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Radiometric calibration for airborne bistatic SAR

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Bistatic radiometric calibration alternatives

- direct computation from power amplifier gain, filter insertion losses, waveguide losses, propagation, antennae gains, digitiser's scale ... SAR synthesis algorithm “gain” (normalisation).
- bistatic transponder (itself calibrated in anechoic chamber).
- relative calibration of “near-monostatic” bistatic acquisition from calibrated monostatic image (typ. of isotropic clutter).
- direct calibration of bistatic acquisition from bistatic RCS modelling of model targets (top-hat, corner reflector, dihedral).

Bistatic radiometric calibration: relative to monostatic



Quiz

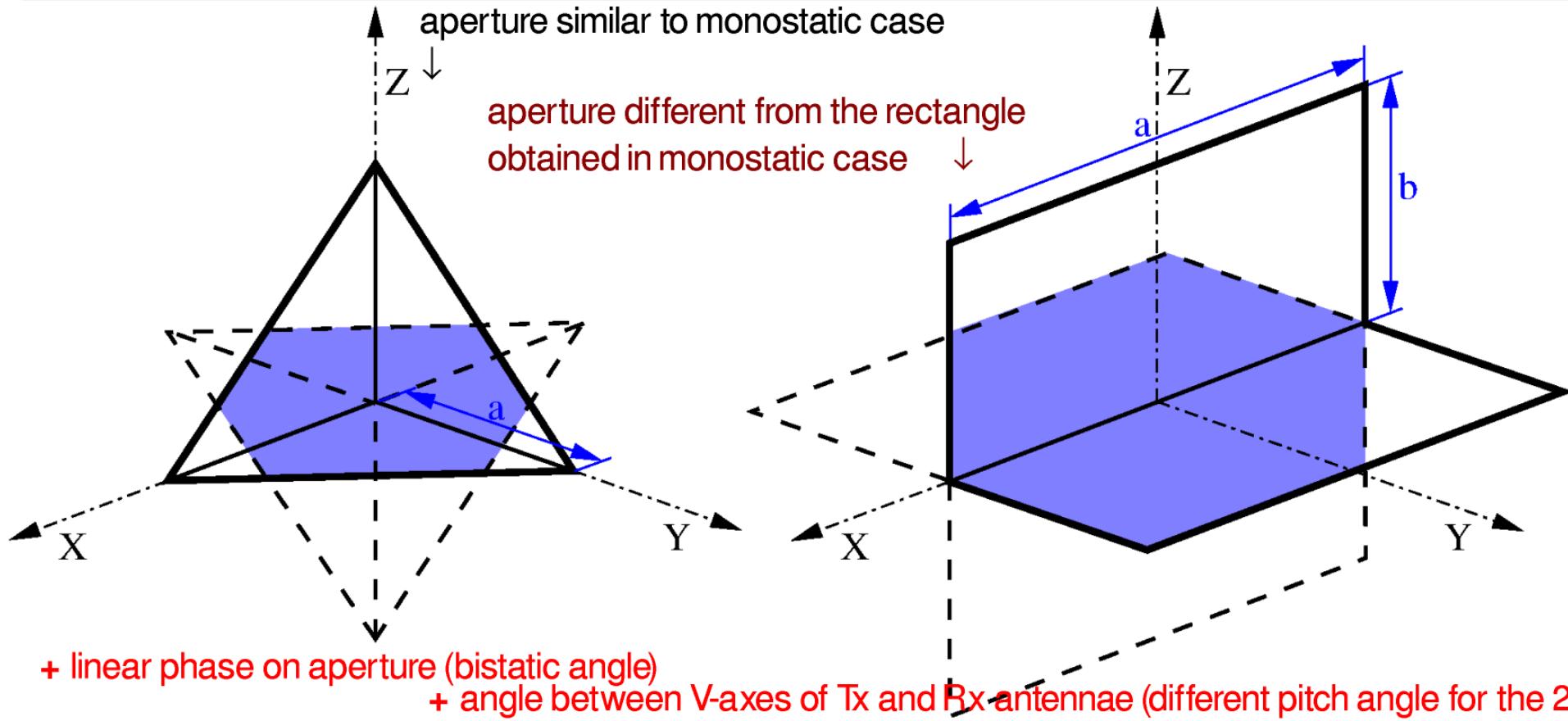
which is which?
monostatic
or
bistatic @ 5°

?

