

Journées 2018 de la SF2A

Jeudi 5 Juillet 2018

Bordeaux

HPC Temps-Réel pour le radiotélescope NenuFAR*

Cedric Viou

on behalf of the

NenuFAR-France team**

*** : LESIA-OP, LPC2E-Orléans, USN-OP,
CEA-Saclay, GEPI, LERMA, ONERA,
ENS/IAP, OCA, ...*



*New Extension in Nançay Upgrading LOFAR



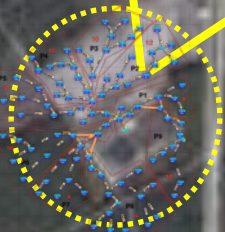
1 km

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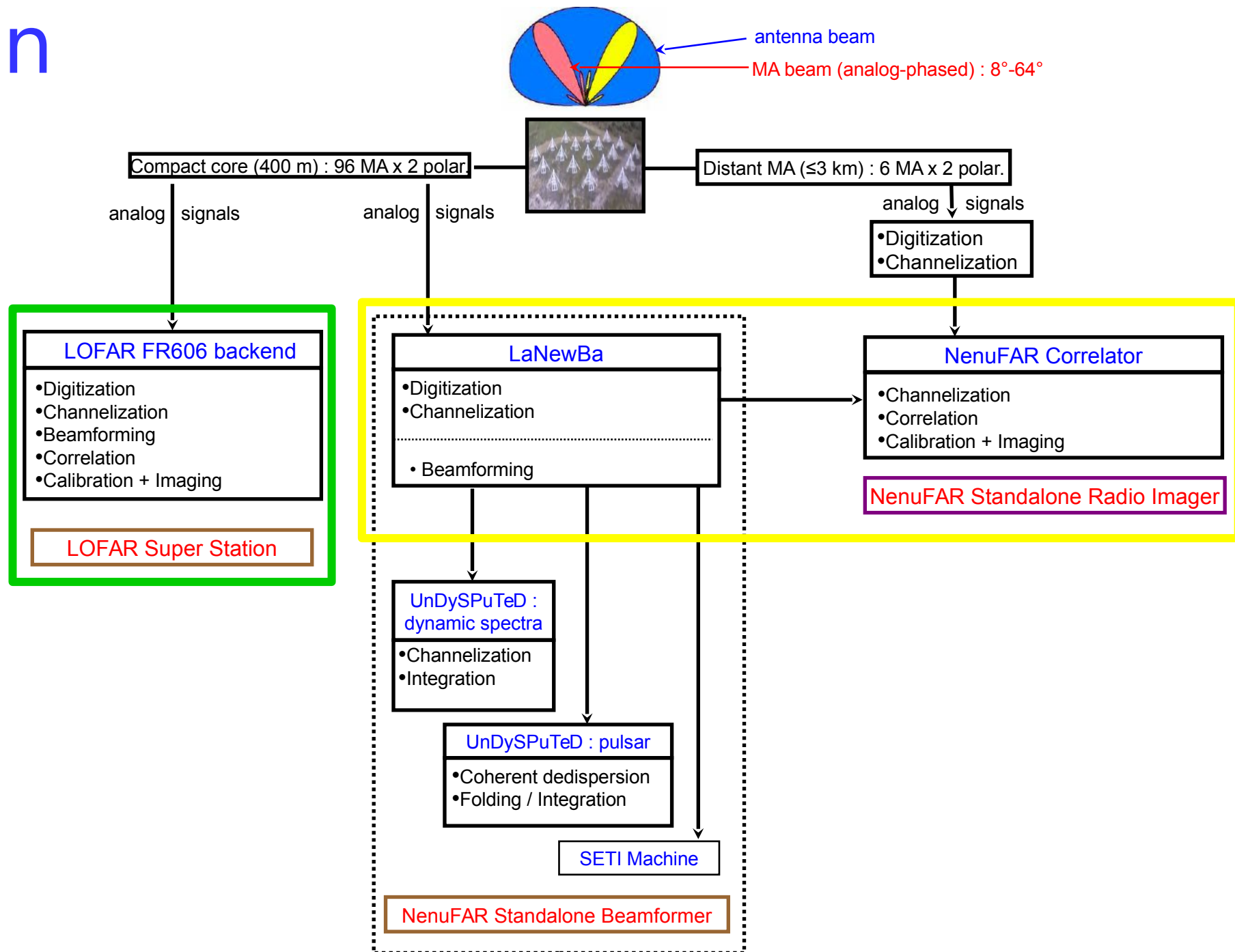


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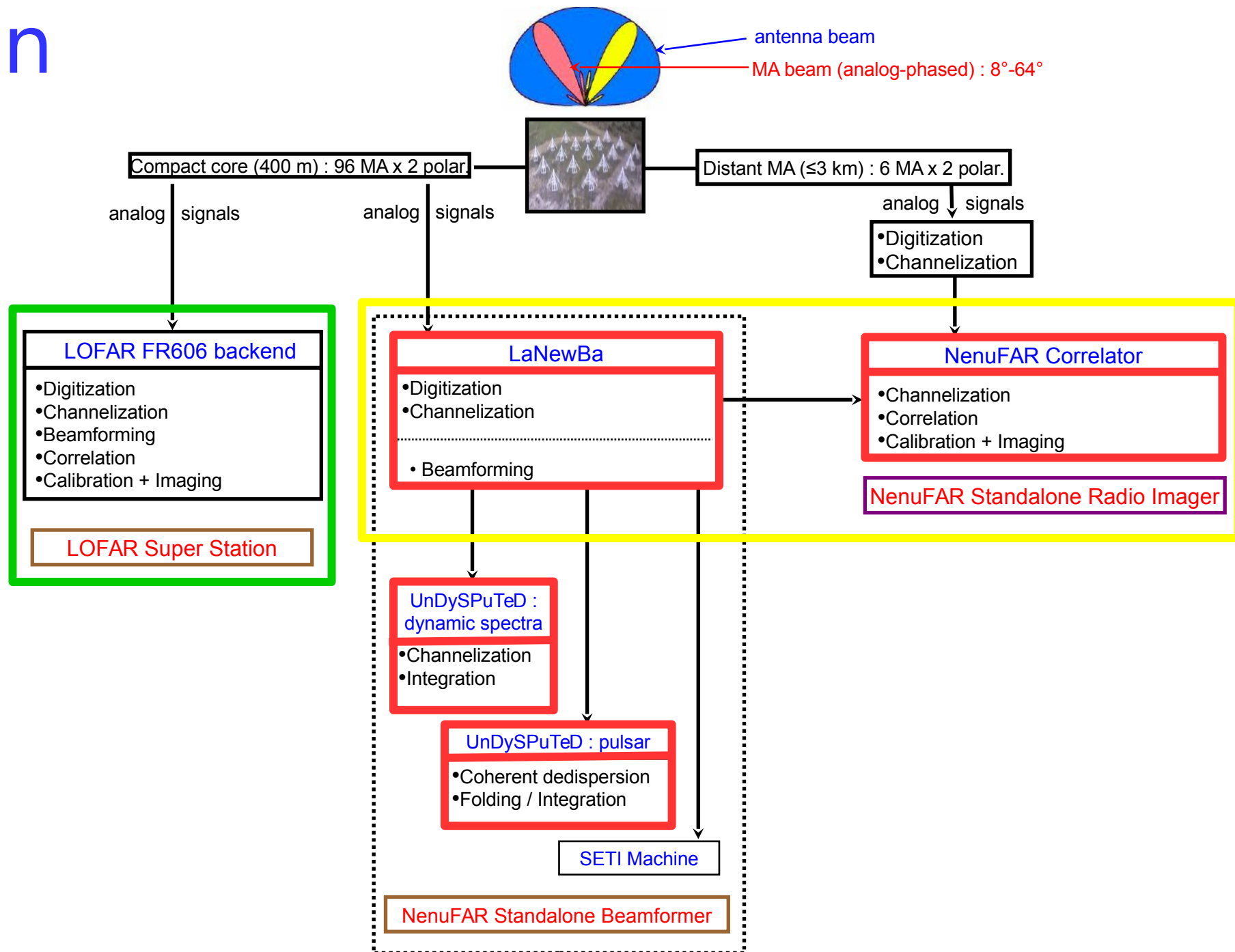
⑥

LSS
+
NenuFAR
+
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Radio-Imageur

