

# ASAR IMG AND APG PRODUCTS: IMAGE QUALITY AND RADIOMETRIC PERFORMANCE

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## ABSTRACT

In this paper are reported the results of the analyses concerning the image quality and the radiometric performances of a data set of ASAR Image Mode Geocoded products (IMG) and Alternating Polarization Geocoded (APG) products.

Some preliminary analyses have been carried out: a Visual Inspection [1], which provides a quick overview of the expected product quality and possible main anomalies of the image, and a Format Verification [1], because a verification of the correct product format is important to ensure complete product compatibility with all the tools developed and available for the product analysis. Both the Visual Inspection and the Format Verification analyses have been performed with IDL (the Interactive Data Language, of the Research Systems Inc., a software for data analysis, visualization, and cross-platform application development) and EnviView (a free ESA application, that allows Envisat data users to open any Envisat data file, and examine its content) over each product.

The image quality has been inferred by measuring the Impulse Response Function (IRF analysis) of each product: this analysis take into account a measurement of the the resolution, both in range and azimuth direction, a measurement of the Peak Side Lobe Ratio (PSLR) and a measurement of the Integrated Side Lobe Ratio (ISLR) of the Impulse Response Function of the ASAR transponders. Furthermore, an evaluation of the Absolute Calibration Factor (ACF) for each transponder have been made.

The Radiometric Resolution of each product has been evaluated by computing the Equivalent Number of Look (ENL) over homogeneous regions contained in the image.

## 1 DATA SET OVERVIEW

In Tab.1 is reported the list of products analysed. All the products are geocoded and they are Image Mode products (IM) or Alternating Polarization products (AP). A short name is associated to each product in the following manner: IMG\_#orbit or APG\_#orbit, where #orbit is the number of the orbit.

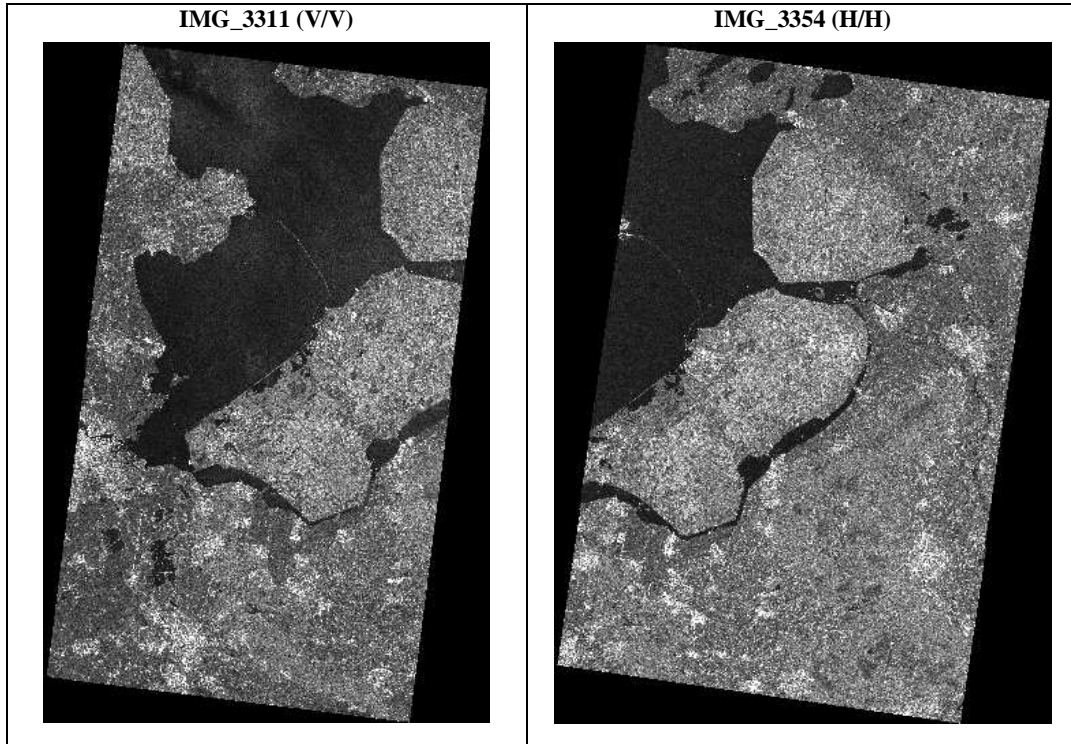
Tab.1. Data set.

Mode	Product Name	Short Name
IM	ASA_IMG_1PXPDE20021018_094453_000000152010_00251_03311_0004.N1	IMG_3311
	ASA_IMG_1PXPDE20021021_095036_000000152010_00294_03354_0000.N1	IMG_3354
	ASA_IMG_1PXPDE20021024_095623_000000152010_00337_03397_0006.N1	IMG_3397
	ASA_IMG_1PXPDE20021027_212507_000000152010_00387_03447_0008.N1	IMG_3447
	ASA_IMG_1PXPDE20021030_213049_000000142010_00430_03490_0007.N1	IMG_3490
	ASA_IMG_1PXPDE20021103_210513_000000152010_00487_03547_0001.N1	IMG_3547
AP	ASA_APG_1PXPDE20021106_094750_000000142011_00022_03583_0004.N1	APG_3583
	ASA_APG_1PXPDE20021106_211048_000000152011_00029_03590_0005.N1	APG_3590
	ASA_APG_1PXPDE20021109_211632_000000152011_00072_03633_0002.N1	APG_3633
	ASA_APG_1PXPDE20021112_095910_000000152011_00108_03669_0000.N1	APG_3669
	ASA_APG_1PXPDE20021122_094458_000000152011_00251_03812_0006.N1	APG_3812

We carried out all the analyses over each product. In particular, it has been possible to perform the IRF/ACF analysis over all the products because all of them contain transponders.

In Fig.1-2-3-4-5-6-7-8 are shown the quick looks of the analysed data set of products.