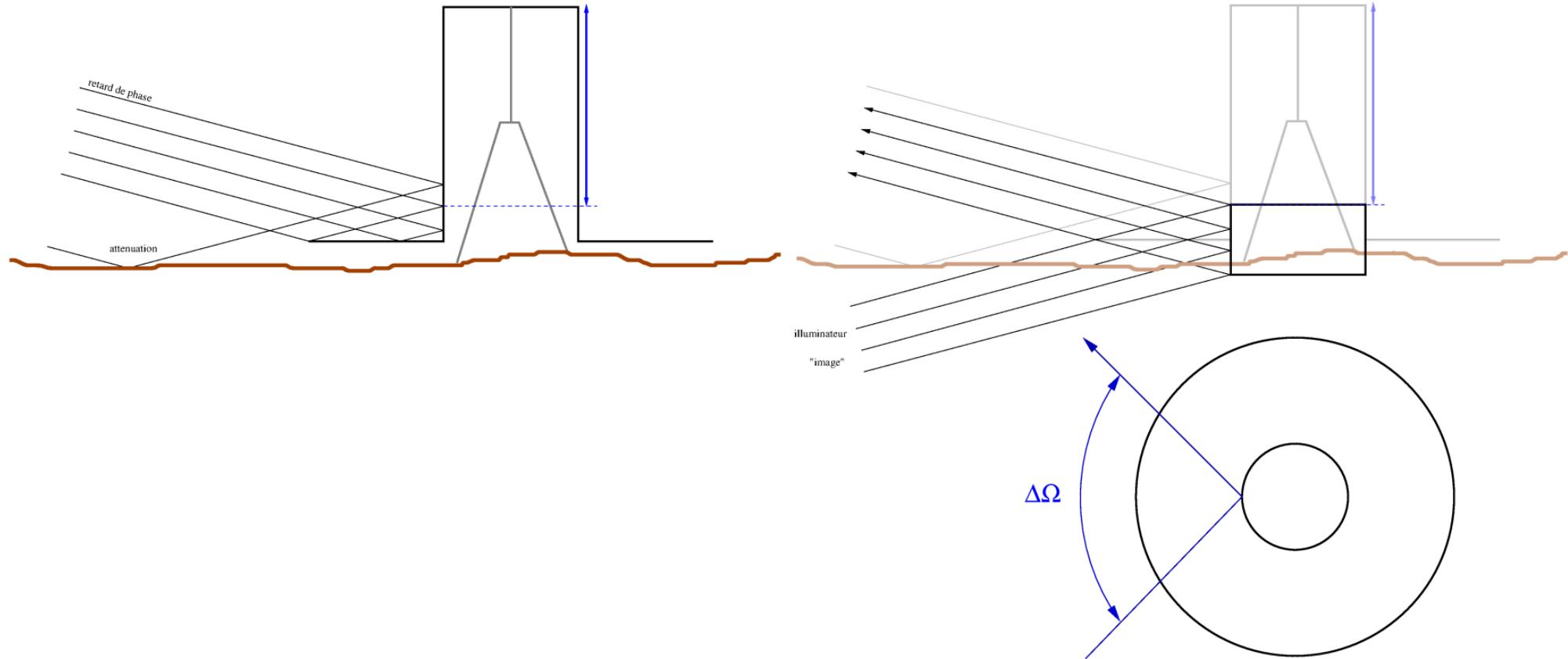


Hint: Rx only aircraft is 3 times closer to ROI, hence bistatic focus is closer to ROI than monostatic focus...

Bistatic G.O. RCS models for canonical targets



Bistatic G.O. RCS models for canonical targets



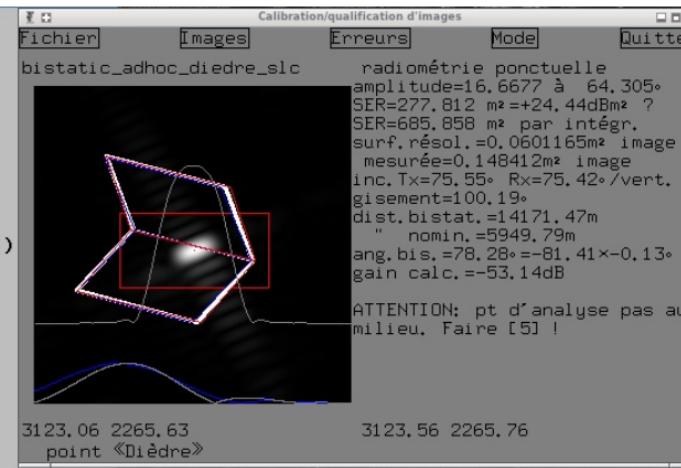
Bistatic G.O. RCS models for canonical targets

Orientation accuracy of the canonical target $\approx 1^\circ$ elevation (mason level acc. $\approx 0.5^\circ$) and $\approx 8^\circ$ heading (navy standard for magnetic compass).

Bistatic RCS highly sensitive to orientation. However relative Tx and Rx LOS known with extremely high accuracy (unit is μRd).

⇒ high RCS sensitivity allows to retrieve canonical target orientation.

```
#point étiqueté n° 1 (Dièdre) sur l'image bistatic_adhoc_diedre_slc
SER max pendant l'intégration: 2364.6 m2 (+33.7376 dBm2)
SER intégrale=586.77 m2 (+27.6847 dBm2)
réponse max I=-14.7932 Q=0
amplitude=14.7932 section efficace=218.838 m2=+23.4012 dBm2
phase=180 °
aberration azimut=+0 m (vers l'avant)
incertitude sur l'amplitude 100.289% (15.035 à 0.199092)
incertitude sur la section efficace 103.277% (226.05 à 0.0396378 m2)
soit 37.5609 dB (-14.0189 à +23.542 dBm2)
incertitude sur la phase 267.143 ° (-185.22 à 81.9231 °)
```



example of calibration with dithedral at 80° bistatism.

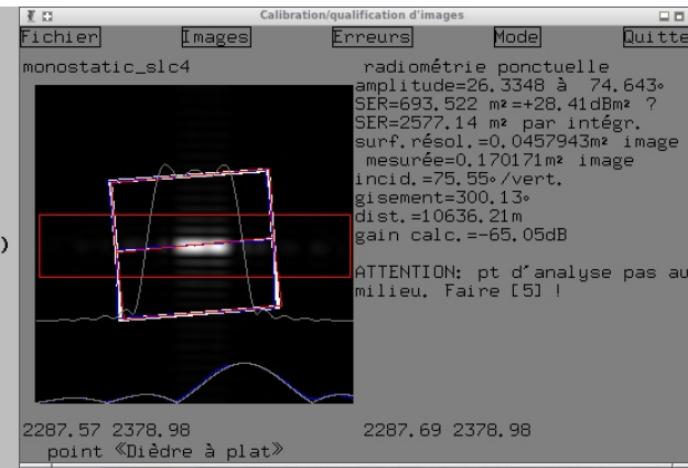
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⇒ high RCS sensitivity allows to retrieve canonical target orientation.

```
#point étiqueté n° 1 (Dièdre à plat) sur l'image monostatic_slc4
SER max pendant l'intégration: 10192.9 m2 (+40.083 dBm2)
SER intégrale=2061.03 m2 (+33.1408 dBm2)
réponse max I=-2.40459 Q=22.6943
amplitude=22.8213 section efficace=520.812 m2=+27.1668 dBm2
phase=96.0483 °
aberration azimut=+0.305744 m (vers l'avant)
incertitude sur l'amplitude 95.1999% (23.629 à 1.90315)
incertitude sur la section efficace 106.508% (558.33 à 3.62199 m2)
soit 21.8794 dB (+5.58948 à +27.4689 dBm2)
incertitude sur la phase 263.956 ° (-66.9802 à 196.976 °)
```



example of monostatic calibration with dithedral.