Plan



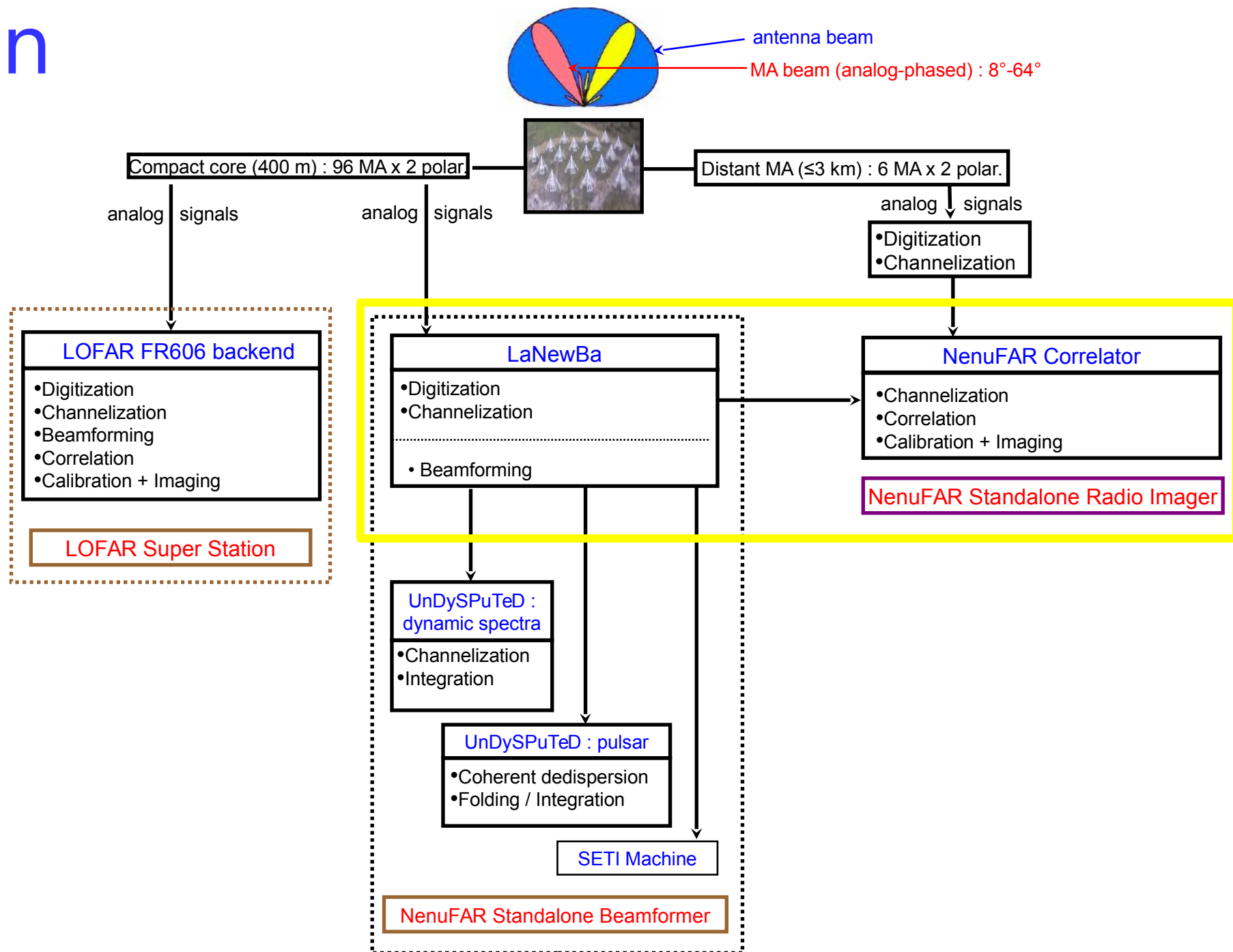
Plan



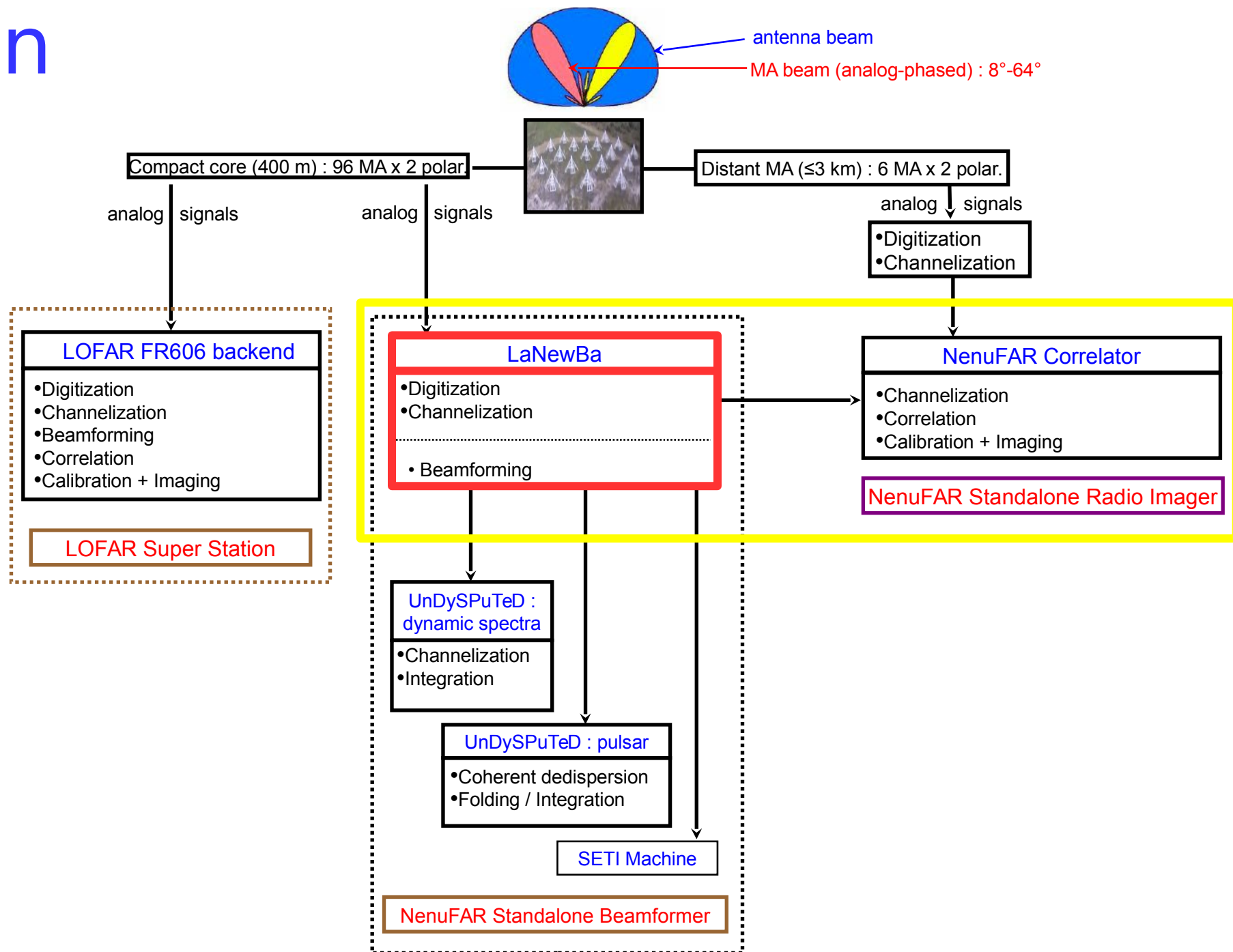
On-site computing facilities



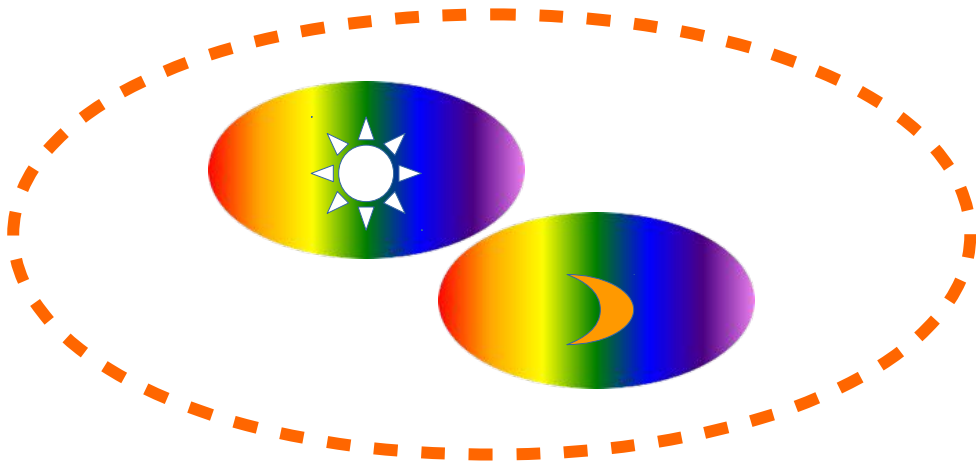
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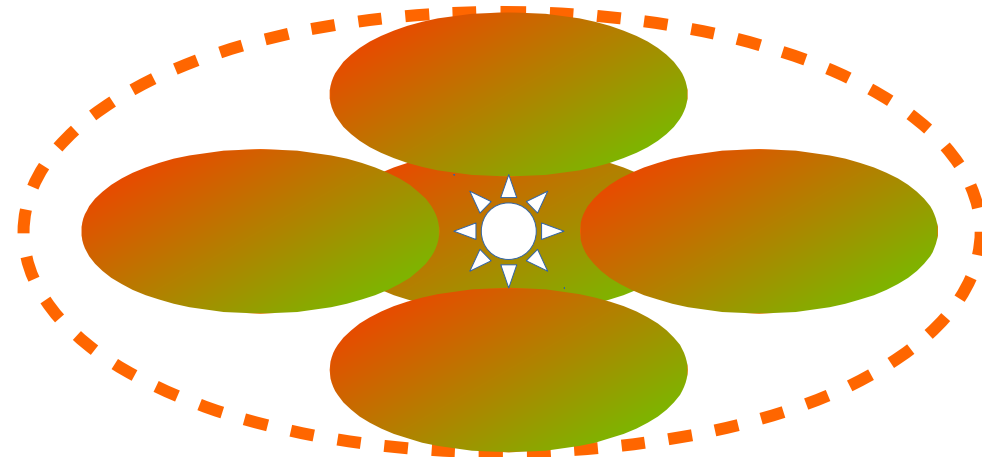
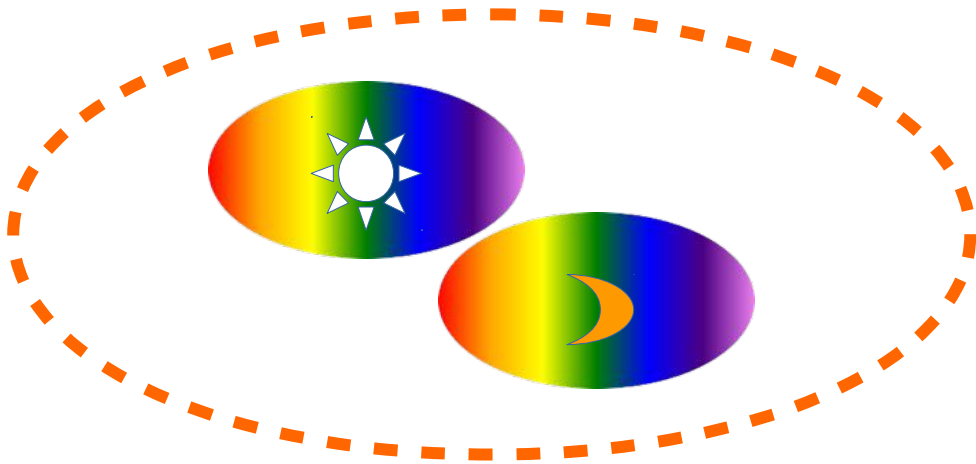
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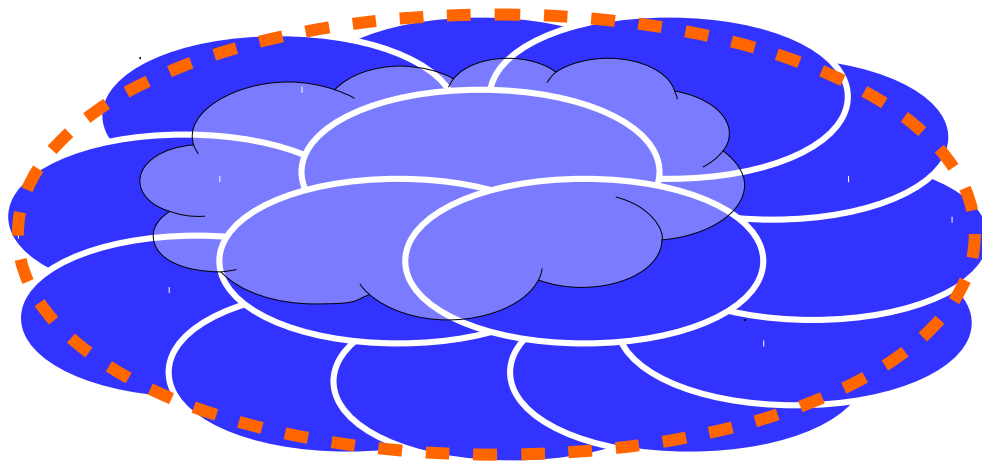
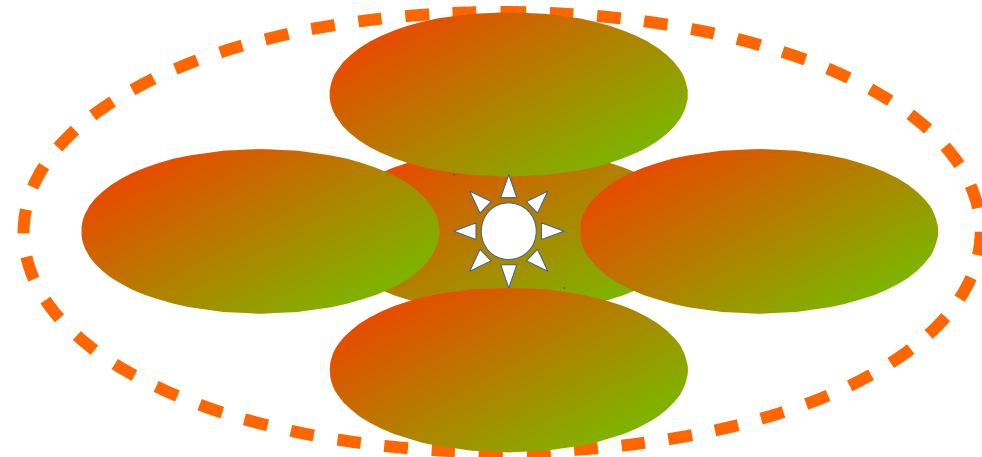
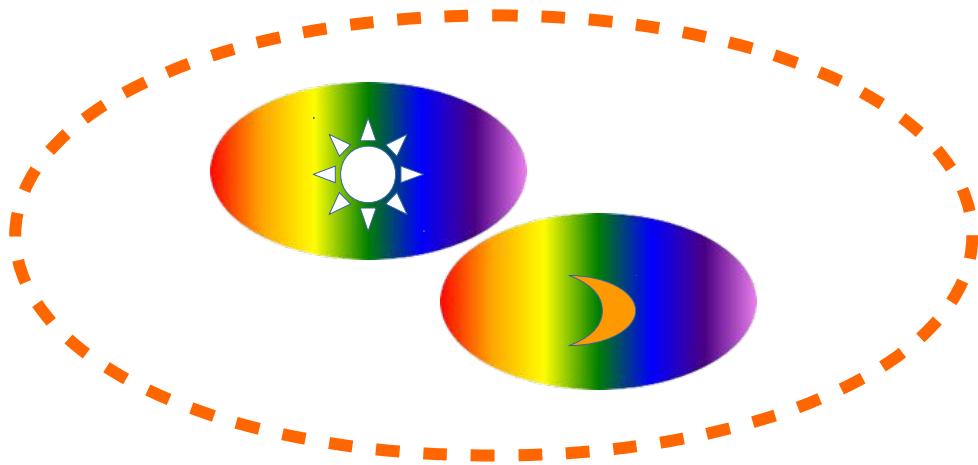
Configurations possibles de pointages



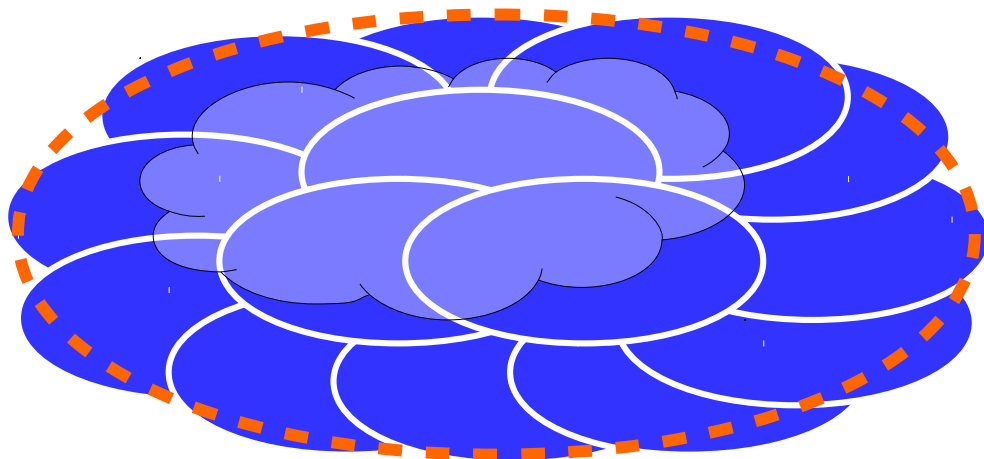
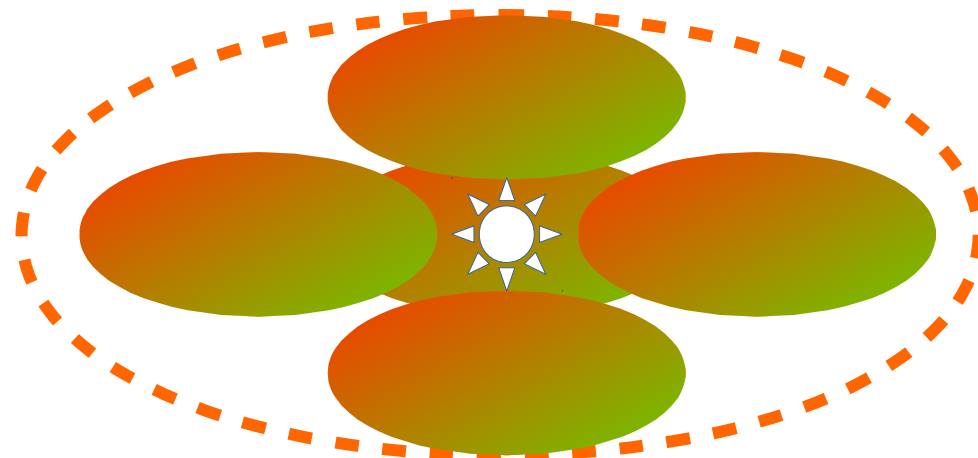
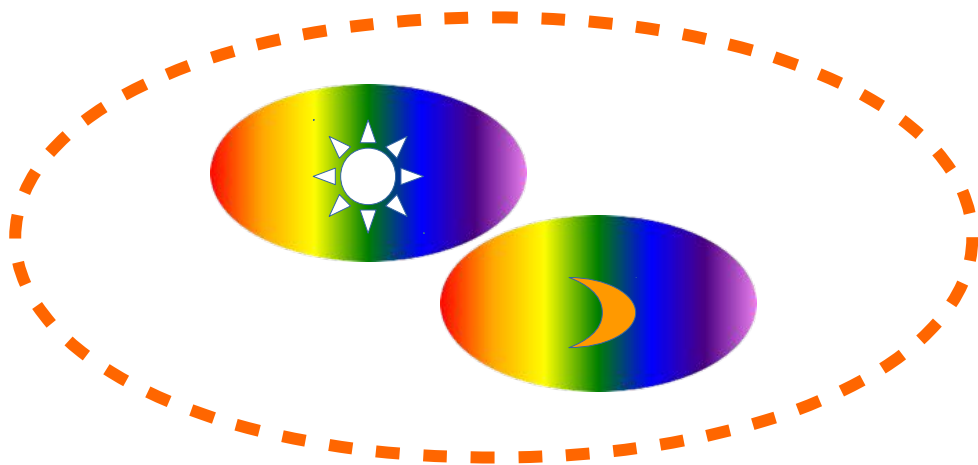
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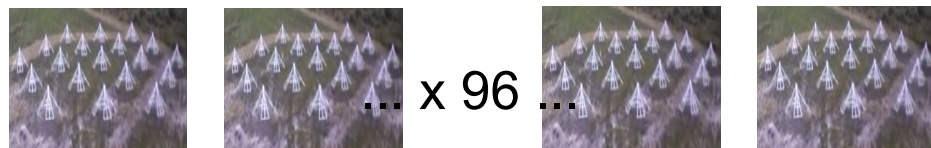