**Fig. 1. Quick look of IMG\_3311 and IMG\_3354.**



**Fig. 2. Quick look of IMG\_3397 and IMG\_3447.**

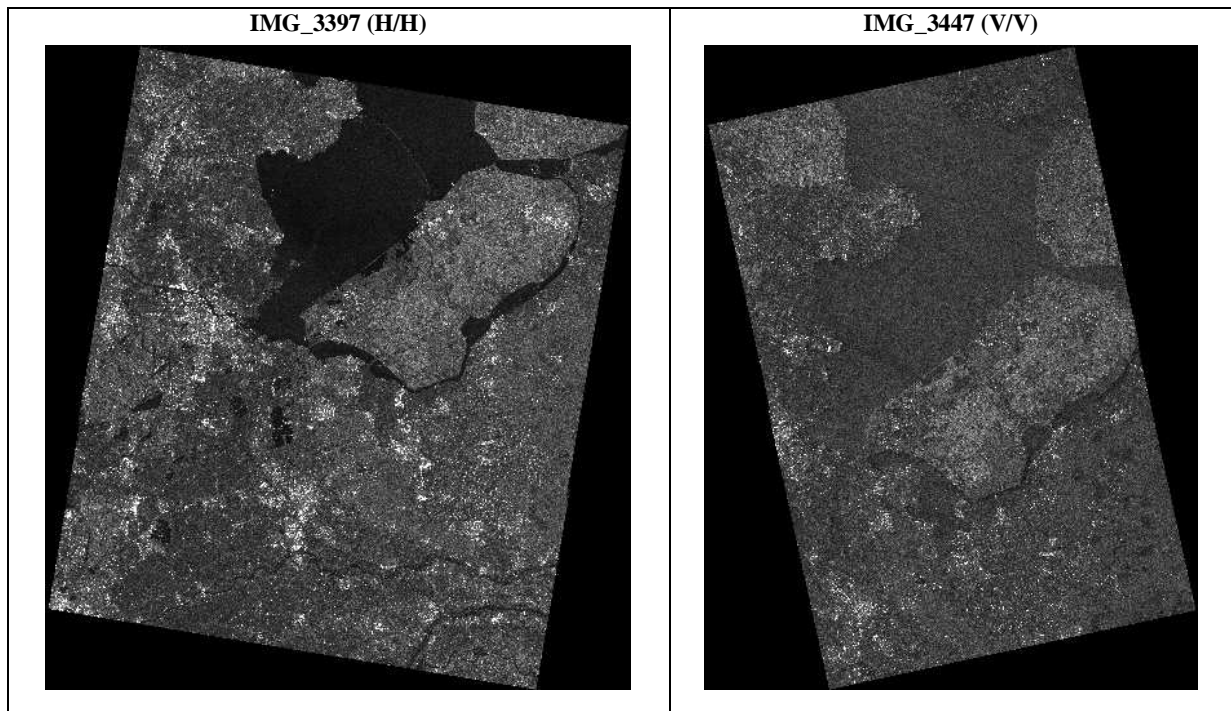


Fig. 3. Quick look of IMG\_3490 and IMG\_3547.

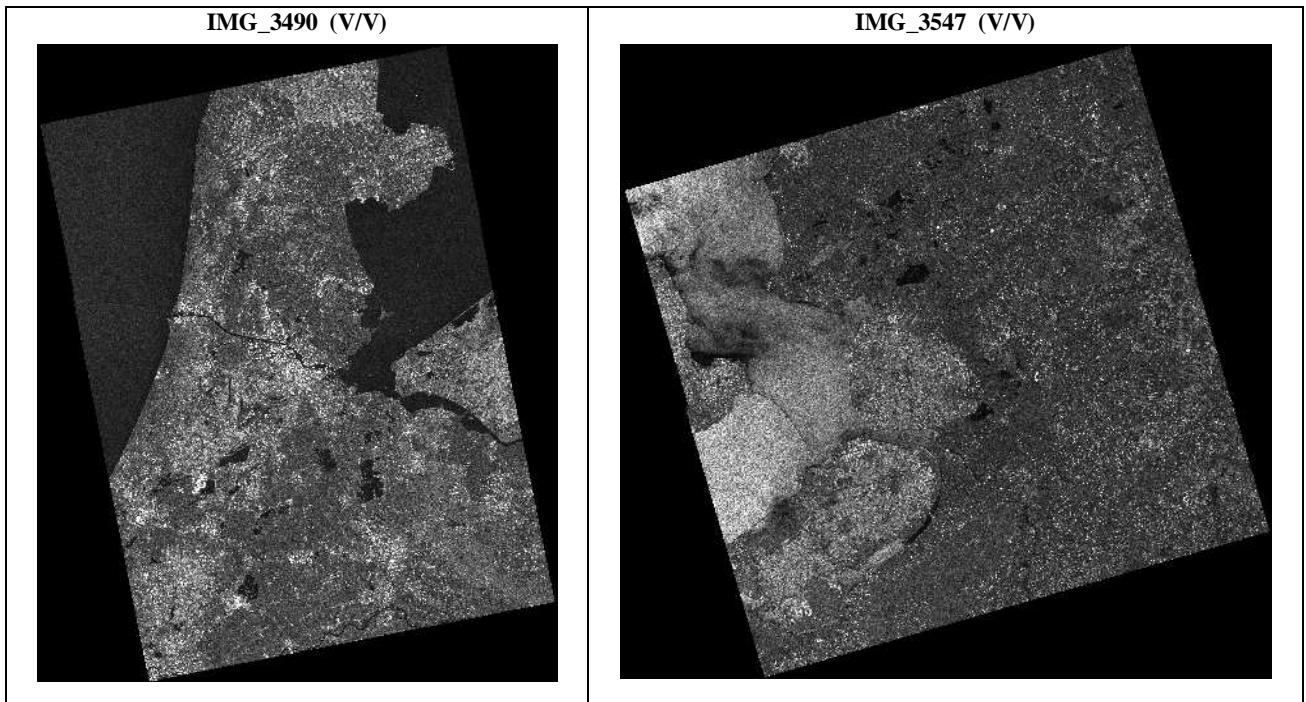


Fig. 4. Quick look of APG\_3583.