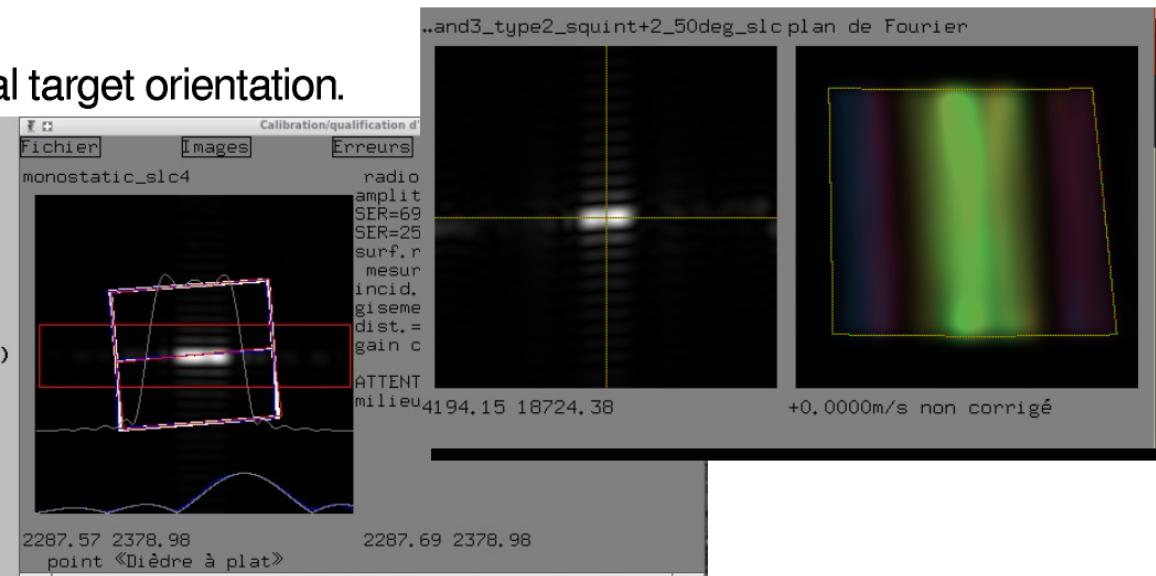
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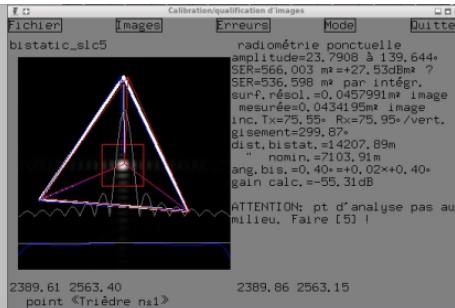


example of monostatic calibration with dithedral.

Bistatic G.O. RCS models for canonical targets

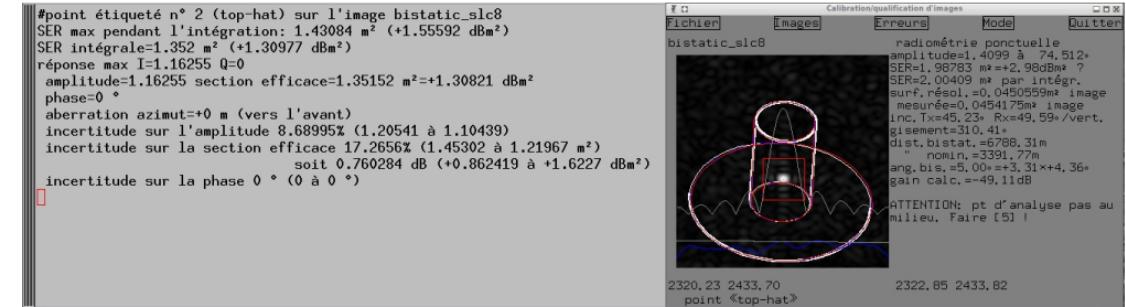
Dihedral prefered target (orientation recovery easier and top RCS). Corner reflector RCS collapses with even small bistatism, top-hat RCS is low, contaminated with clutter reflexion and sensitive to $\eta_T - \eta_R$.

```
#point étiqueté n° 0 (Trièdre n°1) sur l'image bistatic_slc5
SER max pendant l'intégration: 381.39 m² (+25.8137 dBm²)
SER intégrale=372.667 m² (+25.7132 dBm²)
réponse max I=19.3045 Q=0
amplitude=19.3045 section efficace=372.662 m²=+25.7132 dBm²
phase=0 °
aberration azimut=+0 m (vers l'avant)
incertitude sur l'amplitude 12.0415% (20.0079 à 17.6833)
incertitude sur la section efficace 23.5106% (400.315 à 312.7 m²)
soit 1.07274 dB (+24.9513 à +26.024 dBm²)
incertitude sur la phase 0 ° (0 à 0 °)
```



CR @ 15° w. 0° bistatism

```
#point étiqueté n° 2 (top-hat) sur l'image bistatic_slc8
SER max pendant l'intégration: 1.43084 m² (+1.55592 dBm²)
SER intégrale=1.352 m² (+1.30977 dBm²)
réponse max I=1.16255 Q=0
amplitude=1.16255 section efficace=1.35152 m²=+1.30821 dBm²
phase=0 °
aberration azimut=+0 m (vers l'avant)
incertitude sur l'amplitude 8.68895% (1.20541 à 1.10439)
incertitude sur la section efficace 17.2656% (1.45302 à 1.21967 m²)
soit 0.760284 dB (+0.862419 à +1.6227 dBm²)
incertitude sur la phase 0 ° (0 à 0 °)
```