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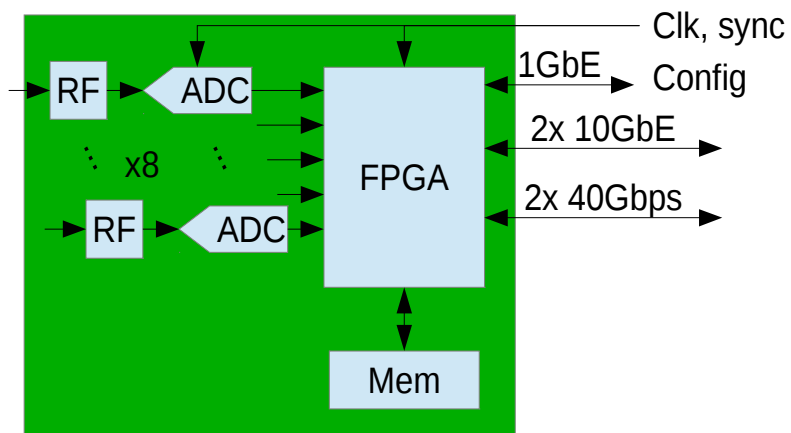
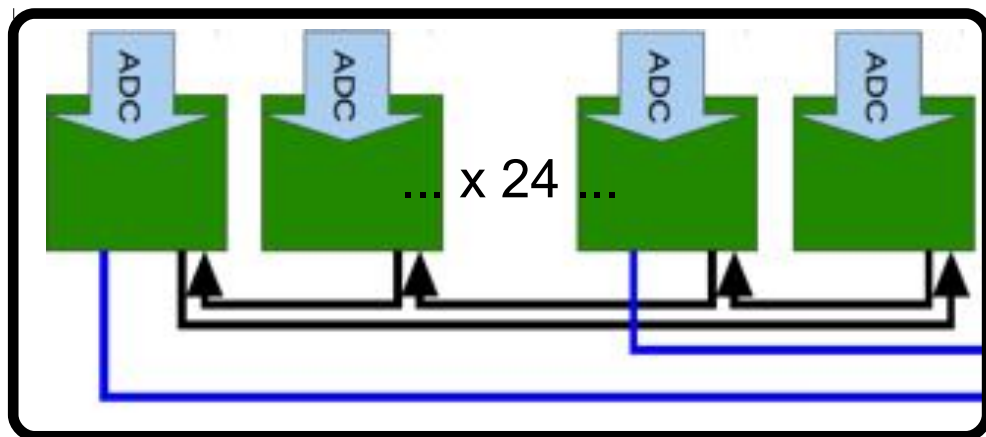


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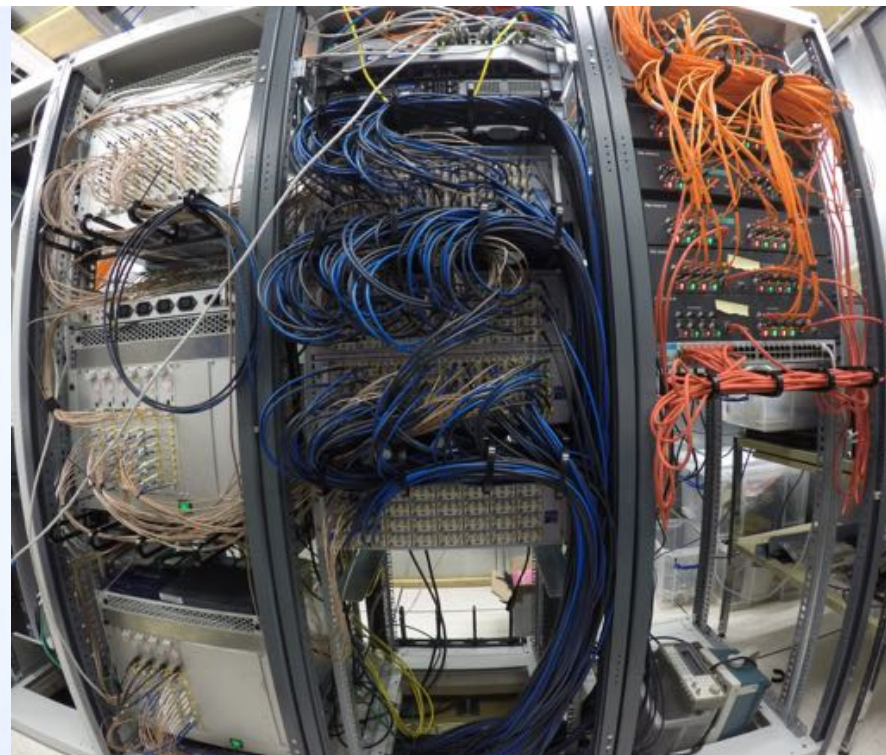


x 96



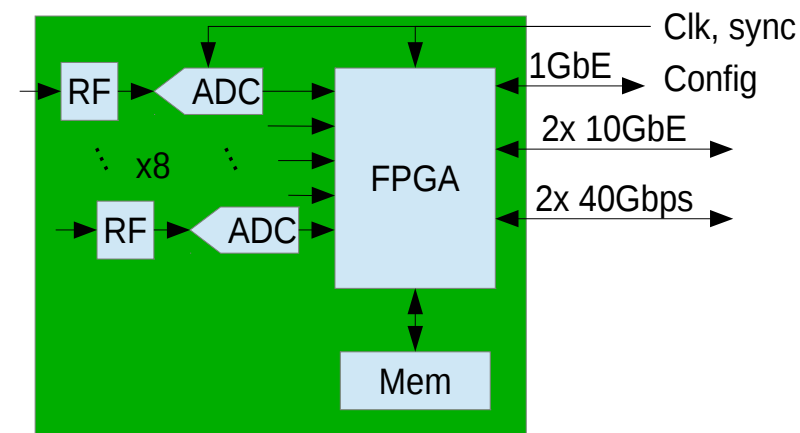
2 beams full-band (~10-85 MHz), full-polar.

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LANewBa

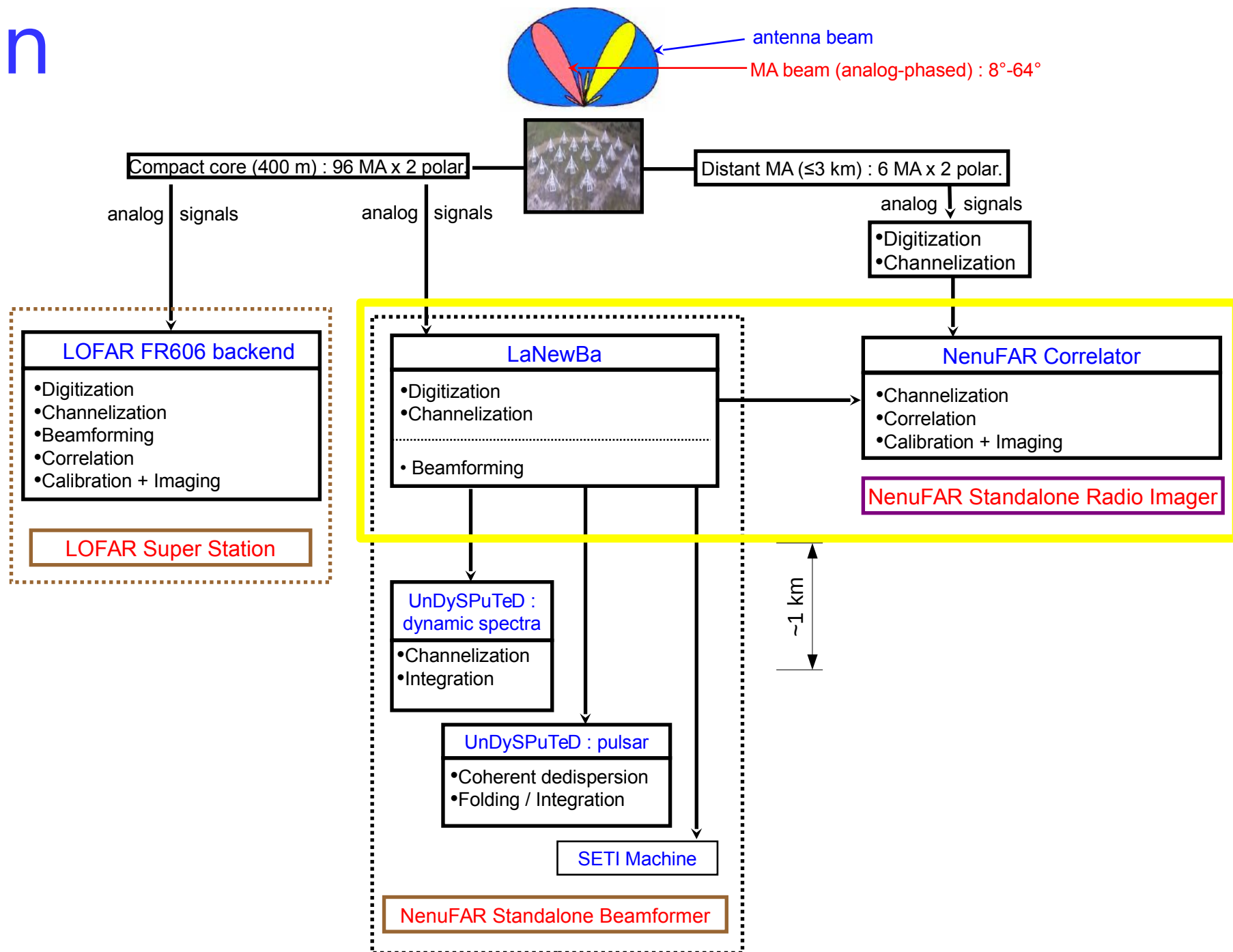
- Numérisation
 - (96x2) x 200 MEch/s - 14 bits ADCs (~400 Mo/s/chan)
 - 45 Go/s aujourd'hui, 77 Go/s pour l'instrument complet, 24/7
 - Synchronisation meilleure que 0.1 ns
- Traitements implémentés en FPGA (Stratix V Altera/Intel)
 - Interfaces matérielles fournies par ALSE (ADC, mémoire, 1G, 10G, 40G,...).
 - Traitement du signal basé sur le code VHDL des RSP LOFAR
 - 1300 GMAC/s distribués sur 24 cartes de calcul
- Channelization :
 - 512 x 0.195 kHz subbands
 - 16-taps PFB + 1k-FFT (614+192 GMAC/s)



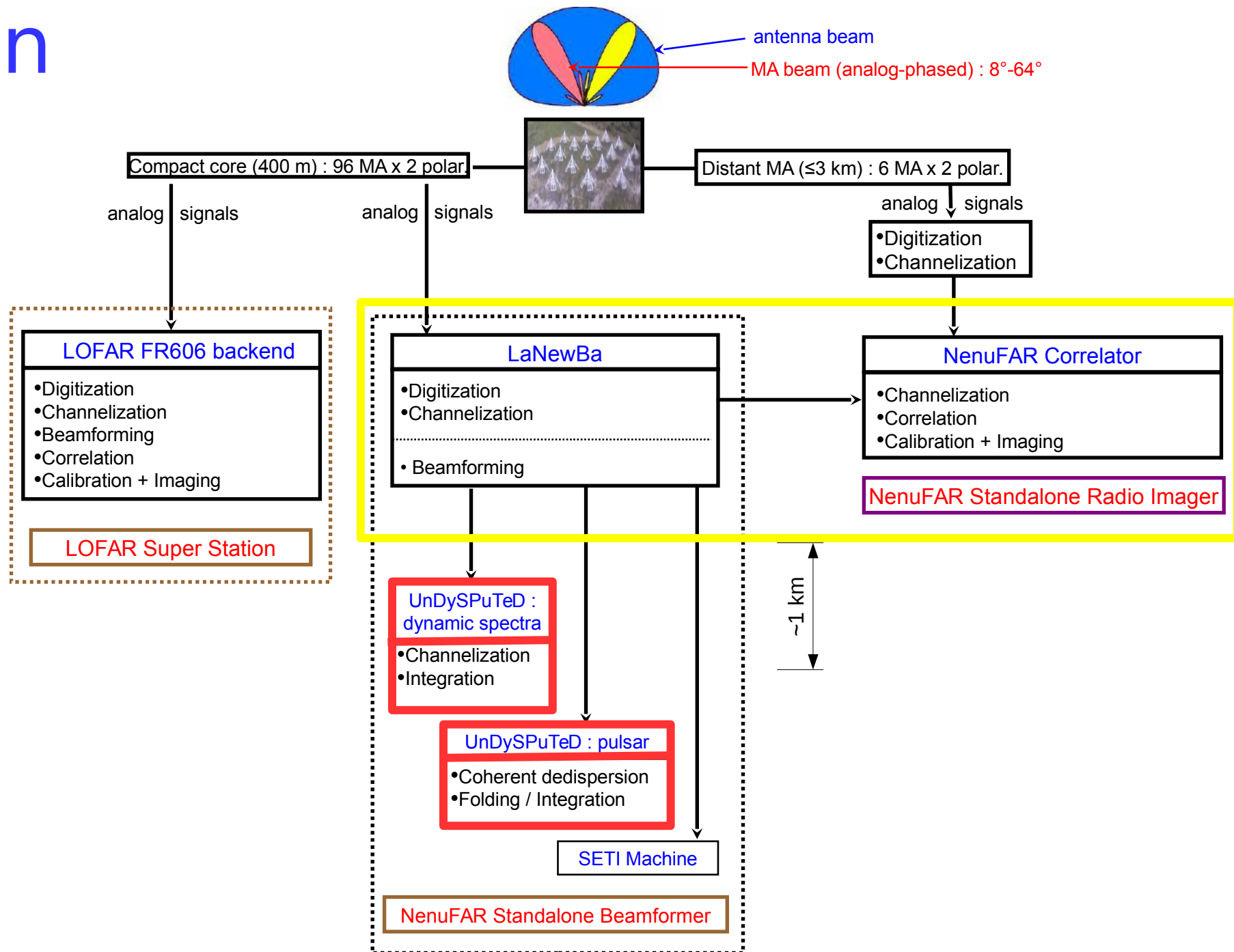
LANewBa

- Formation de faisceau (beamforming)
 - Sélection des sous-bandes à phaser (768 parmi 512)
 - Retard par rotation de phase (Approximation bande étroite)
 - Sommation dans un anneau (14 Gb/s, 58 GAcc/s)
 - Export par 10GbE (2x 300-600 Mo/s)
- Calibration du réseau
 - Mesure par corrélation (16 ssb/s -> 512 ssb/30s)
 - Échange de données dans l'anneau (18 Gb/s)
 - MAC au sein de chaque cartes (90 Mo/s x 2.2 Go/s)
 - 461 GMAC/s
- Monitoring et diagnostics
 - Calcul de statistiques sur les flux haut-débits
 - Enregistrement des paramètres physiques du système (T°C, U, I, flags)
- 1 baie, 1500 W

