK (DSN)	ScanSAR (WB1/WB2)	POLARIMETRY (PLR)
Central Frequency	1270 MHz				
PRF	1500 - 2500 Hz (discrete stepping)				2 x FBS PRF
range Sampling Frequency	32 MHz	16 MHz	16 MHz	16 MHz (WB1)/ 32 MHz (WB2)	16 MHz
Chirp bandwidth	28 MHz	14 MHz	14 MHz	14 MHz (WB1) / 28 MHz (WB2)	14 MHz
Polarsation	HH or VV	HH/HV or VV/VH	HH or VV	HH or VV	HH/HV + VV/VH
Off-nadir angle [deg]	9.9-50.8	9.9-50.8	9.9-50.8	20.1-36.5	9.7-26.2
Incidence angle [deg]	7.9-60.0	7.9-60.0	7.9-60.0	18.0-43.3	8-30
Swath Width [Km]	40-70	40-70	40-70	250-350	20-65
Bit quantization [bits]	5	5	3 or 5	5	3 or 5
Data rate [Mbps]	240	240	120	120 or 240	240

Table 1. PALSAR acquisition modes

Out of the potential 132 PALSAR modes, JAXA has defined the following default acquisition modes which will be calibrated with higher priority:

DEFAULT PALSAR ACQUISITION MODES AS DEFINED BY JAXA (Calibrated with higher priority)					
	FINE BEAM SINGLE POLARISATION (FBS)	FINE BEAM DOUBLE POLARISATION (FBD)	DIRECT DOWNLINK (DSN)	ScanSAR (WB1)	POLARIMETRY (PLR)
Chirp bandwidth [Mhz]	28 MHz	14 MHz	14 MHz	14 MHz	14 MHz
Polarsation	HH	HH/HV	HH	HH	HH/HV + VV/VH
Off-nadir angle [deg]	34.3	34.3	34.3	20.1-36.5	21.5
Incidence angle [deg]	7.5-60.0	7.5-60.0	7.5-60.0	18.0-43.3	8-30
Swath Width [Km]	70	70	70	35	30
Bit quantization [bits]	5	5	5	5	5
Data rate [Mbps]	240	240	120	120	240

Table 2. PALSAR default acquisition modes

It is recommended to ADEN users to use, as much as possible, data acquired in the default modes to ensure the maximum product quality, calibration accuracy and probability of successful acquisition/observation.

5 PRODUCT FORMAT SPECIFICATIONS

ALOS PALSAR products follow the standard CEOS format convention. The detailed product format specifications have been defined and are maintained by JAXA. Detailed information is available at:
http://www.eorc.jaxa.jp/ALOS/doc/format.htm

6 AVAILABLE PRODUCTS

PALSAR products provided by ADEN are generated using the Jaxa PALSAR processor, integrated in the ADEN ground segment. Therefore, product format and auxiliary information provided in the product (product coordinates, calibration parameters, etc) are those defined by Jaxa.

PALSAR product levels available to users are listed in the table below:

Processing Level	Definition
1.0	• The data of 1 scene area is extracted from received data. • The number of SAR data files is the same as the number of polarizations in the case of dual polarization and polarimetry modes. • The data in SCAN SAR mode is not divided into individual scans. • This corresponds to raw data products ready to be processed into single look complex (L1.1) or precision images (L1.5). • Data type: 8 bit(I) + 8 bit(Q)
1.1	• Single Look Complex products. • Provided in slant range geometry • Phase preserving products. • Natural pixel spacing • Data type: 32 bit(I) + 32 bit(Q) (*1)
1.5	• Detected products. • Provided in ground range geometry • Multi-look in range and azimuth. • Pixel spacing can be selected for the Fine mode. • Latitudes and longitudes in the product are calculated without considering the terrain height but based on ellipsoid GRS80. • 16 bit unsigned integer (*2)

Table 3. Processing Levels Definition.

Note (1): I and Q are real data based on IEEE. Byte order is Big Endian.