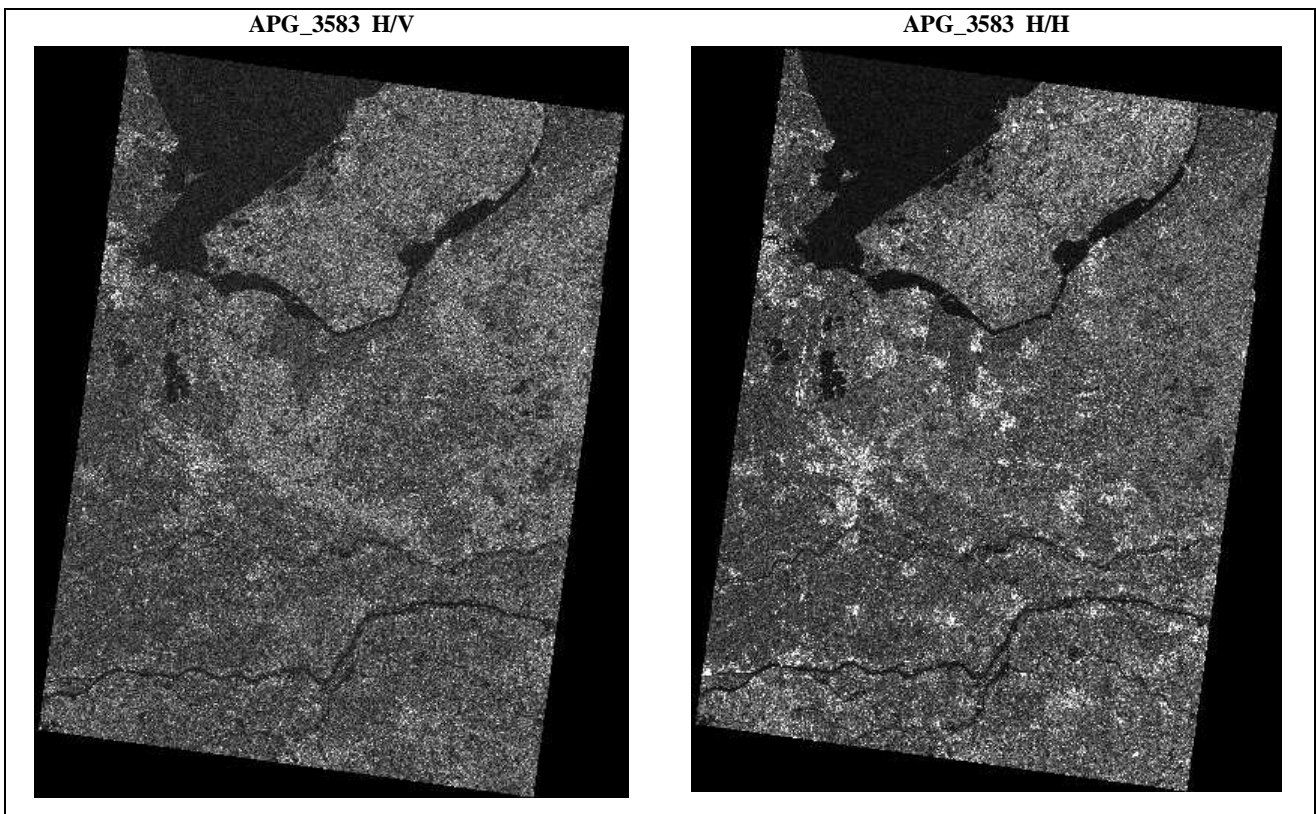


Fig. 5. Quick look of APG\_3590.