Plan



Plan



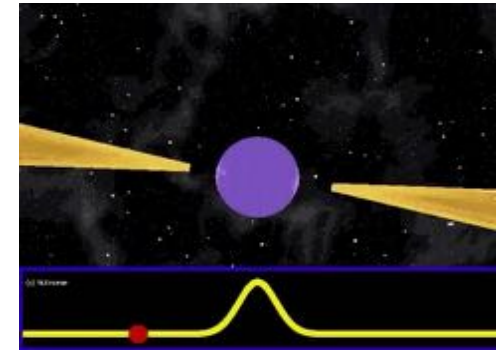
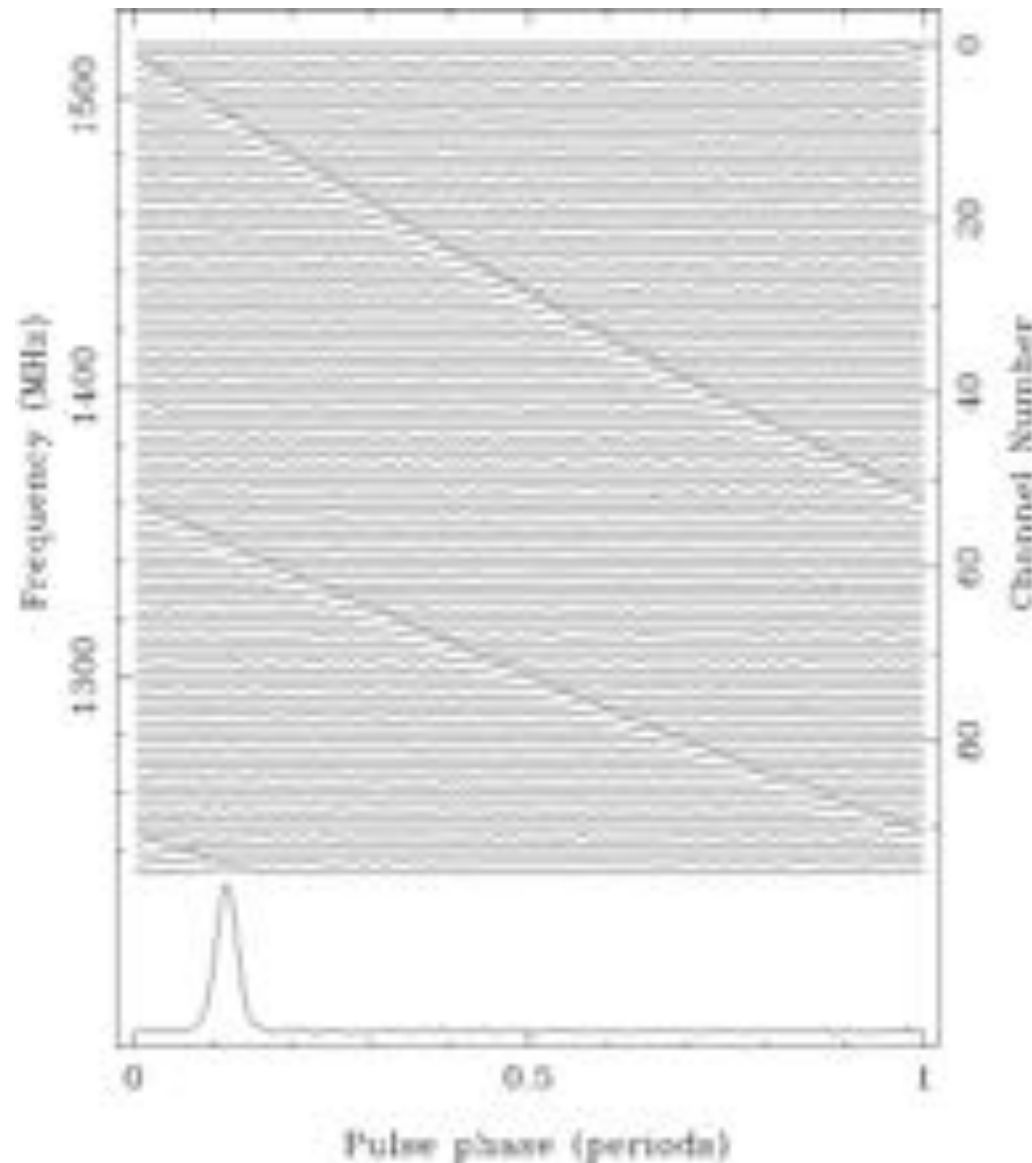
UnDySPuTeD

- 2x Serveurs :
 - 2x Intel Xeon E5-2620v4 8cores
 - 32GB DDR4
 - 2x GPU Nvidia GTX 1080

UnDySPuTeD dynamic spectra

- Dynamic Spectra (en construction/test)
 - Traitera 1 à 2 flux de 4.8 Gb/s, $B=195$ kHz, $dt = 5.12 \mu s$
 - FFT + $\langle |x_i \cdot x_j|^2 \rangle$ pour produire les 4 Stokes, en continu, en temps réel
 - $B_{min} = 762$ Hz, $dt_{min} = 1$ ms
 - $B_{max} = 195$ kHz, $dt_{max} = 1$ s
 - Flux à traiter : 300-600 Mo/s (int8-int16) $\rightarrow$ 1.2 Go/s (float32)
 - Calcul FFT : ~ 2 GFLOPS

UnDySPuTeD pulsar : LUPPI



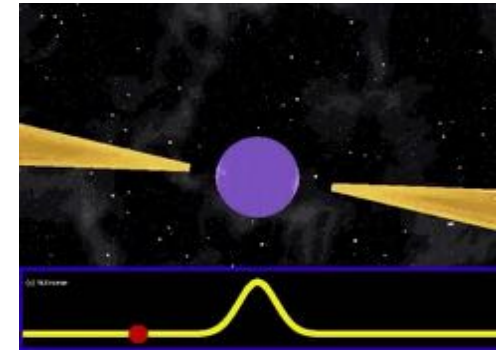
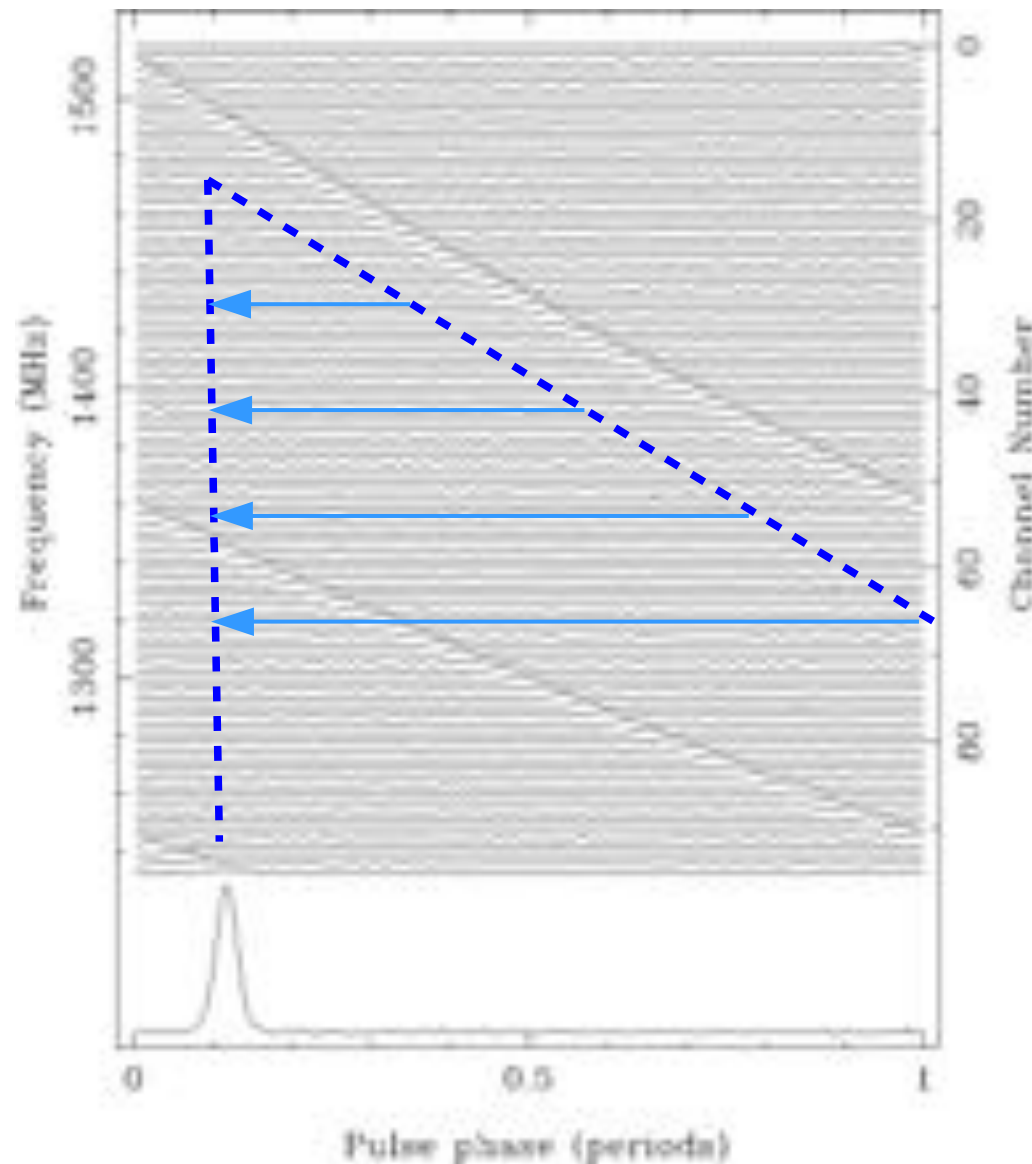
- Signal impulsif déformé (dispersé) par le milieu interstellaire (e-)
- Correction avant intégration t-f
=> Dédispersion

$$H(\nu + \nu_0) = \exp\left(i 2 \pi D \frac{\nu^2}{\nu_0^2 (\nu + \nu_0)}\right)$$

- Convolution moins coûteuse à appliquer dans le domaine spectral

$$\begin{aligned} X[k] &= \mathbf{TF}(x[n]) \\ X_{dedis}[k] &= X[k] \cdot H[k]^{-1} \\ x_{dedis}[n] &= \mathbf{TF}^{-1}(X_{dedis}[k]) \end{aligned}$$