Note (2): Byte order is Big Endian

The product levels available for each PALSAR acquisition mode are described in the following table:

Observation Mode		**Processing Level**			**Remarks**
		1.0	1.1	1.5	
Fine mode	**Single polarization (FBS)**	√	√	√	18 beams
	Dual polarization (FBD)	√	√	√	18 beams
Scan SAR mode	**Burst mode 1 (WB1)**	√	Not available	√	3 scans 4 scans 5 scans (default)
	Burst mode 2 (WB2)	√	Not available	√	3 scans 4 scans 5 scans (default)
Direct Downlink mode (DN)		√	√	√	18 beams
Polarimetry mode (PLR)		√	√	√	12 beams

Table 4. Product Levels available per acquisition mode

The complete list of possible off-nadir angles for the FB modes, ScanSAR and Polarimetry mode is provided in the following table:

Beam ID	off nadir angle [deg]	look angle at near range [deg]	look angle at far range [deg]	mode
0	9.9	5.9	13.9	
1	14.0	10.1	17.9	
2	18.0	14.3	21.7	
3	21.5	18	25	
4	25.8	22.5	29.1	
5	28.8	25.7	31.9	
6	30.8	27.9	33.7	
7	34.3	31.6	36.8	
8	36.9	34.4	39.2	FBS
9	38.9	36.3	40.9	
10	41.5	39.4	43.6	
11	43.4	41.5	45.3	
12	45.2	43.5	46.9	
13	46.6	45	48.2	
14	47.5	46.3	49.3	
15	49.0	47.6	50.4	
16	50.0	48.7	51.3	
17	50.8	49.4	52	
18	20.1	16.9	24.1	
19	26.1	23	29.4	
20	30.6	27.8	33.6	WB1 & WB2
21	34.1	31.1	36.5	
22	36.5	33.7	38.7	
23	9.7	subset of FBS#0		
24	13.8	subset of FBS#1		
25	16.2			
26	17.3	subset of FBS#2		
27	18.1			
28	19.3			
29	20.5			PLR
30	21.5	subset of FBS#3		
31	23.1			
32	24.2			
33	25.2	subset of FBS#4		
34	26.2			

Table 5. List of beams for the PALSAR modes with corresponding off-nadir angles and range of elevation angles. Please note that the PLR beams are a subset of the FBS beams.

The table below provides the main characteristics for the products acquired in the default modes:

PARAMETER	PRODUCT LEVEL	PROCESSING SETTINGS	FINE BEAM SINGLE POLARISATION (FBS)	FINE BEAM DOUBLE POLARISATION(FBD)	DIRECT DOWNLINK (DSN)	POLARIMETRY (PLR)	SCANSAR (WB1/WB2)
Pixel spacing	1.5	1 look rg & 2 looks az.	6.25 m x 6.25 m	-	-	-	-
		1 look rg & 4 looks az.	12.5m x 12.5 m	12.5m x 12.5 m	12.5m x 12.5 m	12.5m x 12.5 m	-
		4 looks rg & 2 looks az.	-	-	-	-	100 m x 100 m
	1.1	1 look rg x 1 look az	4.6 m rg	9.3 m rg	9.3 m rg	9.3 m rg	-
			2.7 m to 4.5 m az	2.7 m to 4.5 m az	2.7 m to 4.5 m az	1.4 m to 2.3 m az	
			(az pixel spacing is PRF dependent, variable around the orbit)				
Spatial resolution	1.5	1 look rg & 4 look az.	~9.5 m rg x 10 m az [@o.n.a.34.3]	~ 19 m x 10 m az [@o.n.a. 34.3]	~ 19 m x 10 m az [@o.n.a. 34.3]	~30 m rg x 10 m az [@o.n.a. 21.5]	-
		4 looks rg & 2 looks az.	-	-	-	-	~71-157 m rg x 100 m az [@5 scan, short burst]
	1.1	1 look rg x 1 look az	~ 5m rg x ~ 4.5 m az	~ 10 m rg x ~ 4.5 m az	~ 10 m rg x ~ 4.5 m az	~ 10 m rg x ~ 4.5 m az	-
Radiometric accuracy	1.5	-	< 1 dB				
Radiometric stability			< 1.5 dB				
Azimuth Scene size	1.0	-	16.4 sec [110 Km]				57.0 sec [385 Km]
	1.1		51-79 Km			62-83 Km	Not Applicable
	1.5						350 Km
Range scene size	1.5	-	70 Km [o.n.a: 9.9 deg - 43.4 deg]			30 Km [o.n.a: 21.5 deg]	350 Km (5 scan)
			50 Km [o.n.a: 45.2deg - 50.0 deg]				300 Km (4 scan)
			40 Km [o.n.a. 50.8 deg]				250 Km (3 scan)
Projection	1.1		Slant Range (non-zero Doppler)				-
	1.5		Georeferenced or Geocoded				
Absolute location accuracy	1.1		< 1 pixel (actual measured value) [Note: Requirement: < 200 m]				
	1.5						