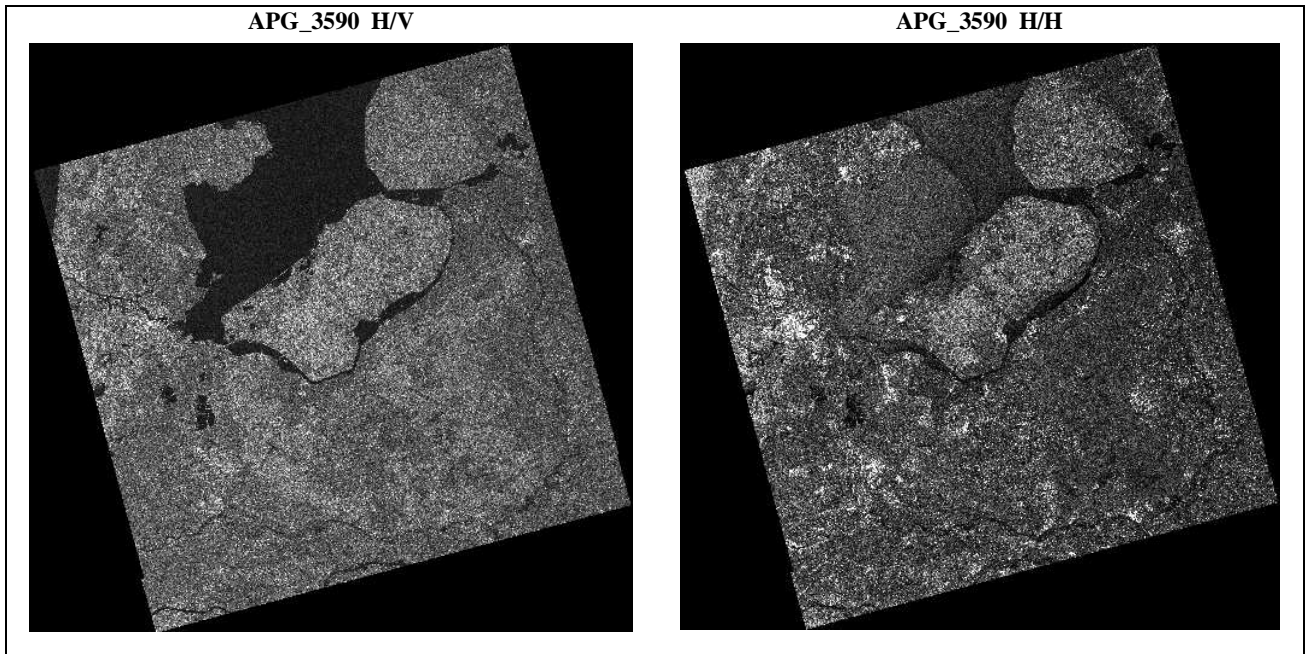
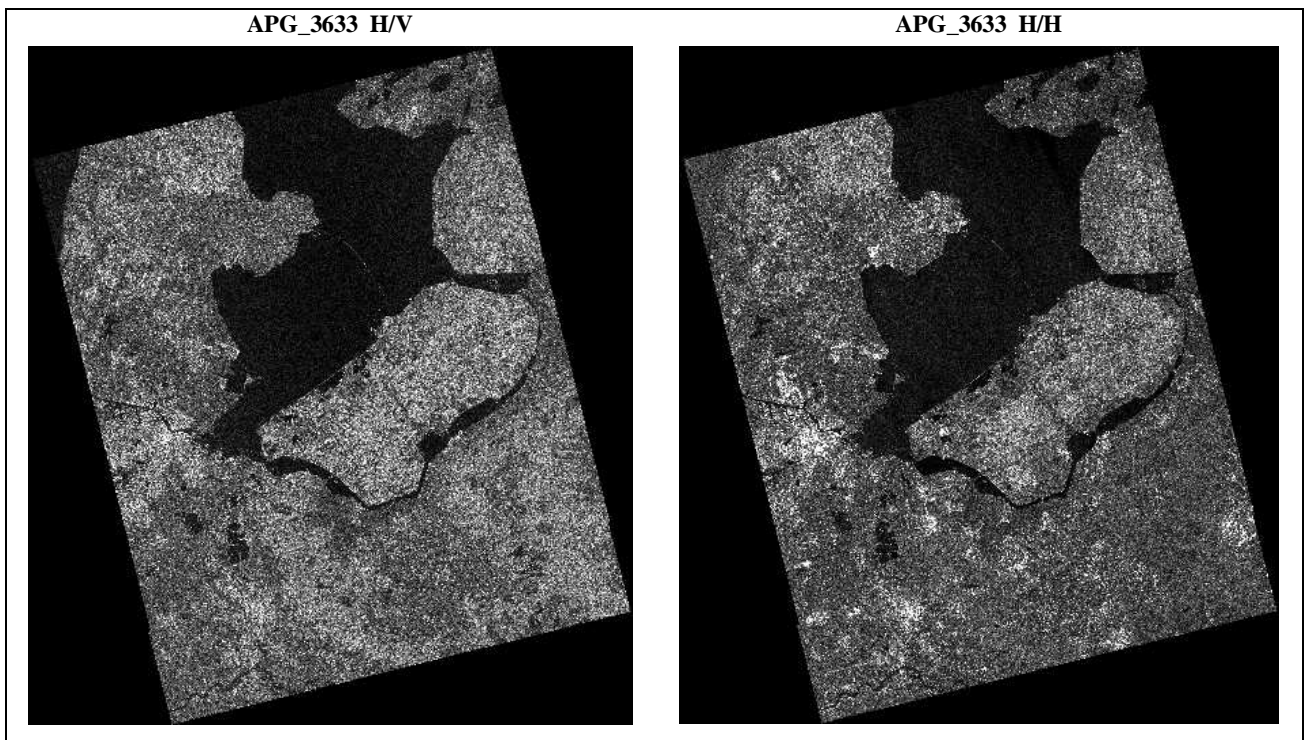
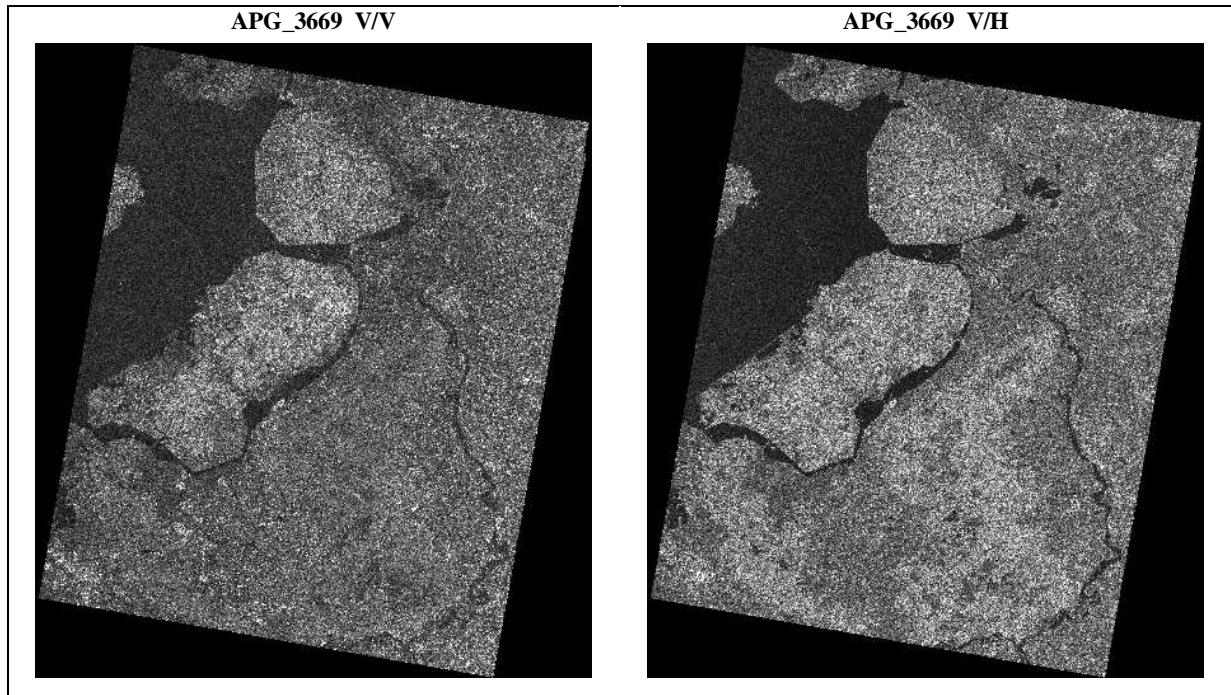