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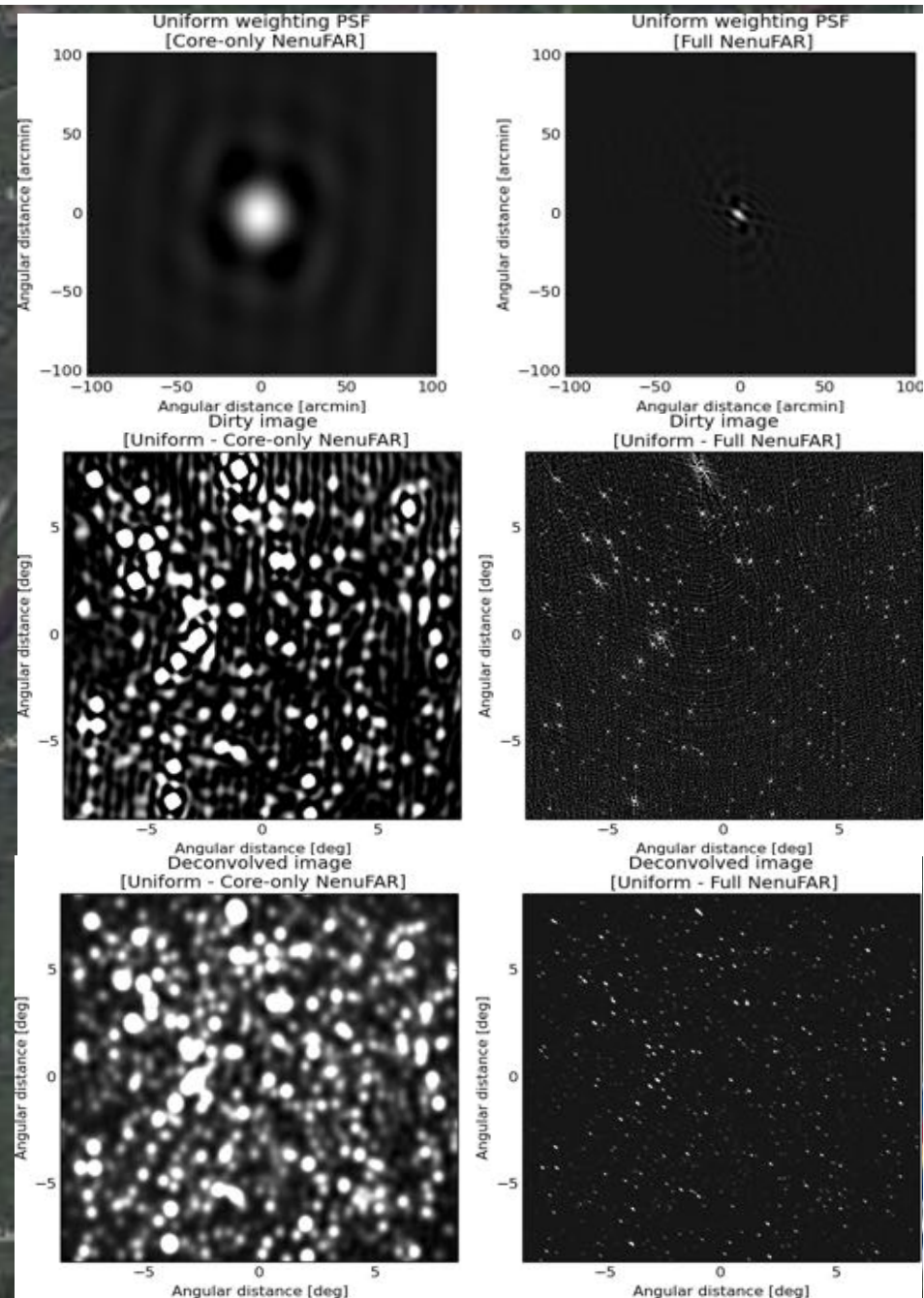
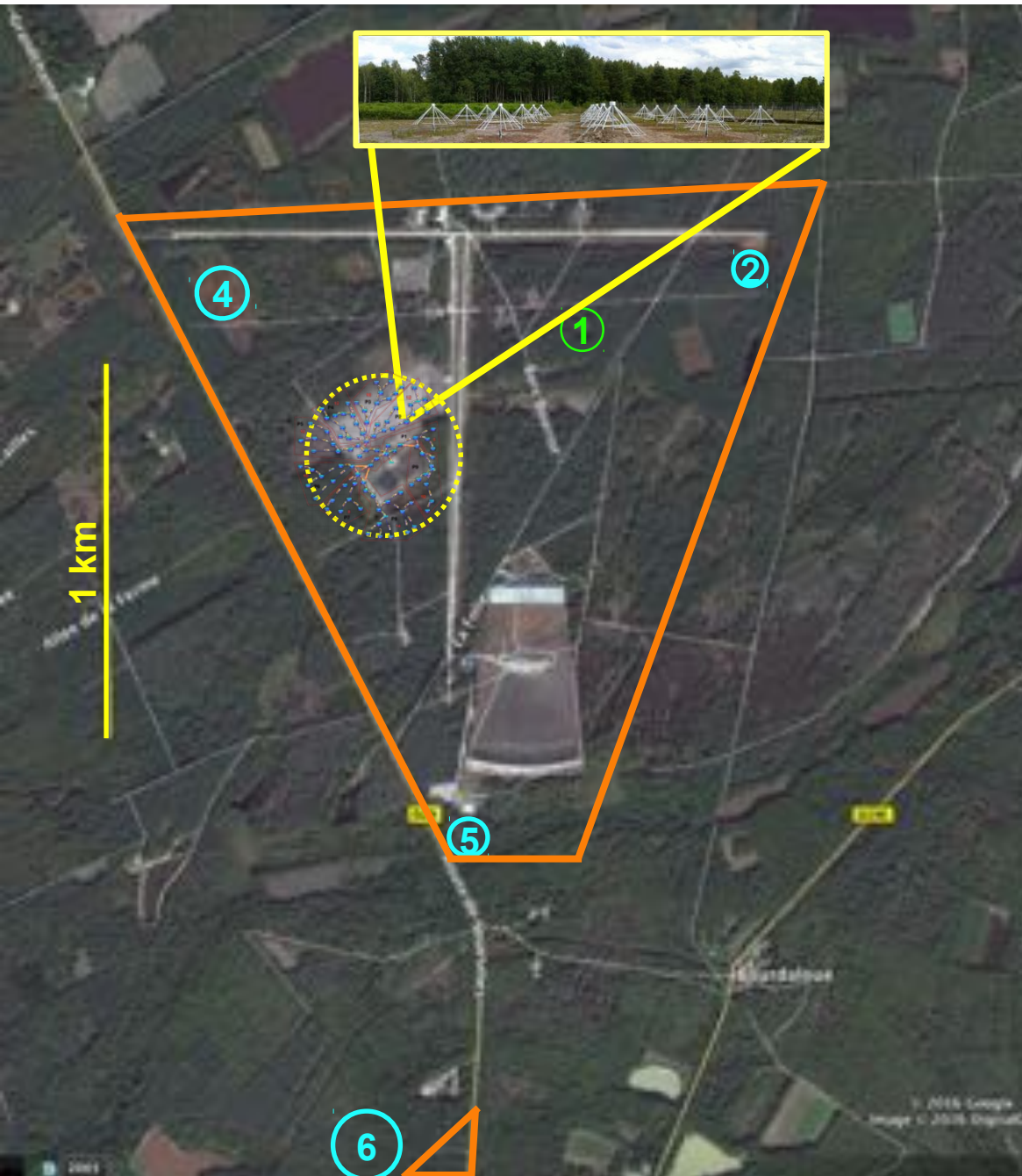
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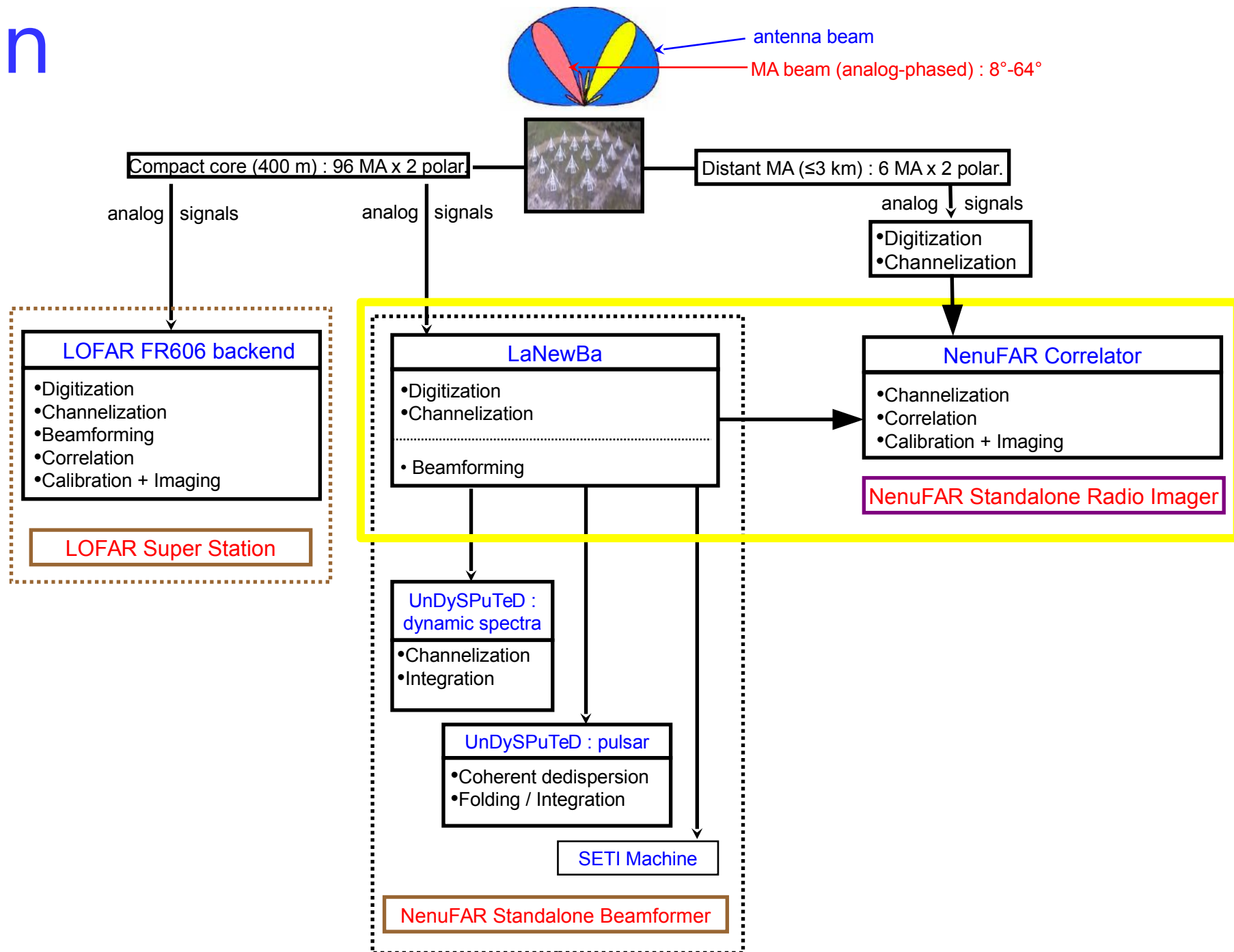
- Flux d'entrée continu (300-600 Mo/s) pendant plusieurs heures
- À basse fréquence, dispersion plus prononcée
=> longs segments de données à traiter (qques s)
 - Taille de FFT : 2M à 16M points
 - Besoin de stocker 256 H[k] de qques 10^6 points
 - ~25 % d'occupation du temps GPU
- Fonctionnement en production
 - Haut temps de disponibilité du système
 - Démarrages/configurations coordonnés avec le pointage