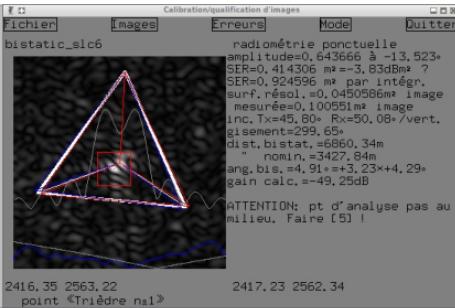


Top-hat @ 45° w. 0° bistatism

Bistatic G.O. RCS models for canonical targets

Dihedral prefered target (orientation recovery easier and top RCS). Corner reflector RCS collapses with even small bistatism, top-hat RCS is low, contaminated with clutter reflexion and sensitive to $\eta_T - \eta_R$.

```
#point étiqueté n° 0 (Trièdre n°1) sur l'image bistatic_slc6
SER max pendant l'intégration: 1.25957 m² (+1.00222 dBm²)
SER intégrale=0.336167 m² (-4.73444 dBm²)
réponse max I=0.169768 Q=-0.363215
amplitude=0.400932 section efficace=0.160746 m²=-7.93859 dBm²
phase=-64.9484 °
aberration azimut=-0.124179 m (vers l'arrière)
incertitude sur l'amplitude 298.145% (1.55358 à 0.358221)
incertitude sur la section efficace 1421.67% (2.4136 à 0.128322 m²)
soit 12.7436 dB (-8.91698 à +3.82666 dBm²)
incertitude sur la phase 295.052 ° (0 à 295.052 °)
```



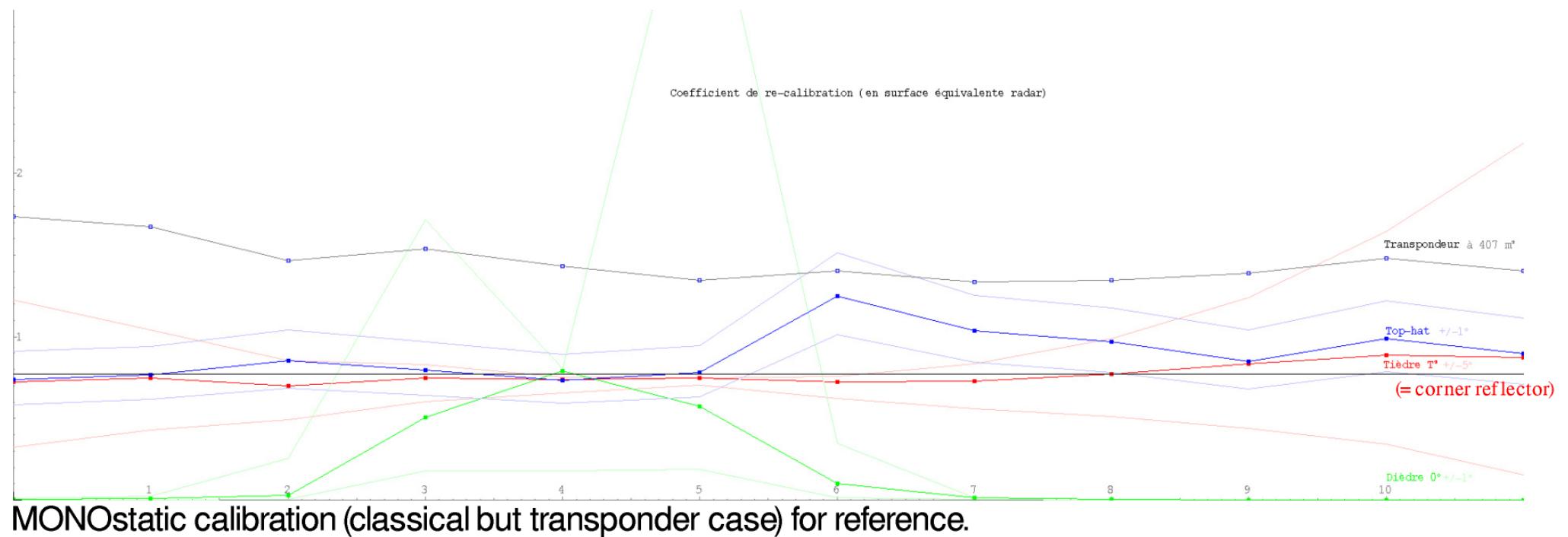
CR @ 45° w. 5° bistatism

```
#point étiqueté n° 2 (top-hat) sur l'image bistatic_slc8
SER max pendant l'intégration: 1.43084 m² (+1.55592 dBm²)
SER intégrale=1.352 m² (+1.30977 dBm²)
réponse max I=1.16255 Q=0
amplitude=1.16255 section efficace=1.35152 m²=+1.30821 dBm²
phase=0 °
aberration azimut=+0 m (vers l'avant)
incertitude sur l'amplitude 8.68995% (1.20541 à 1.10439)
incertitude sur la section efficace 17.2656% (1.45302 à 1.21967 m²)
soit 0.760284 dB (+0.862419 à +1.6227 dBm²)
incertitude sur la phase 0 ° (0 à 0 °)
```