Table 6. Main product requirements for the default PALSAR modes It should be noted that the values provided the table correspond to the quality requirements for PALSAR products or to the theoretical values (depending on the parameter).

7 GEOMETRIC CALIBRATION

In order to derive accurate geolocation information for standard PALSAR products, the following procedures are recommended.

PALSAR L1.0 products

The slant range distance to a given range sample 'i' can be estimated using one of the two equations below:

$$\text{Eq. 1: } Slrg = \frac{c}{2} \cdot \left(\frac{i}{f_{sampling}} + \frac{Rank}{PRF} + \Delta t \right)$$

$$\text{Eq. 2: } Slrg = \frac{c}{2} \cdot \left(\frac{i}{f_{sampling}} + Rank \cdot PRI + SWST + SWSTbias \right)$$

PALSAR L1.1 products

The slant range distance to a given range sample 'i' can be estimated for L1.1 products using the following equation:

$$\text{Eq. 3: } Slrg = R_0 + \frac{c}{2} \cdot \frac{i}{f_{sampling}}$$

Definition of parameters and constants

Parameter	Definition	Access within the product	
		L1.0	L1.1
Ro	Slant range distance to first range sample	to be estimated (see equation #1)	bytes 117-120 of 412 bytes of header information available in each product line
Fsampling	A/D Sampling Rate [16 MHz or 32 MHz]	field 12, bit 1 of PALSAR auxiliary data (PALSAR auxiliary data: bytes 289-388 of signal data records)	
i	slant range sample number		
Δt	SWST + SWST bias [μsec]	bytes 121-124 of signal data records	N/A
N	Rank	Number of PRIs between a pulse is transmitted and the corresponding backscattering is received (see table #9)	N/A
PRF	Pulse repetition Frequency [mHz]	bytes 57-60 of signal data records	N/A
PRI	Pulse repetition interval [μsec]	bytes 32-33 of PALSAR auxiliary data (PALSAR auxiliary data: bytes 289-388 of signal data records)	N/A
SWST	Sampling Window Start Time [μsec]	bytes 38-39 of PALSAR auxiliary data (PALSAR auxiliary data: bytes 289-388 of signal data records)	N/A
SWST bias	Sampling Window Start Time bias [μsec]	-8.31539	N/A

Table 8. Definition of basic acquisition parameters required to estimate the slant range distance to product samples.

MODE	OFF-NADIR ANGLE	RANK
FBS/FBD	9.9	10
	14.0	10
	18.0	11
	21.5	9
	25.8	12
	28.8	11
	30.8	10
	34.3	12
	36.9	11
	38.9	10
	41.5	12
	43.4	11
	45.2	13
	46.6	12
	47.5	12
	49.0	13
	50.0	13
	50.8	13
WB1/WB2	20.1	8
	26.1	12
	30.6	9
	34.1	12
	36.5	11
PLR	9.7	18
	13.8	18
	16.2	18
	17.3	16
	18.1	15
	19.3	19
	20.5	18
	21.5	19
	23.1	18
	24.2	16
	25.2	16
	26.2	20

Table 9. Definition of instrument rank per each off-nadir angle.