NenuFAR-Radio-Imageur

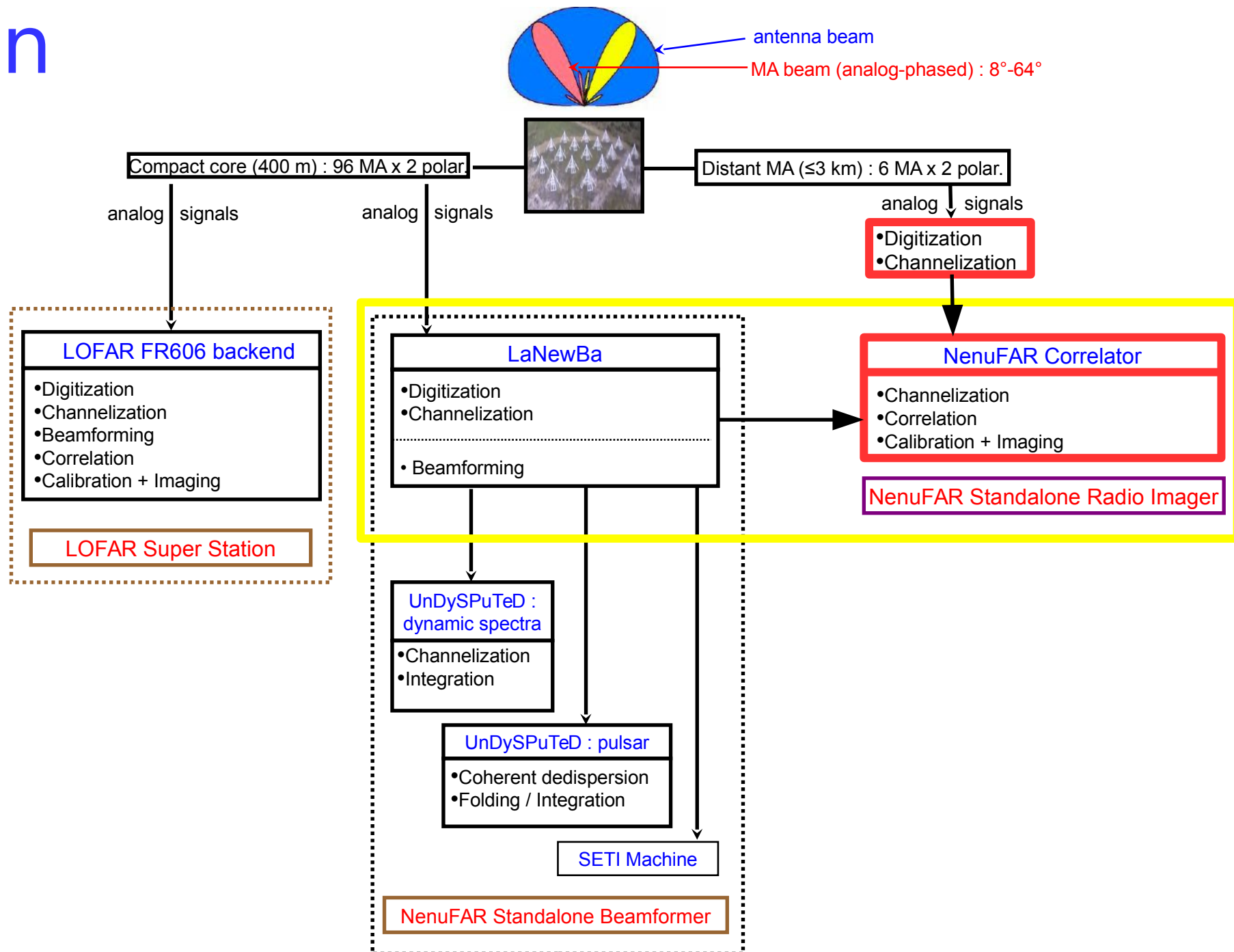
ANR «NRI» 2017-2019



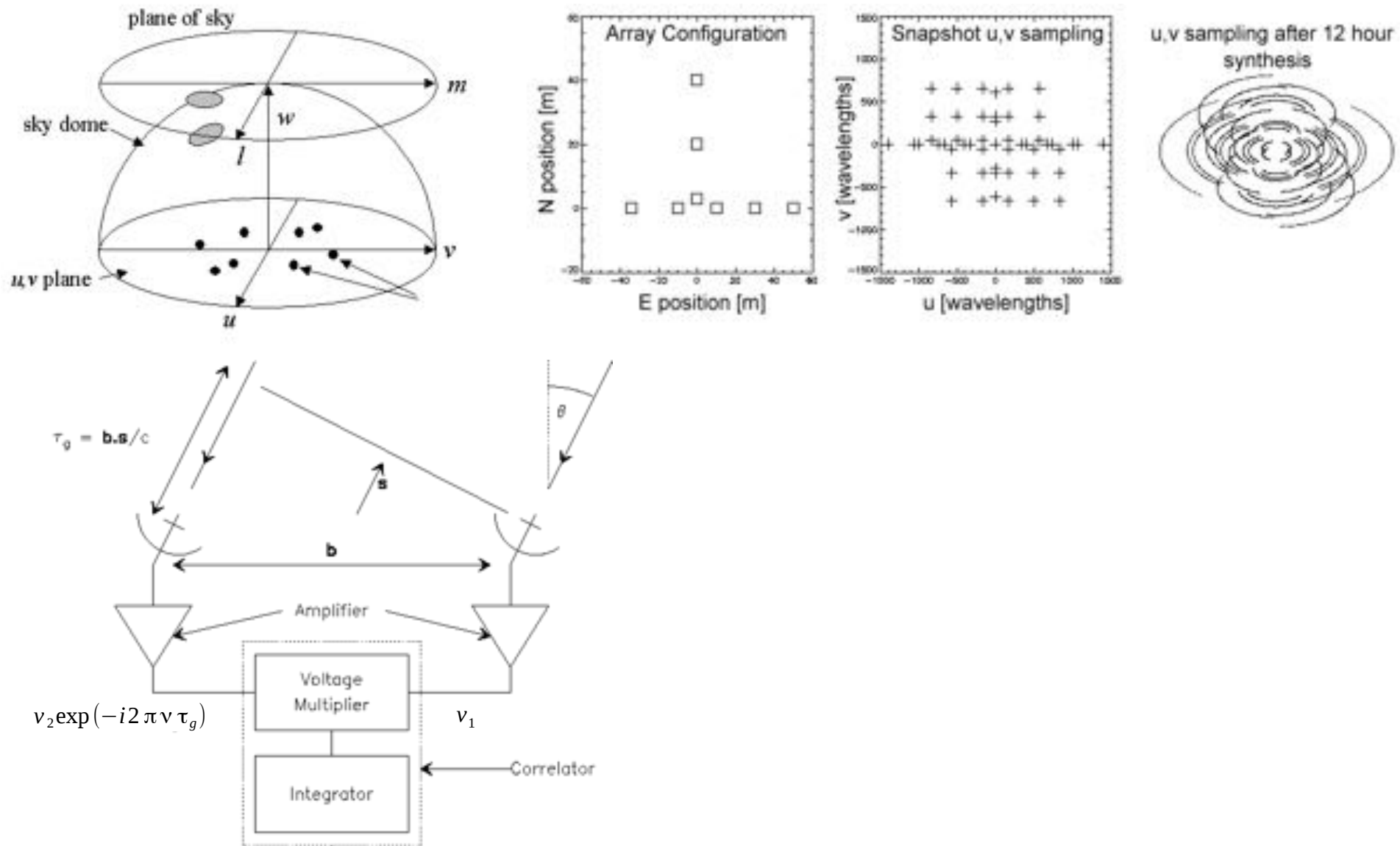
Plan



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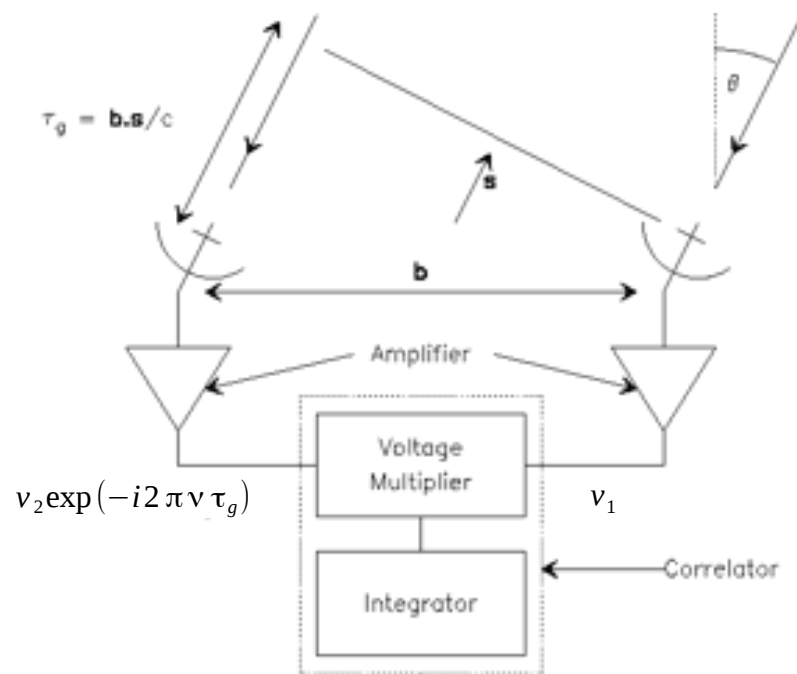
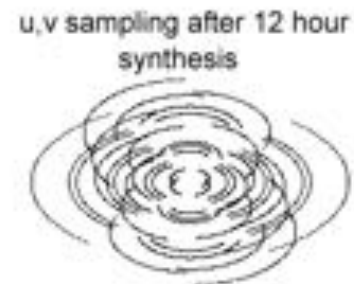
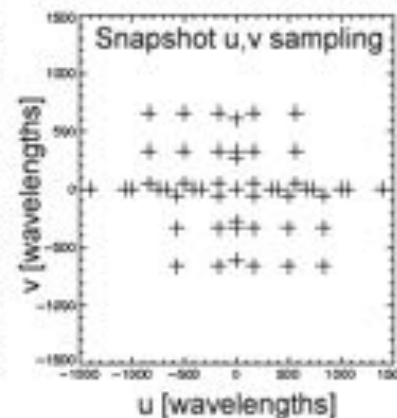
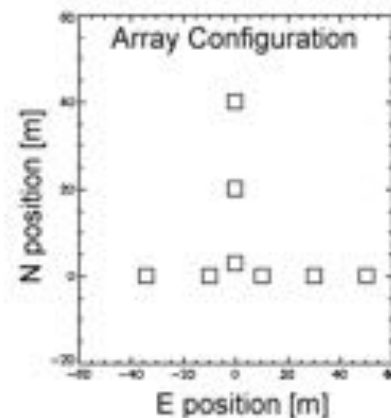
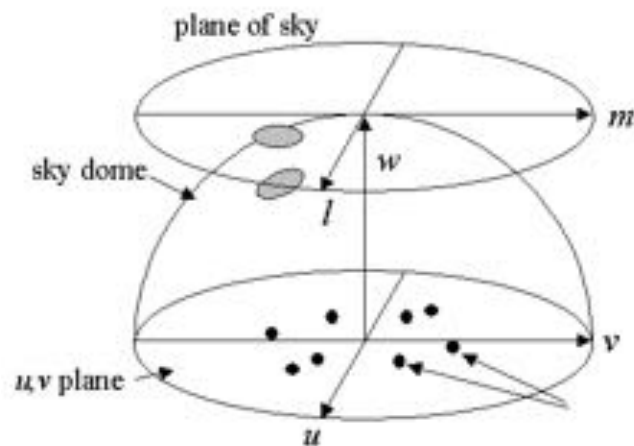


Imagerie par interférométrie radio



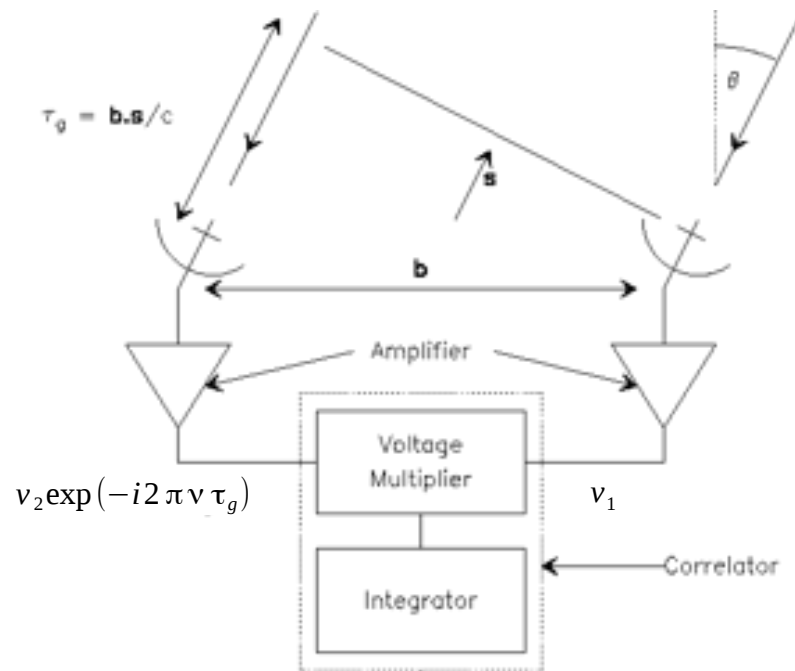
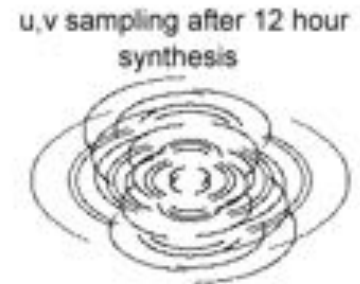
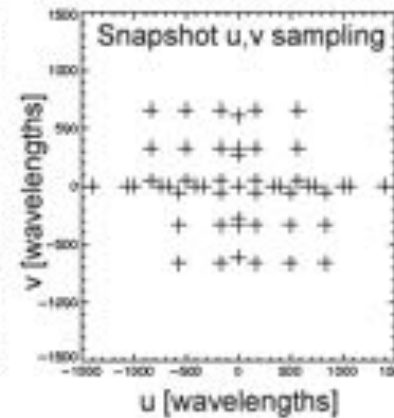
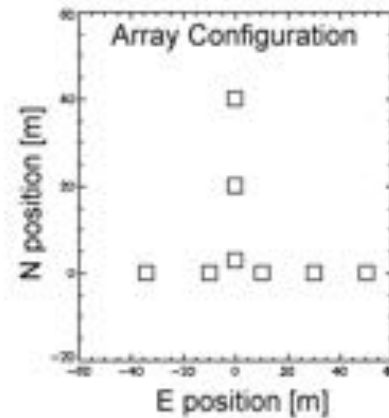
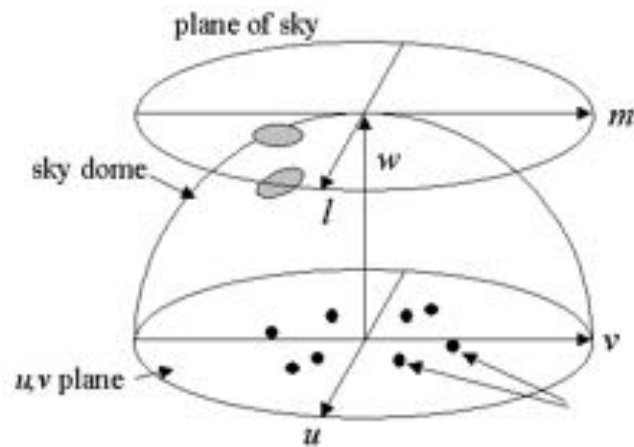
$$V = \langle v_1 v_2 \exp(-i 2 \pi \nu \tau_g) \rangle = |v_1 v_2| \exp(i 2 \pi \nu \tau_g)$$

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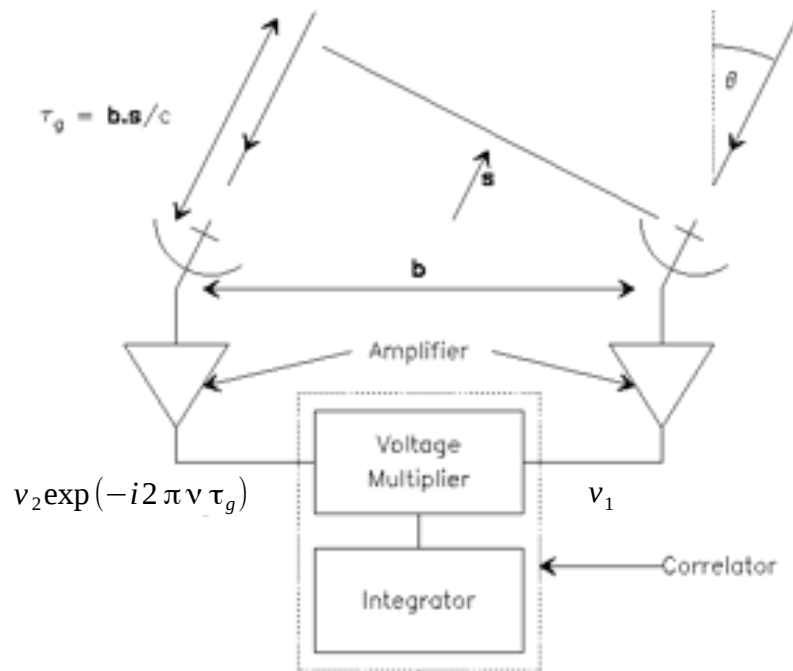
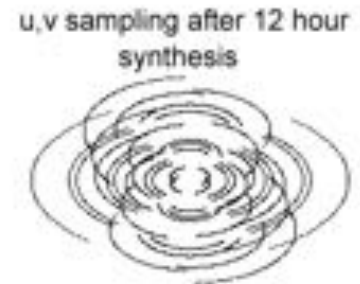
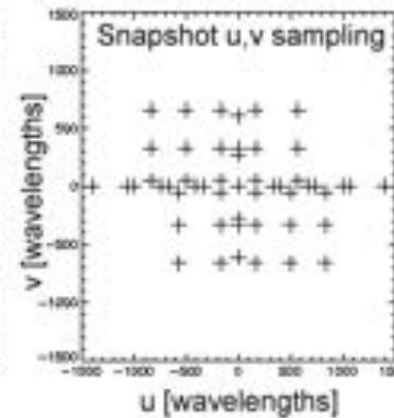
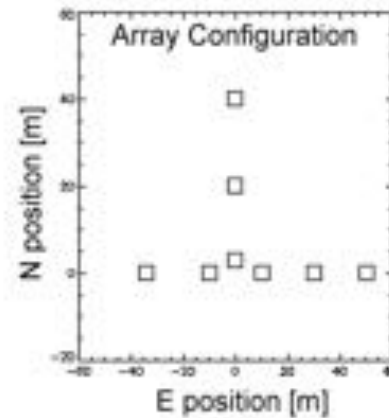
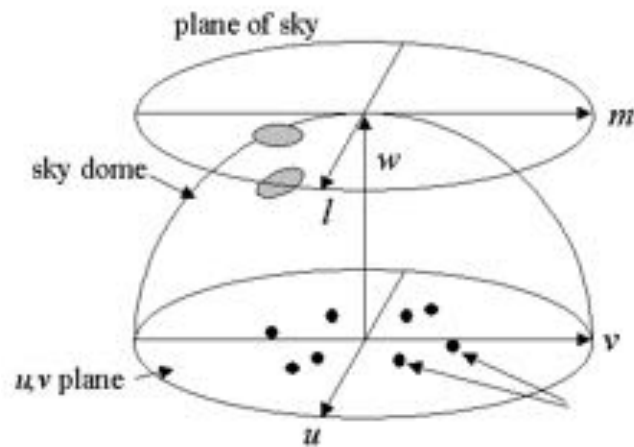
Imagerie par interférométrie radio