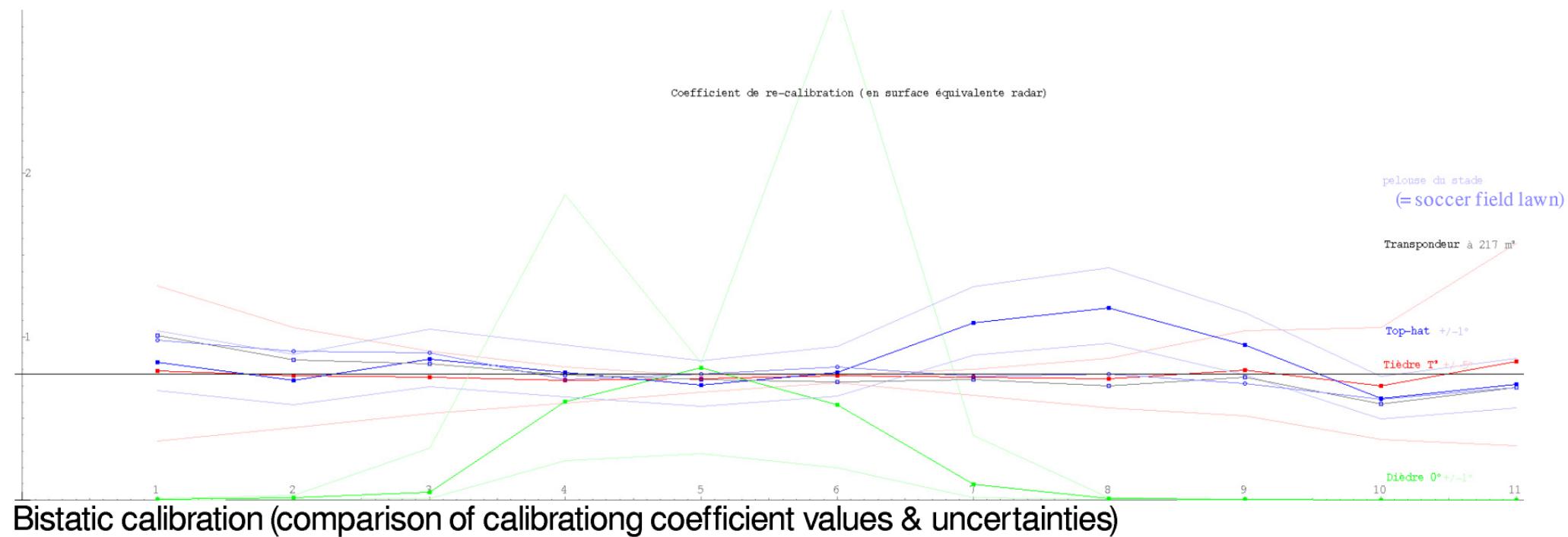


Top-hat @ 45° w. 0° bistatism

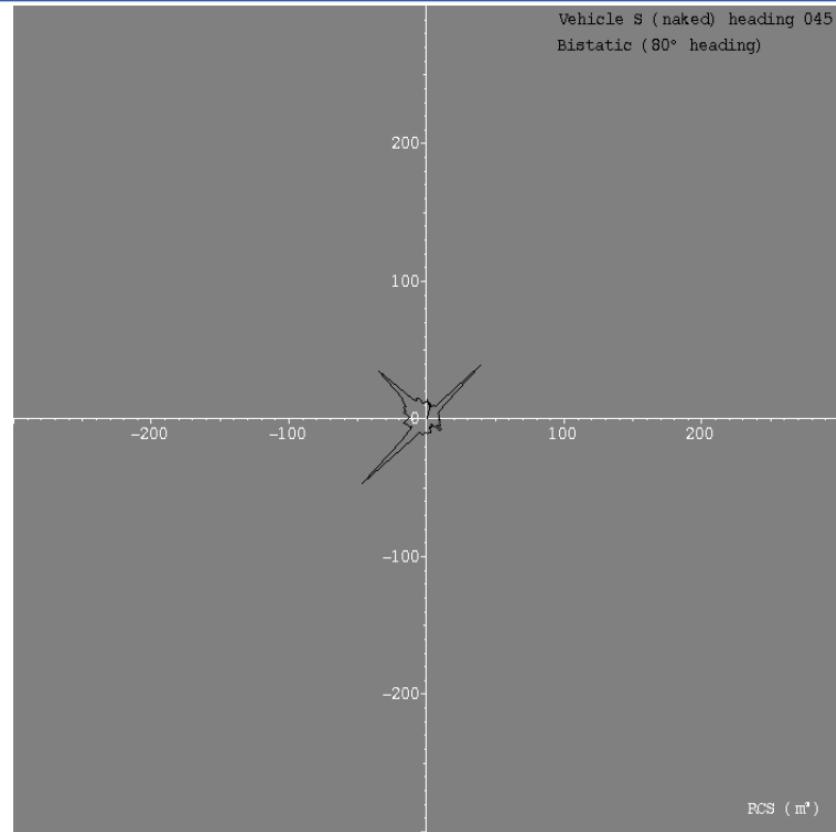
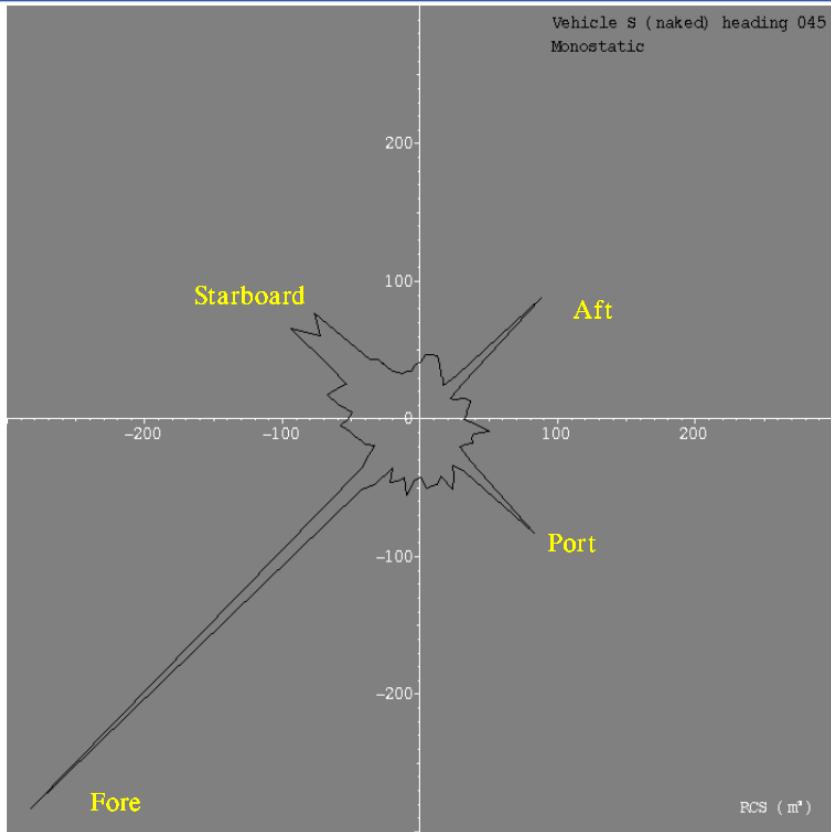
Bistatic radiometric calibration: summary