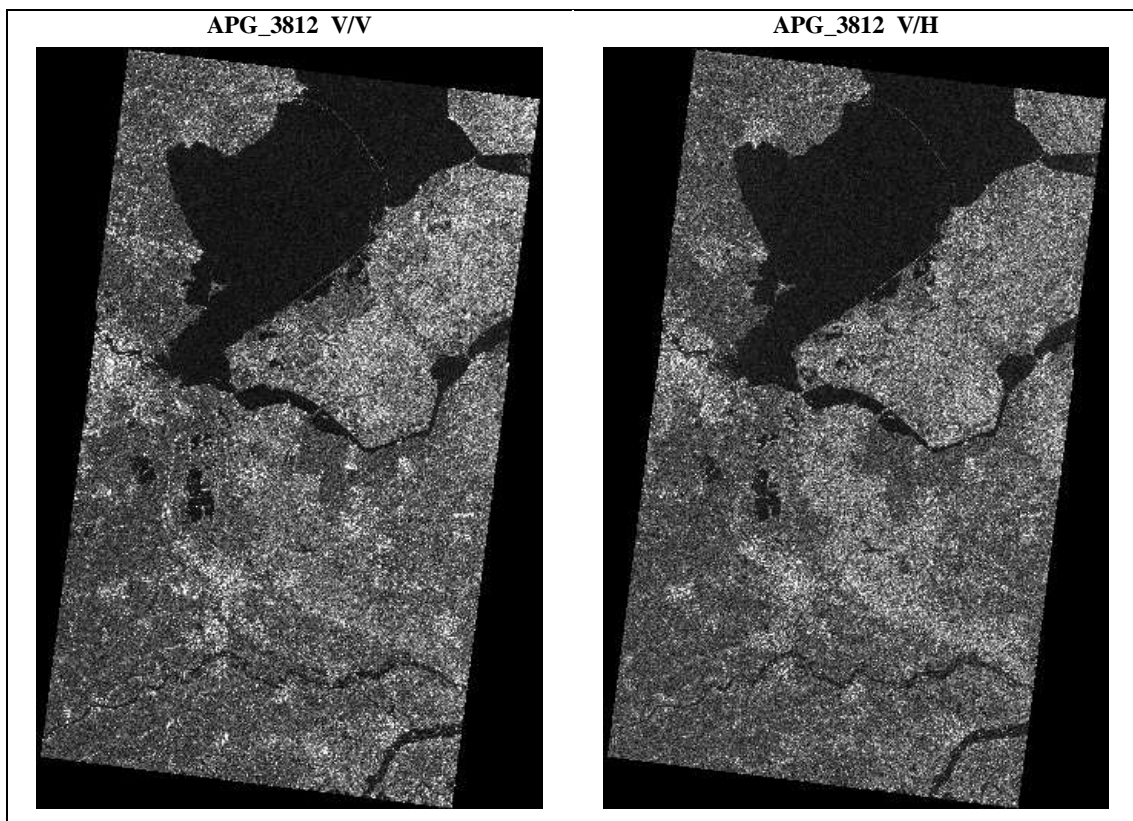
Fig. 6. Quick look of APG\_3633.



**Fig. 7. Quick look of APG\_3669.**



**Fig. 8. Quick look of APG\_3812.**



## 2 FORMAT VERIFICATION

As we have already mentioned, a verification of the correct product format is important to ensure complete product compatibility with all the tools developed and available for the products analysis.

The format verification has been carried out by reading the products, both with EnviView and with special routines developed in IDL, and by checking all the records of each product: Headers (MPH, SPH), Measurement Data Sets (MDS1/2), Annotation Data Sets (SQ-ADSRs, Main Processing parameters, Doppler Centroid parameters, Slant Range to Ground Range conversion parameters, Chirp parameters, Antenna Elevation Pattern 1/2, Geolocation Grid ADSRs) and Map Projection parameters.

It results that in IMG\_3311, IMG\_3397, IMG\_3490, IMG\_3547, APG\_3583, APG\_3590, APG\_3669 and APG\_3812 the chirp parameters are missing. This is due to specific needs during the processing of them but it is not really a problem, in general, because it is restricted only to these products and it will not affect any other one.

**Tab. 2. Summary of the Format Verification**

Product	Success	Comment
IMG_3311	No	Chirp Parameters are missing
IMG_3354	Yes	-
IMG_3397	No	Chirp Parameters are missing
IMG_3447	Yes	-
IMG_3490	No	Chirp Parameters are missing
IMG_3547	No	Chirp Parameters are missing
APG_3583	No	Chirp Parameters are missing
APG_3590	No	Chirp Parameters are missing
APG_3633	Yes	-
APG_3669	No	Chirp Parameters are missing
APG_3812	No	Chirp Parameters are missing

## 3 IMPULSE RESPONSE FUNCTION ANALYSIS (IRF) AND ABSOLUTE CALIBRATION FACTOR EVALUATION (ACF)

A basic product quality assessment is obtained [1] through the Impulse Response Function (IRF) analysis over the transponders. The result of this analysis is the validation of the basic product quality parameters or the identification of quality anomalies to be investigated. It is foreseen to perform this analysis using transponders and corner reflectors deployed in different areas around the world. Our data set contains products with the ASAR transponders deployed in The Netherlands.