- Stabilité instrumentale pour les MRDs

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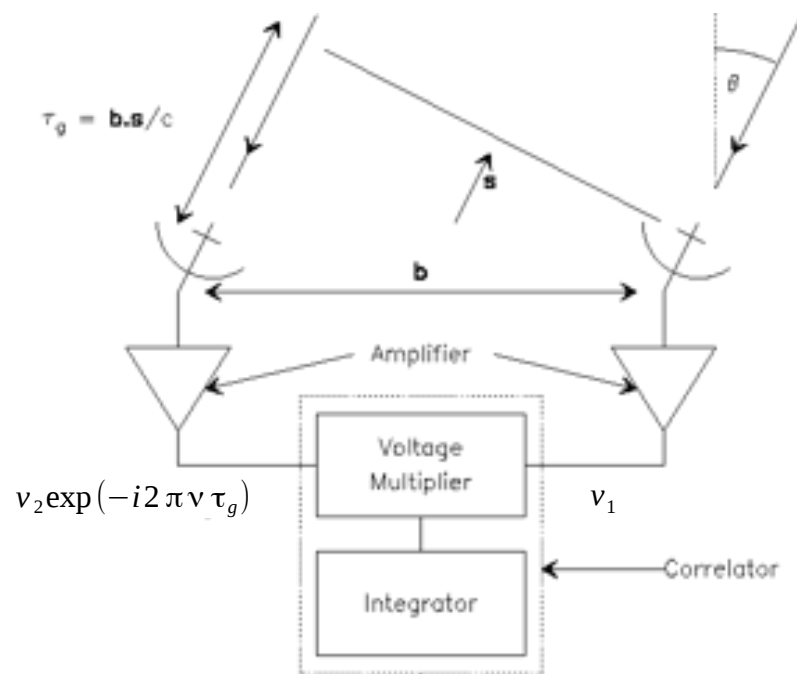
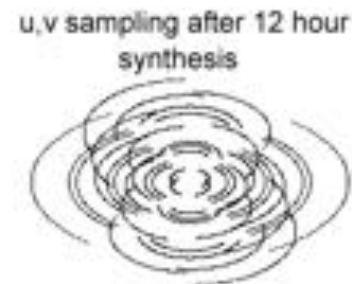
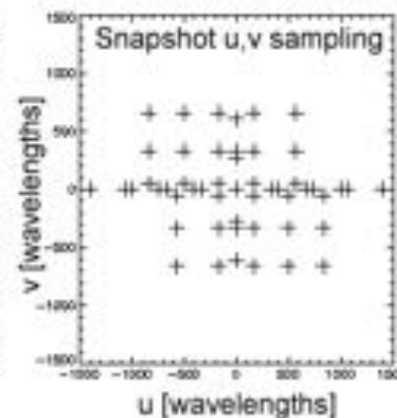
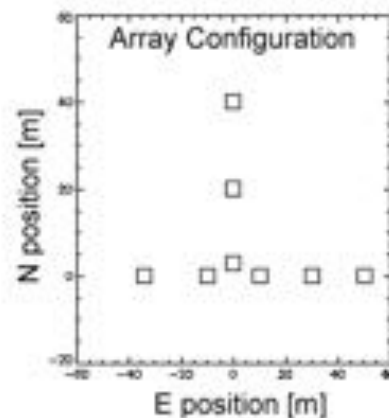
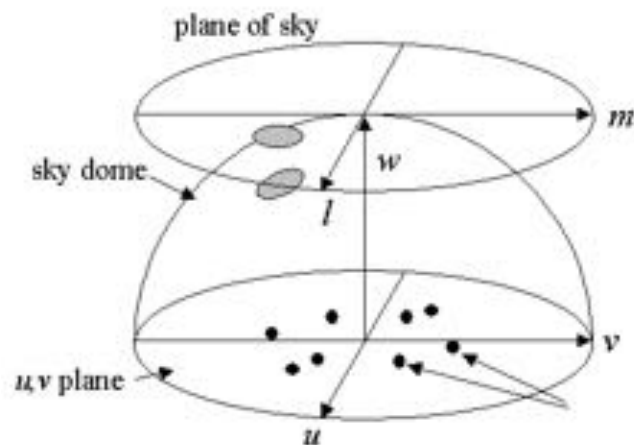
Imagerie par interférométrie radio



- Stabilité instrumentale pour les MRDs
- N feeds $\rightarrow N(N+1)/2$ visibilités
 - 96 MRs polarisés $\rightarrow 18528$ visibilités
 - Chaque visibilité coûte $4 B_{\text{Hz}}$ MAC/s (ou FLOPS)
 - 96 MRs dans 75 MHz $\rightarrow 5$ TFLOPS

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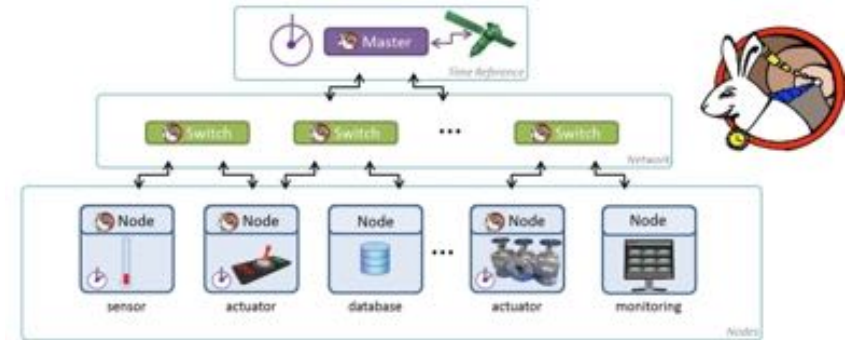


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- Transposition Antennes VS Bande coûteuse

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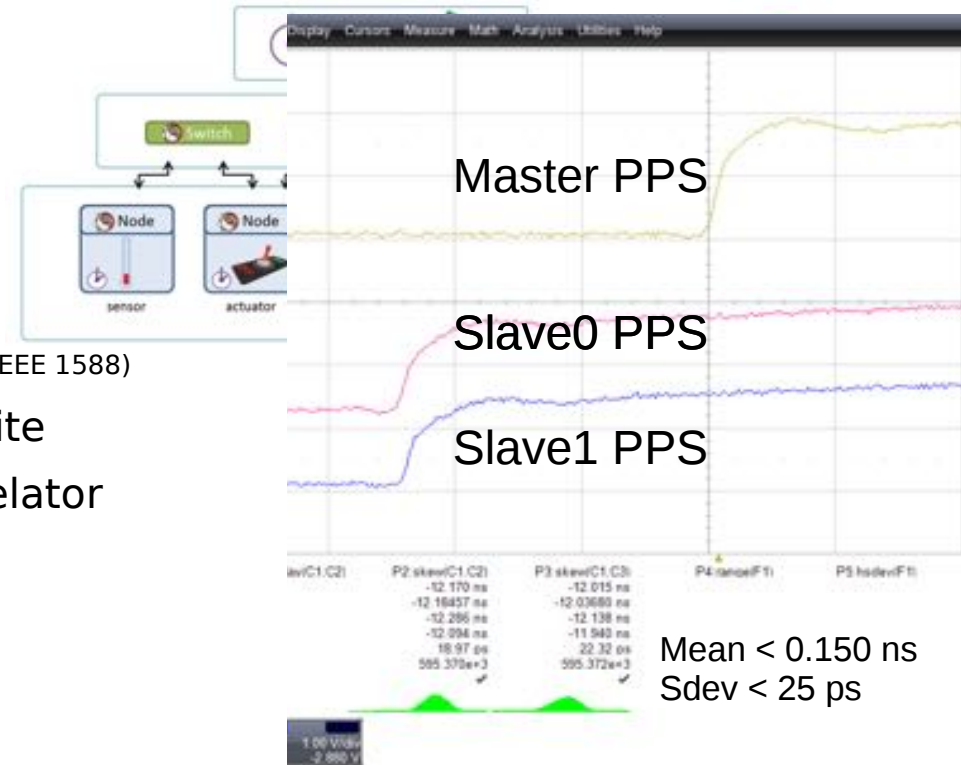
NenuFAR-Radio-Imageur

- Remote Digitization
 - WhiteRabbit network
 - Sub-ns fiber-based timing distribution (next IEEE 1588)
 - PPS and 10 MHz refclock regenerated on-site
 - 10GbE streams of beamlets towards the correlator
 - On-field constraints (cooling, RFI shielding,...)
 - Prototype en cours d'intégration



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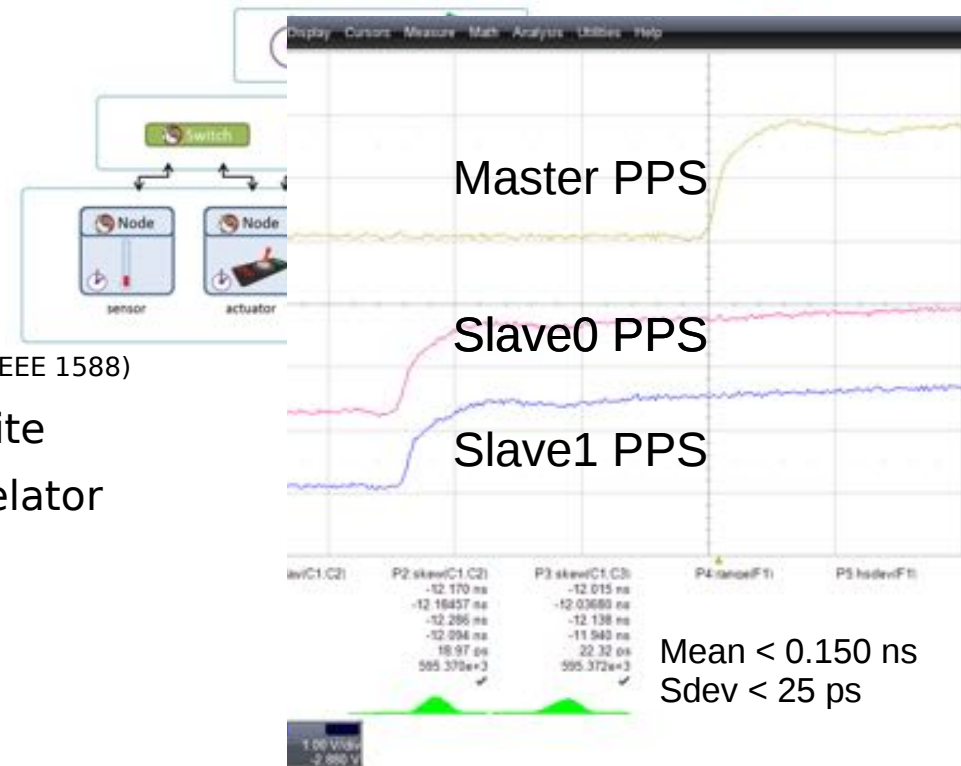
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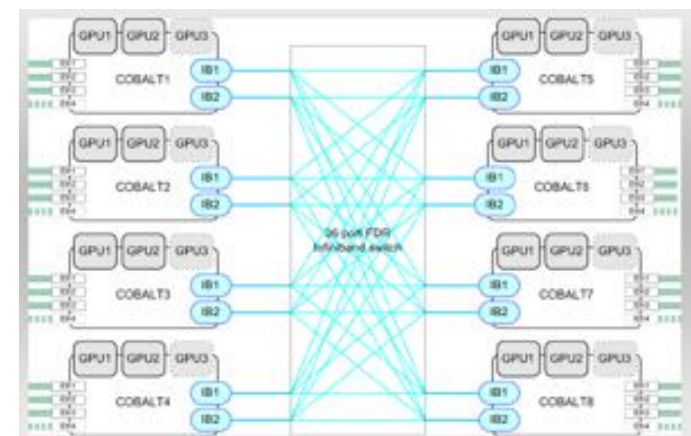
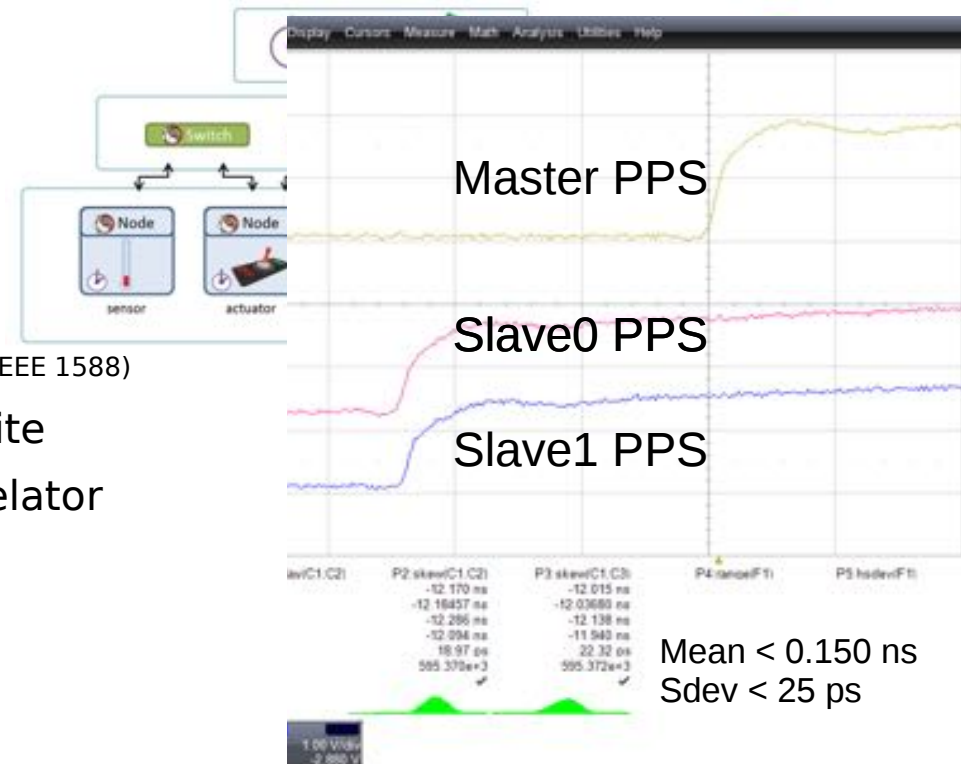
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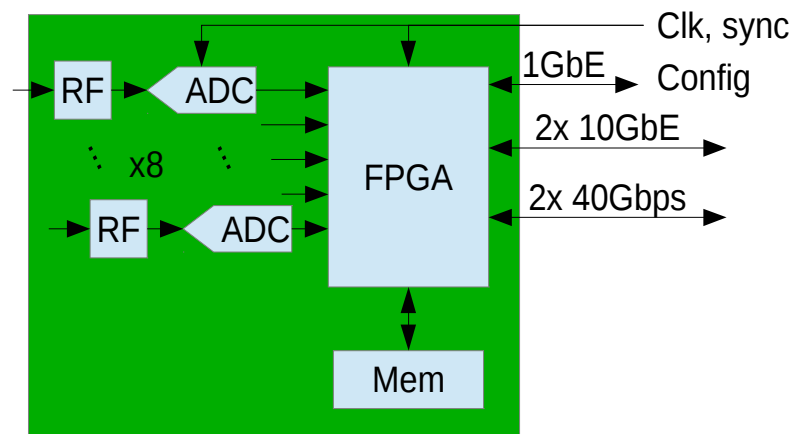
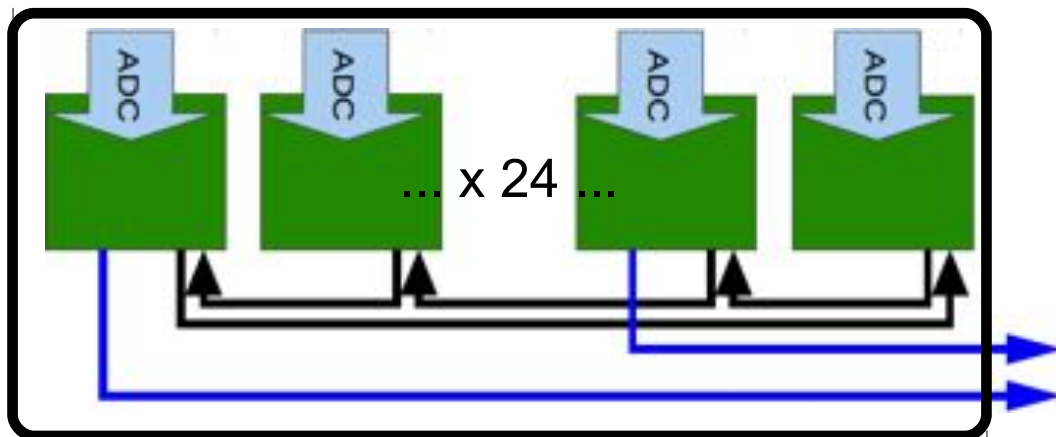
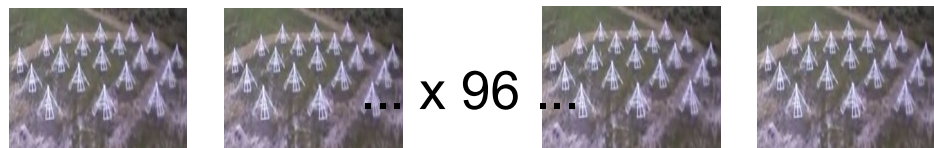
- Correlator
 - LOFAR-COBALT(1-2) based, (FPGA-based ???)
 - 96 antenna fields
 - 384 subbands (75 MHz)