8 RADIOMETRIC CALIBRATION

Calibration of L1.1 and L1.5 PALSAR products is defined in the PALSAR product specifications, "Radiometric Data Record", bytes 21-36. A summary is provided hereafter.

8.1 General principles and assumptions

To perform a precise absolute image calibration and derive the radar backscattering coefficient σ^0 for detected ground range products, a detailed knowledge of the local slope (i.e. local incidence angle) is required. Since this information is usually not available at the processing time, a "flat terrain" is assumed during processing (based on the ellipsoid GRS80) and the final intensity image is therefore proportional to the radar brightness of the illuminated scene.

The relationship between the value of the image pixels ("DN"), the radar brightness (β^0) and the radar backscattering coefficient (σ^0) can be written as:

$$DN^2 = \text{constant} \cdot \beta^0$$

The constant factor is hereafter referred as "absolute calibration constant" (K), which is derived from measurements over precision transponders.

This factor has been adjusted for PALSAR to be constant for the same product level for different modes, while it differs between L1.1 and L1.5 products.

PALSAR slant range products (L1.1) are provided with the same radiometric corrections as for detected ground-range products (L1.5), i.e. the elevation antenna pattern and range spreading loss have been corrected during the data processing.

8.2 Sigma and gamma nought derivation for PALSAR 1.1 and 1.5 products

Calibrated sigma nought and gamma images for detected products can be derived as:

$$\sigma^0_{i,j} = \frac{DN^2_{i,j}}{K} \qquad \gamma_{i,j} = \frac{\sigma^0_{i,j}}{\cos\left(\alpha_{i,j}\right)} \qquad \textit{for } i = 1 \ldots \mathrm{L} \text{ and } j = 1 \ldots \mathrm{M}$$

where	K	=	absolute calibration constant
	$DN_{i,j}^2$	=	pixel intensity value at image line and column "i,j"
	$\sigma_{i,j}^0$	=	sigma nought at image line and column "i,j"
	L,M	=	number of image lines and columns
	$\alpha_{i,j}$	=	local incidence angle at image line and column "i,j"

The average backscattering coefficient for an area of interest can be derived as an average of $\sigma_{i,j}^0$ for the N pixels within the distributed target as:

$$\sigma^0 = \frac{1}{N}\left(\sum_{i=1}^{i=L} \sum_{j=1}^{j=M} \sigma_{i,j}^0 \right)$$

Finally, to convert sigma nought to dB:

$$\sigma^0[dB] = 10 \cdot \log_{10}\left(\sigma^0\right)$$

The calibration constant values for L1.1 and L1.5 in dB are provided below:

Calibration constant	L1.1	L1.5
K [dB]	-115 dB	-83 dB

Table 10. PALSAR absolute calibration constants

The elevation antenna pattern for PALSAR beams is provided by JAXA and it can be access at: **WEB LINK TB added!**
The format description for this file is provided in Annex A of this document.

9 ALOS ORBIT

The main ALOS orbit characteristics are summarized in the following table:

Orbit	Sun-Synchronous Sub-Recurrent
	Repeat Cycle: 46 days Sub Cycle: 2 days
	Altitude: 691.65 km (at Equator)
	Inclination: 98.16 deg.
Attitude Determination Accuracy	2.0 x 10^{-4}degree (with GCP)
Position Determination Accuracy	1m (off-line)

Table 11. ALOS Orbit

The orbital tube was reduced to 500 m vertical by 2500 m horizontal on 7 August 2006. Resulting baselines are expected to be around 1 Km.