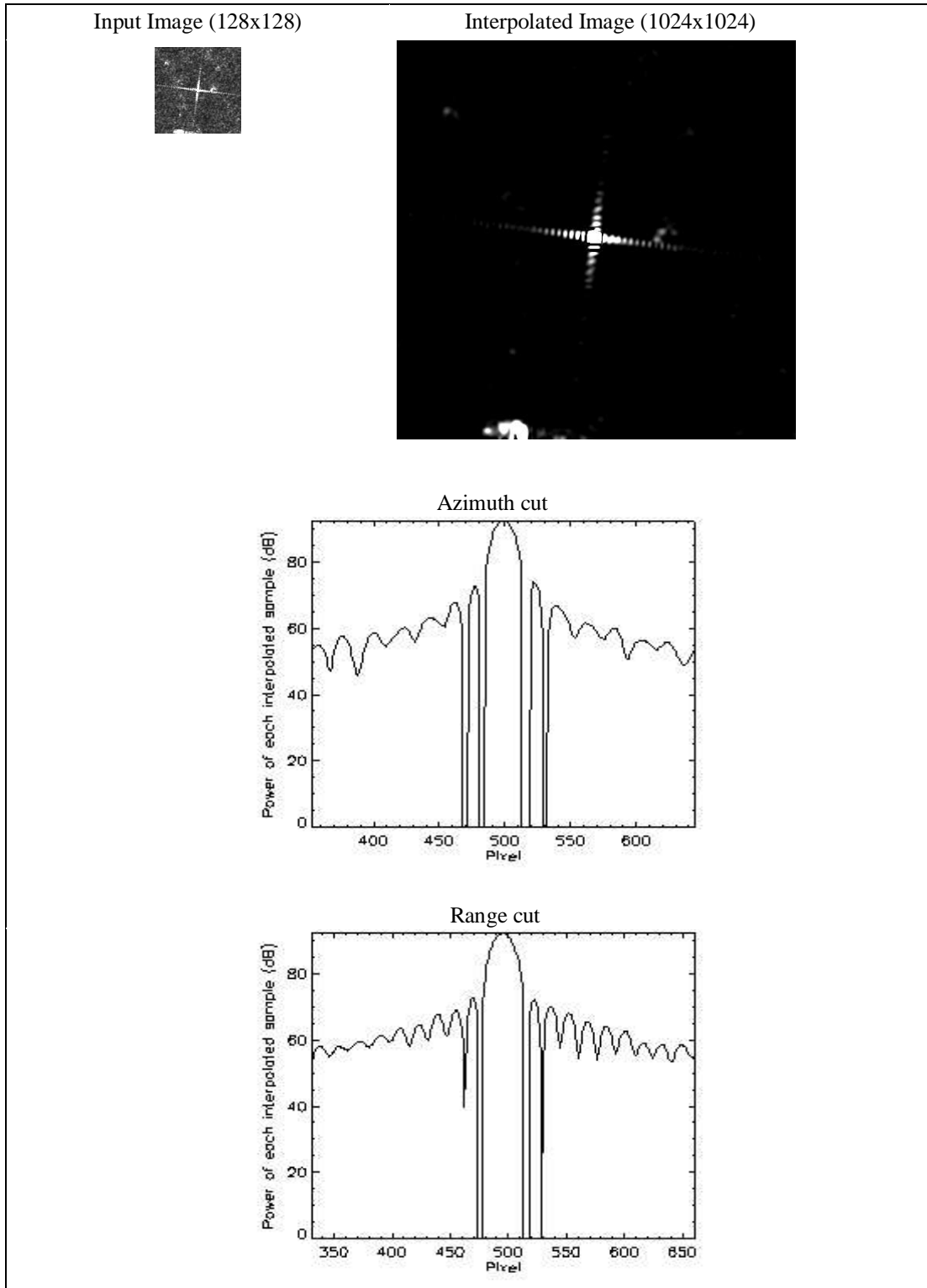
In a complete IRF analysis it is foreseen to perform the following measurements (on the interpolated and background corrected image) [2]: spatial resolution in range and azimuth, peak side lobe ratio (PSLR), spurious side lobe ratio (SSLR), integrated side lobe ratio (ISLR) and ratio of total power to peak height. For this analysis it is foreseen to perform the computation of:

- the spatial resolution, both in range and in azimuth direction, which is defined as the width, in metres, of the IRF where the intensity reaches the 50% of the peak value (i.e. -3dB width)
- the PSLR which is defined as the ratio of the intensity of the most intense peak of the IRF outside a rectangle of 2x2 resolution lengths and within a rectangle of 10x10 resolution lengths to the peak intensity in the mainlobe (i.e. within a rectangle of 2x2 resolution lengths). The PSLR in azimuth/range is defined as the maximum PSLR, in dB, along the azimuth/range IRF cut. The PSLR is the maximum between azimuth PSLR and range PSLR.
- the ISLR which is defined as the ratio, in dB, of the energy in the sidelobes (outside a rectangle of 2x2 resolution lengths and within a rectangle of 20x20 resolution lengths) to the energy in the mainlobe.

This analysis has been carried out by special routines developed in IDL and the results are compared with the requirements and the theoretical predictions.

Fig. 9 shows, as an example, the portion 128x128 pixel (Input Image) of the IMG\_3311 product centred on the Edam transponder, considered to perform the IRF analysis, the corresponding Interpolated (by a factor of 8) Image and the profiles along the range and the azimuth directions. Considering the range/azimuth profile, the width of the main peak at -3dB of the peak value is the range/azimuth resolution.

**Fig. 9. Example of IRF for the Edam transponder in IMG\_3311.**



In Tab. 3-4-5-6-7-8-9-10-11-12-13 are summarized the results of the IRF/ACF analyses.

**Tab. 3. IRF/ACF analysis results over IMG\_3311**

IMG_3311 IS7 – V/V	Transponder				Theor. Limit	Req.
	Edam	Swifterbant	Aalsmeer	Zwolle		
Position (col, row)	(1304.25,3641.13)	(4655.25,3261.00)	Out of image	Out of image		
Range Resolution [m]	26.46	27.50	-	-	< 29.28 near < 27.87 far	< 30
Azimuth Resolution [m]	21.69	20.46	-	-	< 22.64	< 30
ISLR [dB]	-14.42	-13.00	-	-	< -7.4	< -12
PSLR [dB]	-19.24	-21.02	-	-	< -16.2	< -20
ACF [dB]	55.43	55.51	-	-	-	-

**Tab. 4. IRF/ACF analysis results over IMG\_3354**

IMG_3354 IS5 – H/H	Transponder				Theor. Limit	Req.
	Edam	Swifterbant	Aalsmeer	Zwolle		
Position (col, row)	Out of image	(2964.88,3598.75)	Out of image	(4793.75,3555.00)		
Range Resolution [m]	-	25.62	-	26.77	< 29.16 near < 26.92 far	< 30
Azimuth Resolution [m]	-	22.90	-	21.63	< 22.34	< 30
ISLR [dB]	-	-14.18	-	-11.92	< -7.4	< -12
PSLR [dB]	-	-18.34	-	-19.57	< -16.2	< -20
ACF [dB]	-	55.49	-	55.43	-	-

**Tab. 5. IRF/ACF analysis results over IMG\_3397**

IMG_3397 IS4 – H/H	Transponder				Theor. Limit	Req.
	Edam	Swifterbant	Aalsmeer	Zwolle		
Position (col, row)	(3142.63,2514.88)	(6492.50,2133.88)	(1962.38,5437.88)	Out of image		
Range Resolution [m]	25.79	27.18	25.55	-	< 29.45 near < 25.52 far	< 30
Azimuth Resolution [m]	22.22	22.10	22.81	-	< 22.35	< 30
ISLR [dB]	-12.05	-12.46	-14.03	-	< -7.4	< -12
PSLR [dB]	-19.00	-18.83	-18.64	-	< -16.2	< -20
ACF [dB]	55.16	55.30	54.83	-	-	-