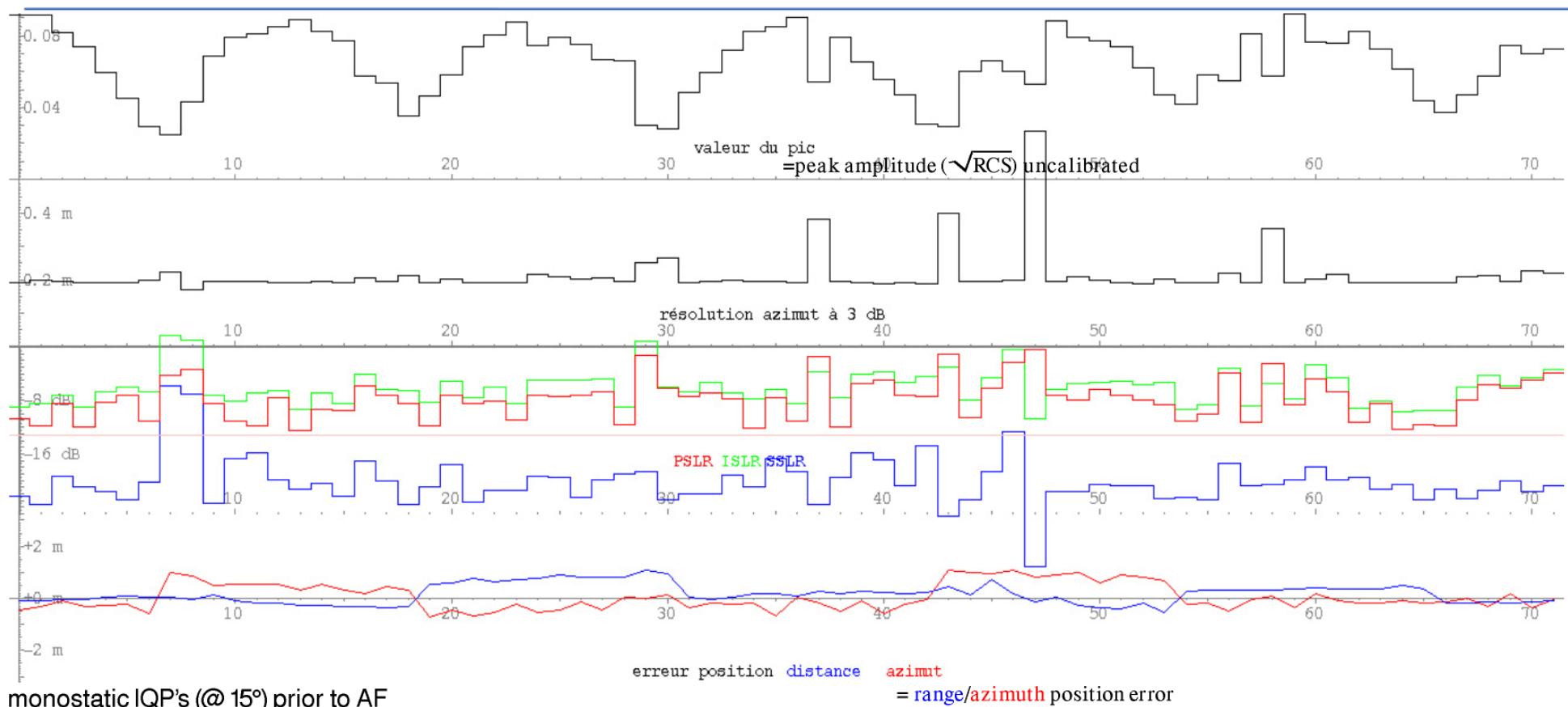
Bistatic radiometric calibration: summary



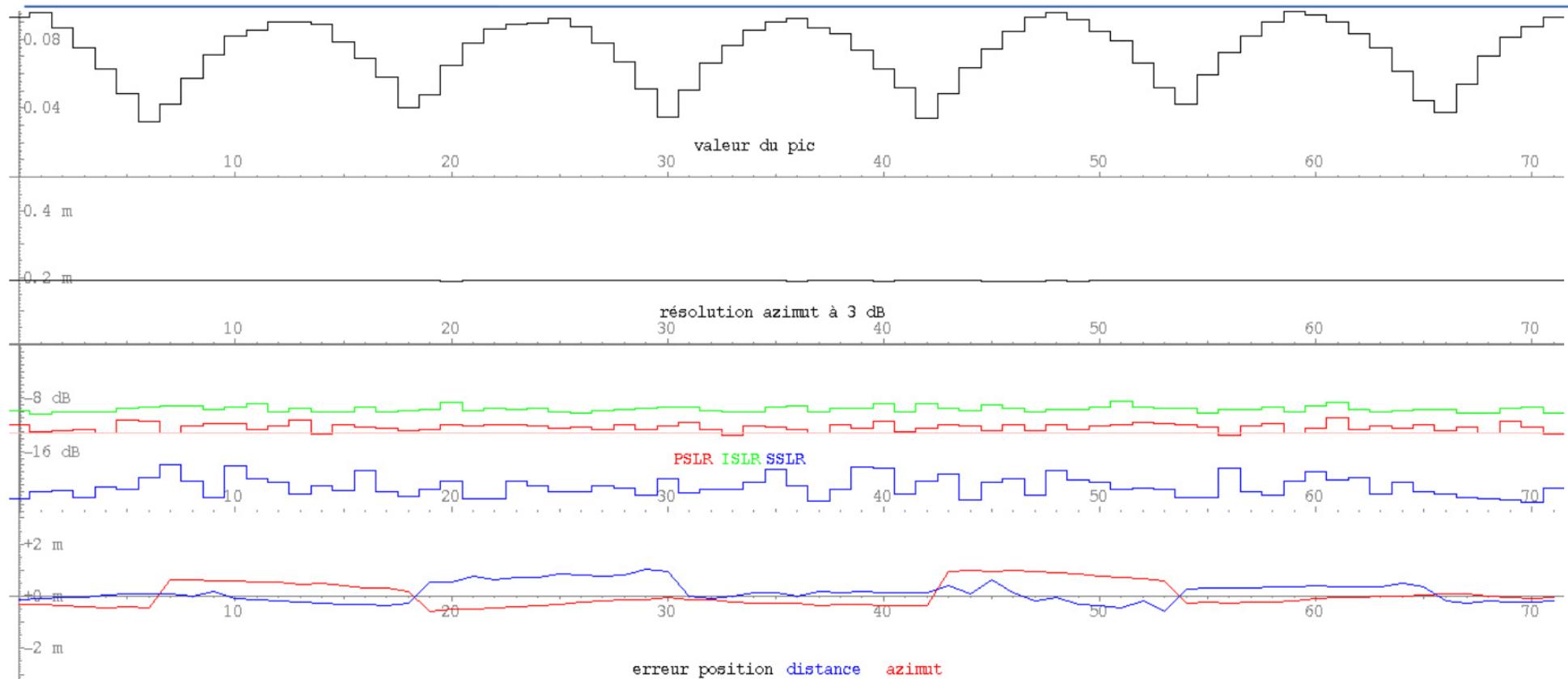
Example of calibrated result: polar RCS of a ground vehicle