10 PALSAR OBSERVATION STRATEGY

A summary of the PALSAR baseline acquisition strategy is provided in the following table:

PALSAR sensor default modes

Sensor mode	Polarization	Off-nadir angle	Pass designation	Civerage	Time window	Observation frequency
Fine Beam Single pol.	HH	34.3°	Ascending	Global	Dec-Feb	1-2 obs/year
Fine Beam Dual pol.	HH+HV	34.3°	Ascending	Global	May-Sept	1-4 obs/year
Fine Beam Polarimatric	HH+HV+VH+VV	21.5°	Ascending	Regional	March-May	2 obs/2 year
ScanSAR 5-beam short burst	HH	20.1°-36.5°	Descending	(a) Global (b) Regional	Jan-Dec	(a) 1 obs/year (b) 8 obs/1 year

Table 12. PALSAR observation strategy summary.

A detailed description of the PALSAR baseline acquisition strategy can be found at:
http://www.eorc.jaxa.jp/ALOS/obs/palsar_strat.htm

11 RECOMMENDATIONS FOR THE SELECTION OF PALSAR MODES/PRODUCTS

11.1 ALOS Systematic Observation Strategy

The general user guidelines for requesting ALOS PALSAR products are provided by JAXA at: http://www.eorc.jaxa.jp/ALOS/obs/palsar_guide.htm

11.2 Recommendation for the selection of PALSAR modes/products

FBS and FBD at 41.5 deg. off-nadir angle
During the PALSAR Commissioning Phase, it has been observed that FBS and FBD products at 41.5 degrees off-nadir angle are subject to range ambiguities. Therefore, JAXA has modified the baseline acquisition scenario, from 2nd October 2006, replacing FBS and FBD 41.5 deg. with FBS and FBD 34.3 deg.

It is therefore recommended to avoid the use of FBS and FBD 41.5 deg, (both for standing orders and for future planning).

WB2
WB2 mode, with 28 MHz chirp bandwidth has twice better resolution then WB1. It was however originally identified by JAXA as experimental mode and it is not part of the baseline acquisition scenario.

During the PALSAR Commissioning Phase it has been observed that small gaps between bursts in the first beam of WB2 appear for some PRF values, resulting in a stripe-like artefact on the first beam in the processed product. Since the improvement of the orbital tube on 7 August 2006, it is expected that the range of PRFs will be reduced and therefore the problem on WB2 minimised or corrected for any position around the orbit.

The comparison between the original and the updated baseline acquisition scenario is summarised in the following table:

Mode	Original baseline scenario	New baseline scenario (from 02-10-2006)
1	FBS + 21.5 + HH	FBS + 21.5 + HH
2	FBS + 34.4 + HH	FBS + 34.4 + HH
3	FBS + 41.5 + HH	FBS + 34.3 + HH
4	FBD + 41.5 + HH+HV	FBD + 34.3 + HH+HV
5	POL + 21.5 + HH+HV+VH+VV	POL + 21.5 + HH+HV+VH+VV
6	SCANSAR 5 beams short bursts, 350 km of swath (120 Mbps)	SCANSAR 5 beams short bursts, 350 km of swath (120 Mbps)

Table 13. Comparison between original and new PALSAR baseline acquisition scenario.

For any other information, please contact ESA HelpDesk at: EOHeLP@esa.int

APPENDIX A PALSAR ANTENNA PATTERN FILE FORMAT

Antenna pattern format description has been defined by JAXA (Masanobu Shimada) as follows:

Type: text file.

bn :beam number : 0
nn :number of the samples : 81
off-0 :off nadir angle at the firt bin of the data : 5.90
dth :off nadir anguler increment : 0.1
Ghh, Ghv, Gvh, Gvv: antenna peak gain for four polarizations, 33.80, 33.76, 33.45,33.41
Ona, angle, ghh, ghv, gvh, gvv: 5.90,41.70, -4.74, -4.79, -4.67, -4.72
here, ona:off nadir angle, angle is the angular value measured from the peak direction of the PALSAR antenna (this information is less valuable), ghh, ghv, gvh, gvv are the relative antenna pattern gains, normalized by the peak values.

bn ranges from 0 to 22, first 0-17 covers the strip mode antenna pattern, and the last five (18-22) corresponds to the patterns of the ScanSAR mode.

The actual antenna pattern file can be accessed at:
WEB LINK