**Tab. 6. IRF/ACF analysis results over IMG\_3447**

IMG_3447 IS5 – V/V	Transponder				Theor. Limit	Req.
	Edam	Swifterbant	Aalsmeer	Zwolle		
Position (col, row)	(1747.00,3993.38)	(5098.13,3613.00)	Out of image	Out of image		
Range Resolution [m]	26.48	24.93	-	-	< 29.16 near < 26.92 far	< 30
Azimuth Resolution [m]	23.42	20.84	-	-	< 22.34	< 30
ISLR [dB]	-14.77	-12.48	-	-	< -7.4	< -12
PSLR [dB]	-18.44	-20.09	-	-	< -16.2	< -20
ACF [dB]	55.80	55.29	-	-	-	-

**Tab. 7. IRF/ACF analysis results over IMG\_3490**

IMG_3490 IS6 – V/V	Transponder				Theor. Limit	Req.
	Edam	Swifterbant	Aalsmeer	Zwolle		
Position (col, row)	(4488.13,3164.38)	Out of image	(4655.25,3261.00)	Out of image		
Range Resolution [m]	25.83	-	26.59	-	< 29.27 near < 27.05 far	< 30
Azimuth Resolution [m]	23.77	-	22.46	-	< 22.32	< 30
ISLR [dB]	-14.48	-	-13.34	-	< -7.4	< -12
PSLR [dB]	-18.06	-	-18.42	-	< -16.2	< -20
ACF [dB]	56.04	-	55.65	-	-	-

**Tab. 8. IRF/ACF analysis results over IMG\_3547**

IMG_3547 IS1 – V/V	Transponder				Theor. Limit	Req.
	Edam	Swifterbant	Aalsmeer	Zwolle		
Position (col, row)	Out of image	(4226,6736)	Out of image	(6048.63,6693.38)		
Range Resolution [m]	-	33.10	-	30.15	< 39.96 near < 26.84 far	< 30
Azimuth Resolution [m]	-	23.88	-	23.93	< 22.40	< 30
ISLR [dB]	-	-11.56	-	-12.92	< -7.4	< -12
PSLR [dB]	-	-18.50	-	-18.85	< -16.2	< -20
ACF [dB]	-	55.52	-	55.27	-	-

Reading the following tables remember that in the AP products each transponder is visible only in one of the two polarizations.

**Tab. 9. IRF/ACF analysis results over APG\_3583**

APG_3583 IS6	Transponder								Theor. Limit	Req.
	Edam		Swifterbant		Aalsmeer		Zwolle			
Polarization	H/V	H/H	H/V	H/H	H/V	H/H	H/V	H/H		
Position (col, row)	-	(1419.00, 898.25)	-	(4769.88, 517.88)	Out	Out	Out	Out		
Range Resolution [m]	-	25.36	-	26.87	-	-	-	-	< 29.52 near < 27.28 far	< 30
Azimuth Resolution [m]	-	28.75	-	27.57	-	-	-	-	< 30.00	< 30
ISLR [dB]	-	-13.10	-	-13.01	-	-	-	-	< -7.4	< -12
PSLR [dB]	-	-18.36	-	-18.55	-	-	-	-	< -16.2	< -20
ACF [dB]	-	60.51	-	60.57	-	-	-	-	-	-

**Tab. 10. IRF/ACF analysis results over APG\_3590**

APG_3590 IS2	Transponder								Theor. Limit	Req.
	Edam		Swifterbant		Aalsmeer		Zwolle			
Polarization	H/V	H/H	H/V	H/H	H/V	H/H	H/V	H/H		
Position (col, row)	-	(2873.25, 3373.00)	(6221.00, 2993.50)	-	(1697.25, 6294.38)	-	(7996.88, 2968.50)	(7996.25, 2967.13)		
Range Resolution [m]	-	27.40	24.24	-	29.83	-	25.15	23.73	< 31.10 near < 23.24 far	< 30
Azimuth Resolution [m]	-	27.86	28.53	-	27.29	-	41.76	28.95	< 29.83	< 30
ISLR [dB]	-	-12.06	-12.68	-	-12.03	-	-2.07	-4.26	< -7.4	< -12
PSLR [dB]	-	-19.74	-18.65	-	-18.62	-	-15.00	-11.64	< -16.2	< -20
ACF [dB]	-	57.25	57.18	-	57.14	-	31.67	40.95	-	-

**Tab. 11. IRF/ACF analysis results over APG\_3633**

APG_3633 IS3	Transponder								Theor. Limit	Req.
	Edam		Swifterbant		Aalsmeer		Zwolle			
Polarization	H/V	H/H	H/V	H/H	H/V	H/H	H/V	H/H		
Position (col, row)	off	off	-	(6142.38, 3718.25)	(1613.88, 7018.63)	-	Out	Out		
Range Resolution [m]	-	-	-	25.10	27.67	-	-	-	< 29.84 near < 25.05 far	< 30
Azimuth Resolution [m]	-	-	-	29.39	27.81	-	-	-	< 30.21	< 30
ISLR [dB]	-	-	-	-11.58	-12.64	-	-	-	< -7.4	< -12
PSLR [dB]	-	-	-	-18.91	-21.01	-	-	-	< -16.2	< -20
ACF [dB]	-	-	-	58.20	57.81	-	-	-	-	-

**Tab. 12. IRF/ACF analysis results over APG\_3669**

APG_3669 IS3	Transponder								Theor. Limit	Req.
	Edam		Swifterbant		Aalsmeer		Zwolle			
Polarization	V/V	V/H	V/V	V/H	V/V	V/H	V/V	V/H		
Position (col, row)	Out	Out	-	(3569.88, 3398.63)	Out	Out	(5433.38, 3368.25)	(5431.75, 3365.00)		
Range Resolution [m]	-	-	-	24.83	-	-	27.84	27.10	< 29.84 near < 25.05 far	< 30
Azimuth Resolution [m]	-	-	-	27.74	-	-	31.05	33.44	< 30.21	< 30
ISLR [dB]	-	-	-	-13.50	-	-	-0.69	7.47	< -7.4	< -12
PSLR [dB]	-	-	-	-19.17	-	-	-12.34	-3.36	< -16.2	< -20
ACF [dB]	-	-	-	57.46	-	-	38.61	30.23	-	-