Quality assessment of (bistatic) images

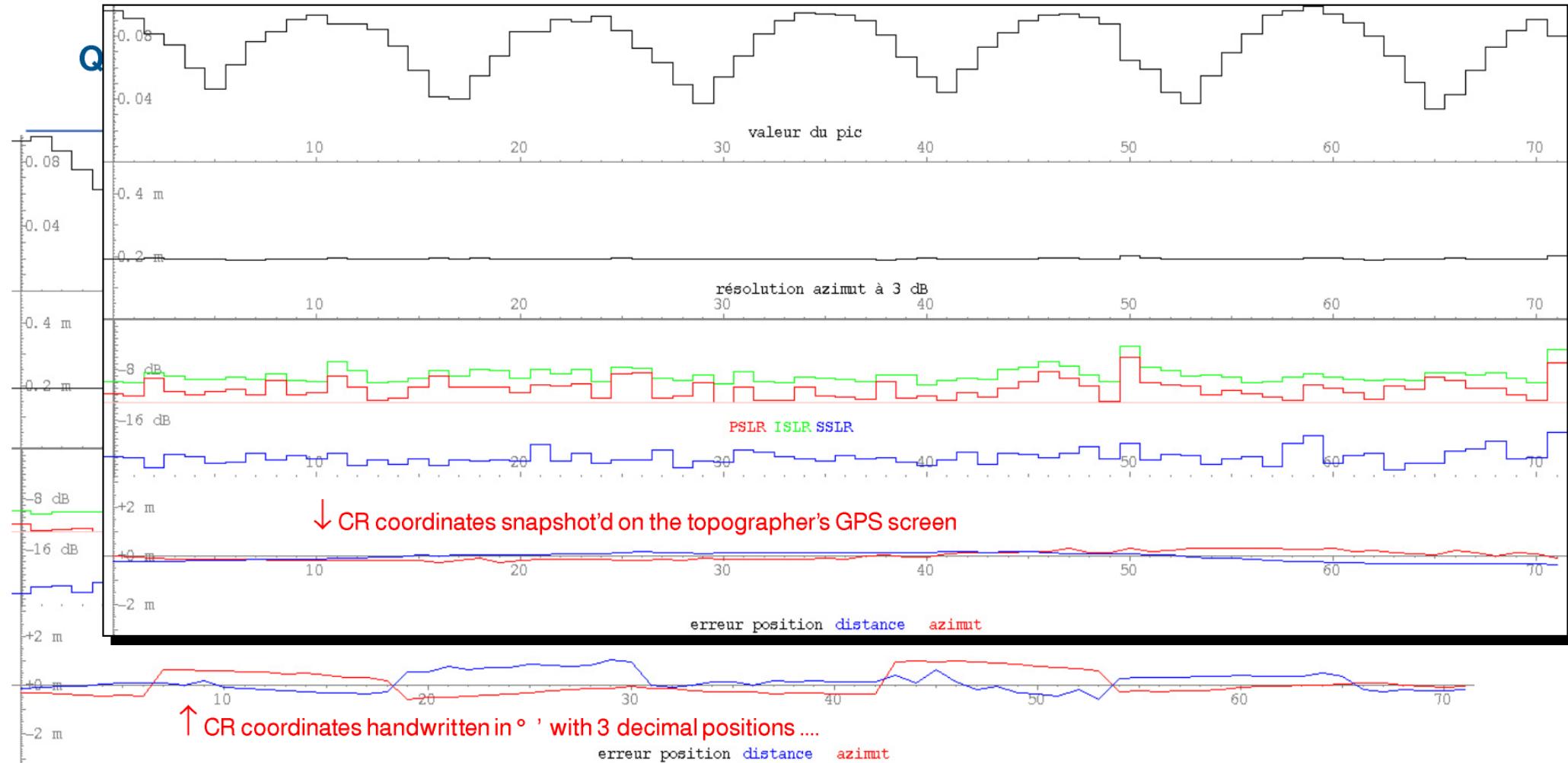


Quality assessment of (bistatic) images

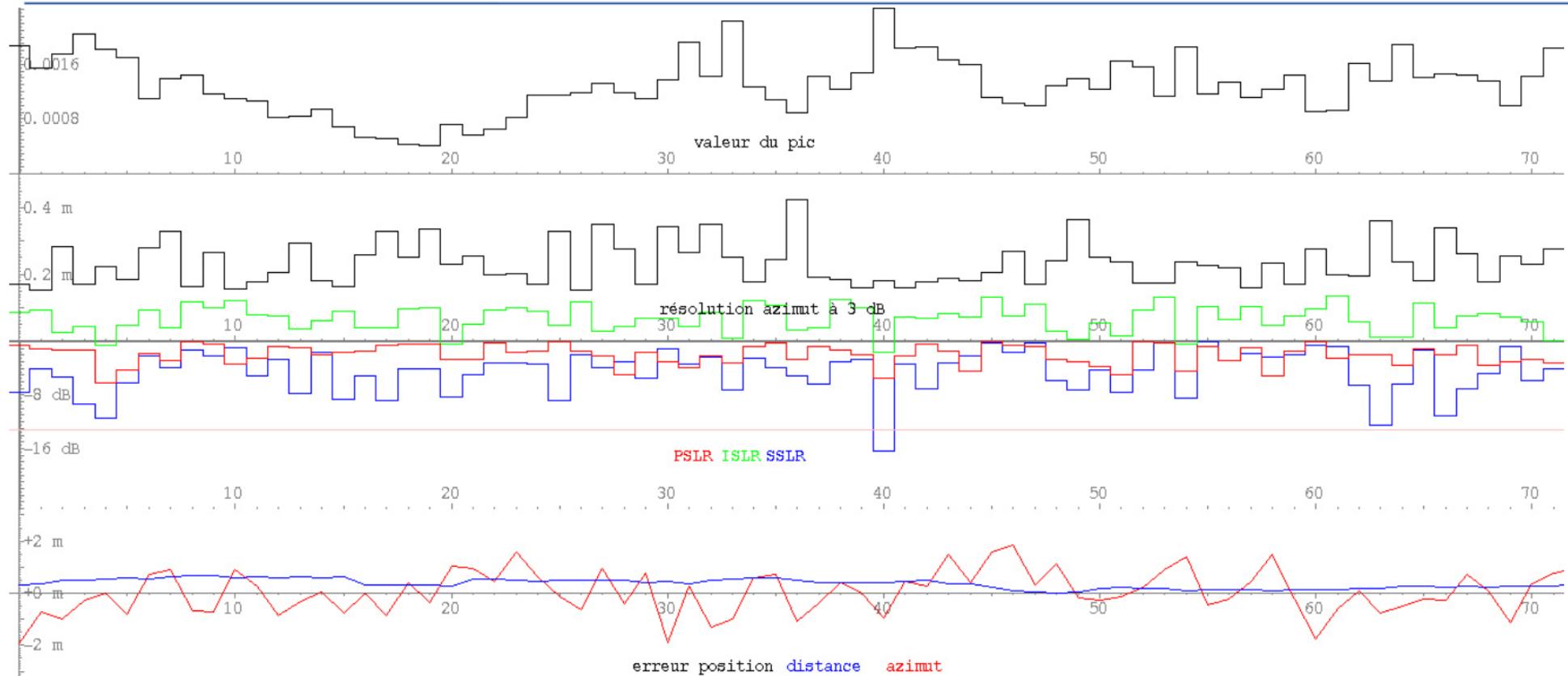


monostatic IQP's (@ 15°) after AF