**Tab. 13. IRF/ACF analysis results over APG\_3812**

APG_3812 IS7	Transponder								Theor. Limit	Req.
	Edam		Swifterbant		Aalsmeer		Zwolle			
Polarization	V/V	V/H	V/V	V/H	V/V	V/H	V/V	V/H		
Position (col, row)	-	(1603.25, 2084.50)	-	(4954.38, 1703.75)	(423.38, 5006.38)	-	Out	Out		
Range Resolution [m]	-	38.47	-	39.93	35.19	-	-	-	< 29.57 near < 28.14 far	< 30
Azimuth Resolution [m]	-	36.48	-	34.70	37.21	-	-	-	< 30.32	< 30
ISLR [dB]	-	-13.18	-	-13.04	-13.14	-	-	-	< -7.4	< -12
PSLR [dB]	-	-16.84	-	-18.44	-15.44	-	-	-	< -16.2	< -20
ACF [dB]	-	64.17	-	64.28	64.56	-	-	-	-	-

In Tab. 14 are summarized all the results of the IRF analysis.

**Tab. 14. Summary of the IRF results**

TA – IRF		Edam	Zwolle	Swifterbant	Aalsmeer
IMG_3311	V/V	OK	Out	OK	Out
IMG_3354	H/H	Out	OK	Req	Out
IMG_3397	H/H	OK	Out	OK	Req
IMG_3447	V/V	Req	Out	OK	Out
IMG_3490	V/V	Req	Out	Out	Req
IMG_3547	V/V	Out	Req	Req	Out
APG_3583	H/V	-	Out	-	Out
	H/H	OK		OK	
APG_3590	H/V	-	(*)	OK	OK
	H/H	OK		-	-
APG_3633	H/V	off	Out	-	OK
	H/H			OK	-
APG_3669	V/V	Out	(*)	-	Out
	V/H			OK	
APG_3812	V/V	-	Out	-	No
	V/H	No		No	-

- OK: all the parameters are within the requirements and within the theoretical limits  
 Out: transponder out of image  
 off: transponder turned off during the acquisition  
 Req: the azimuth resolution is within the requirements but out of the theoretical limits  
 No: the range and azimuth resolutions are out the theoretical limits and out of the requirements  
 (\*): the IRF is bad in both the polarizations and not good for measurements

#### 4 RADIOMETRIC RESOLUTION ANALYSIS

Radiometric products characterization and comparison [1] with expected performance are necessary to assess the basic product quality.

Using an IDL routine specially developed for this purpose, we compute the Equivalent Number of Looks as [2]:

$$ENL = \frac{\mu^2}{\sigma^2} \quad (1)$$

where  $\mu$  is the mean and  $\sigma$  the standard deviation of the signal power in the region.

The IDL routine computes the ENL of a user-selected polygonal image area. The obtained values are compared with the theoretical predictions and with the requirements.

For each product the ENL measurements have been computed over homogeneous regions and repeated 12 times neglecting the minimum and maximum values.

**Tab. 15. Results of the ENL measurements over IMG products.**

Product	ENL			Theor. Limit	Req.
	Average	Standard Deviation			
IMG_3311	3.53	0.11	3 %	> 3.51	> 1.65
IMG_3354	3.767	0.035	1 %		
IMG_3397	3.656	0.067	2 %		
IMG_3447	3.60	0.13	4 %		
IMG_3490	3.631	0.073	2 %		
IMG_3547	3.65	0.10	3 %		

**Tab. 16. Results of the ENL measurements over APG products.**

Product		ENL			Theor. Limit	Req.
		Average	Standard Deviation			
APG_3583	H/V	1.890	0.019	1 %	> 1.71	> 0.65
	H/H	1.818	0.030	2 %		
APG_3590	H/V	1.868	0.019	1 %		
	H/H	1.740	0.051	3 %		
APG_3633	H/V	1.878	0.026	1 %		
	H/H	1.804	0.064	4 %		
APG_3669	V/V	1.767	0.036	2 %		
	V/H	1.885	0.030	2 %		
APG_3812	V/V	1.762	0.038	2 %		
	V/H	1.883	0.028	1 %		

**5 CONCLUSIONS**

The results of the image quality and radiometric performance analysis of our data set of IMG and APG product are summarized in Tab. 17.

**Tab. 17. Summary of all the results**

Product	FV - FORMVERI	TA – ACF	RA - RADRES
IMG_3311	chirp parameters are missing	OK	OK
IMG_3354	OK	Az Res out of theoretical limits but within the requirements	OK
IMG_3397	chirp parameters are missing		OK
IMG_3447	OK		OK
IMG_3490	chirp parameters are missing		OK
IMG_3547	chirp parameters are missing		OK
APG_3583	chirp parameters are missing		OK
APG_3590	chirp parameters are missing	3 transp. OK, 1 bad transp. in both the polarizations	OK
APG_3633	OK	OK	OK
APG_3669	chirp parameters are missing	1 transp. OK, 1 bad transp. in both the polarizations	OK
APG_3812	chirp parameters are missing	Rg/Az Res out of the theor. limits and out of the requirements	OK

For what concerns the format verification it results that in IMG\_3311, IMG\_3397, IMG\_3490, IMG\_3547, APG\_3583, APG\_3590, APG\_3669 and APG\_3812 the chirp parameters are missing. This is due to specific needs during the processing of them but it is not really a problem, in general, because it is restricted only to these products and it will not affect any other one.

About the IRF analyses, in IMG\_3354, IMG\_3397, IMG\_3447, IMG\_3490, IMG\_3547 although the azimuth resolution for some transponders is out of the theoretical limits it is always within the requirements. In APG\_3590 and APG\_3669 there is one of the transponders (Zwolle) which has a weak, but not so much, response in both the polarizations and in any case not good enough to be considered as a transponder's response. Further, in the case of APG\_3812 all the transponders have the range and the azimuth resolution both out the theoretical limits and out of the requirements. Finally, the ENL, linked to the radiometric resolution, is within the limits for all the products analysed.

## 6 REFERENCES

- [1] ASAR CAL/VAL Team, *ENVISAT ASAR Calibration / Validation Plan*, PO-TN-ESA-GS-1206, issue 1/revision 1, 56-60, 12-Jul-2001
- [2] ASAR CAL/VAL Team, *Quality measurements definition for ASAR Level 1 products*, issue 1/revision 1, 3-6, 4-March-2002