Q

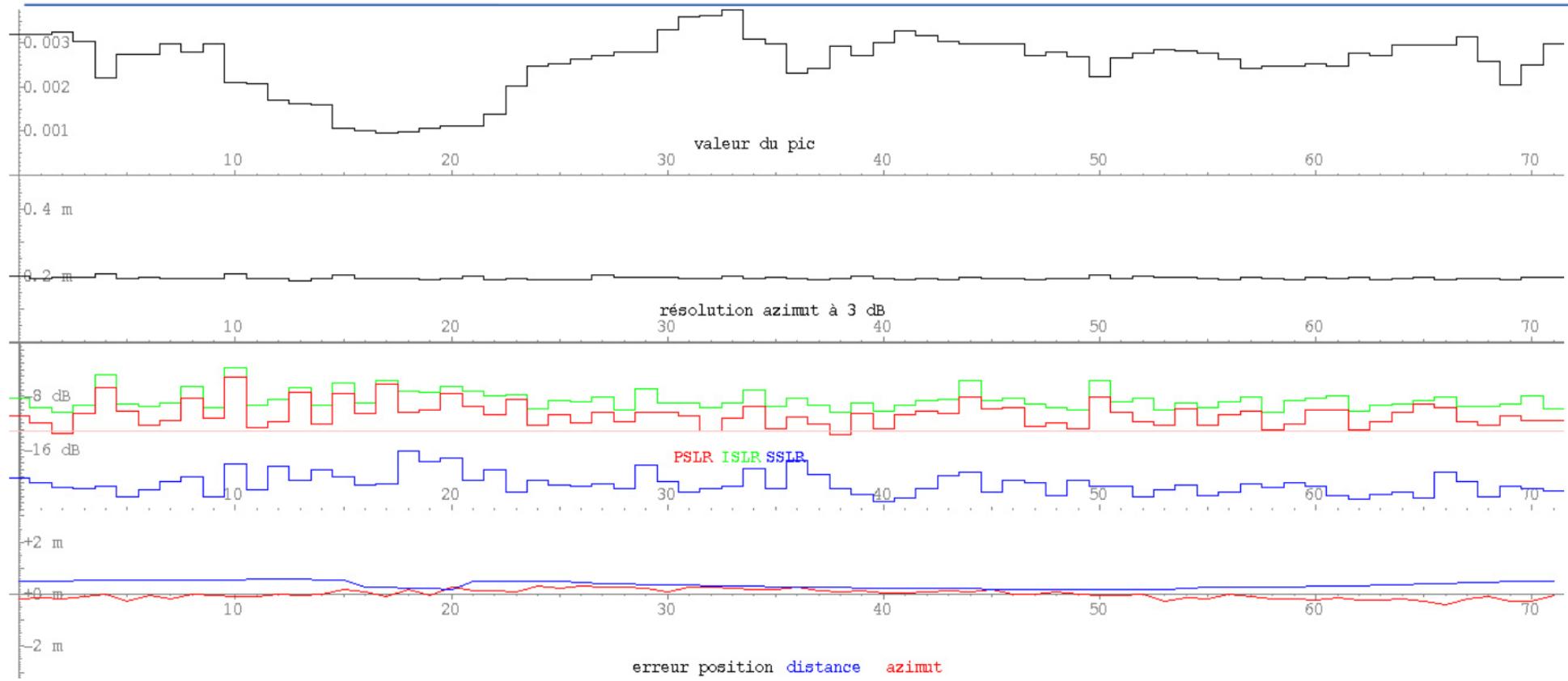


Quality assessment of (bistatic) images



bistatic IQP's (@ 15°) GPS-discipline only

Quality assessment of (bistatic) images



Questions ?