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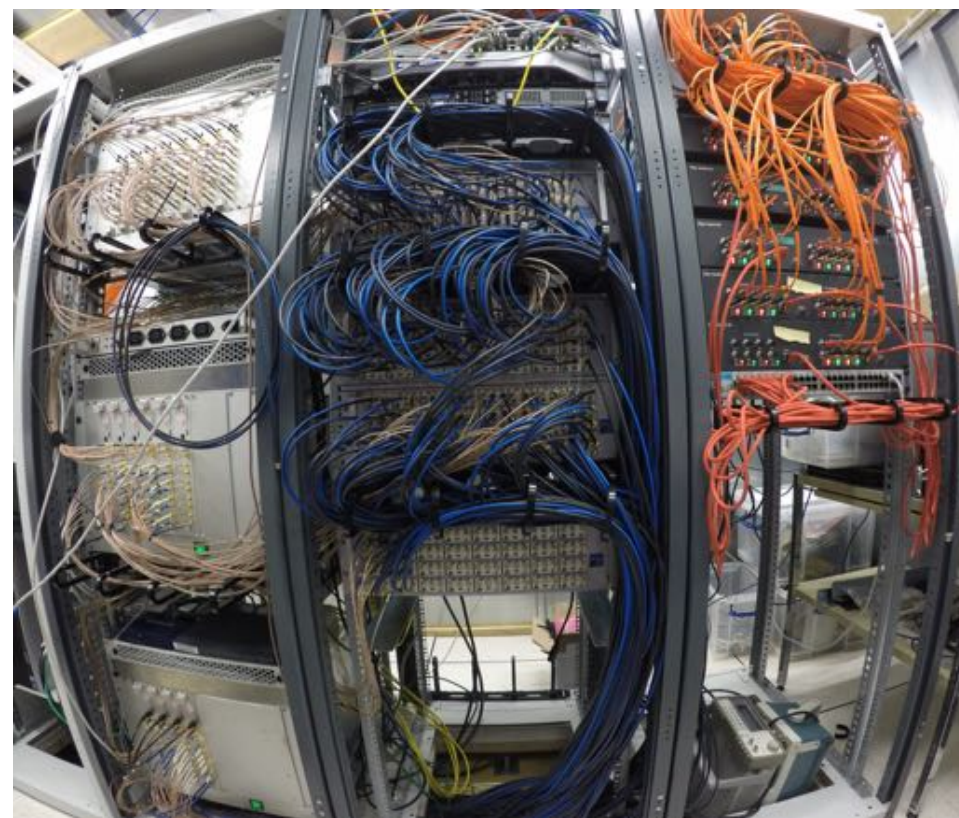
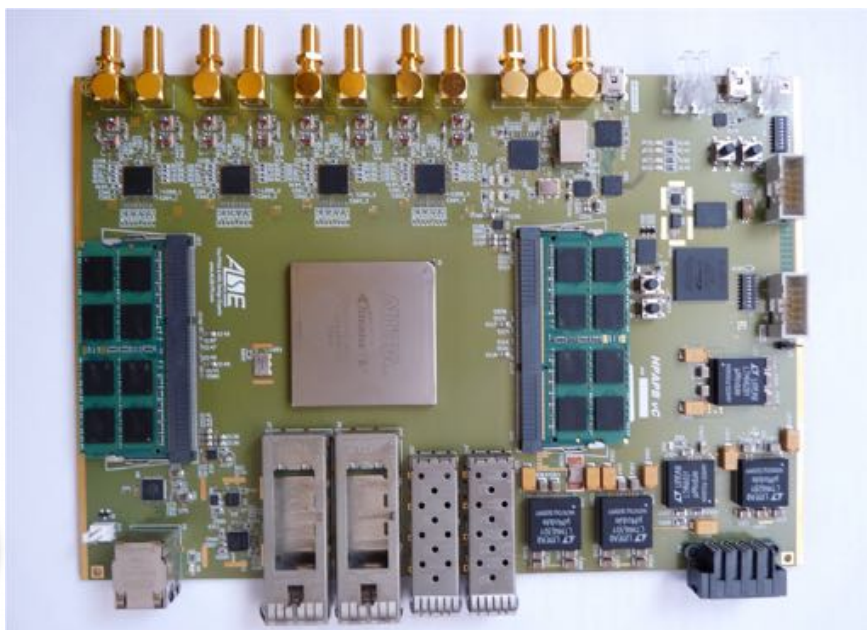
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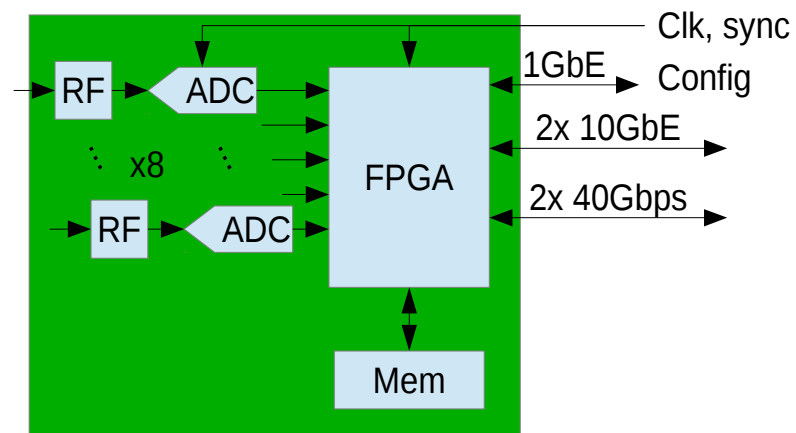
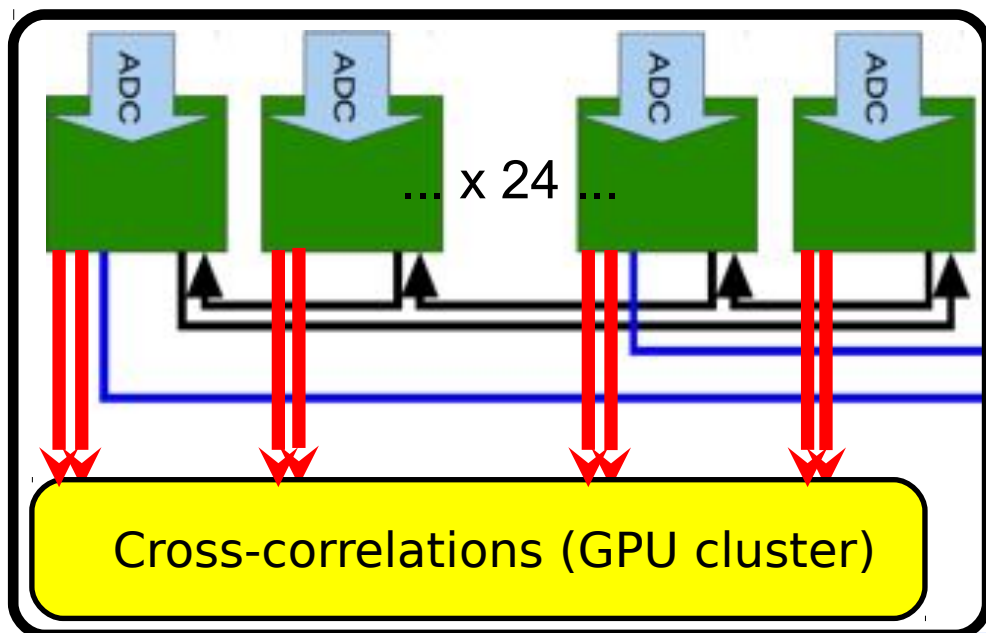
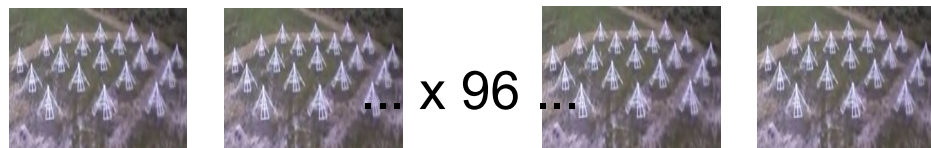




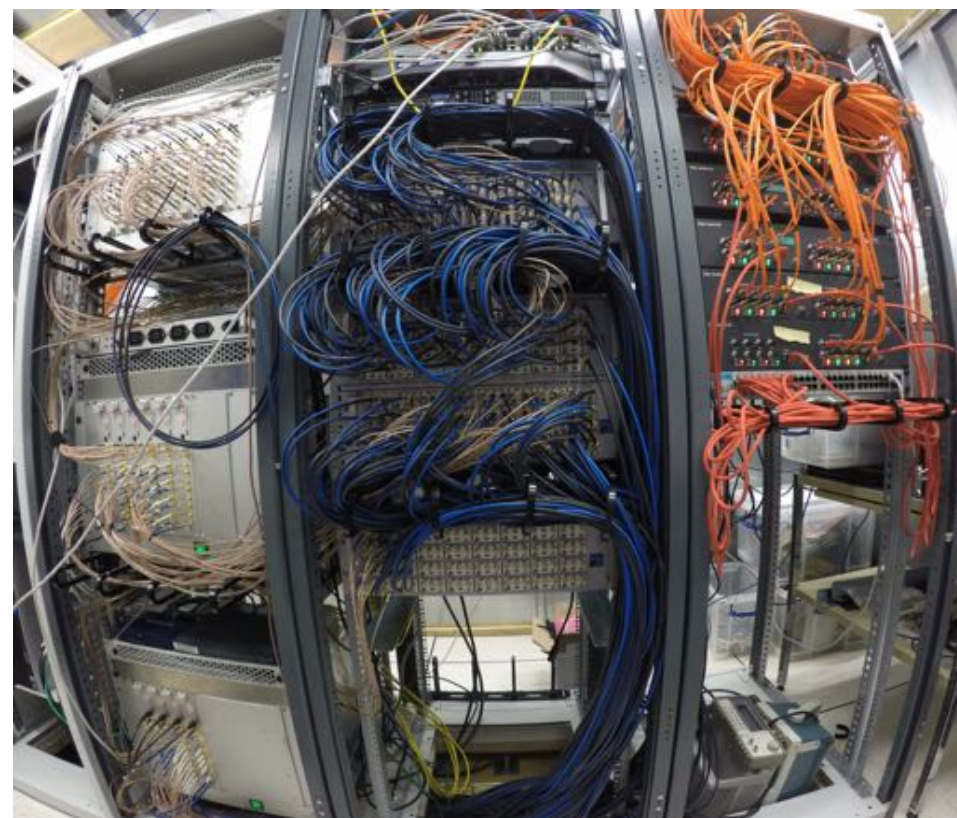
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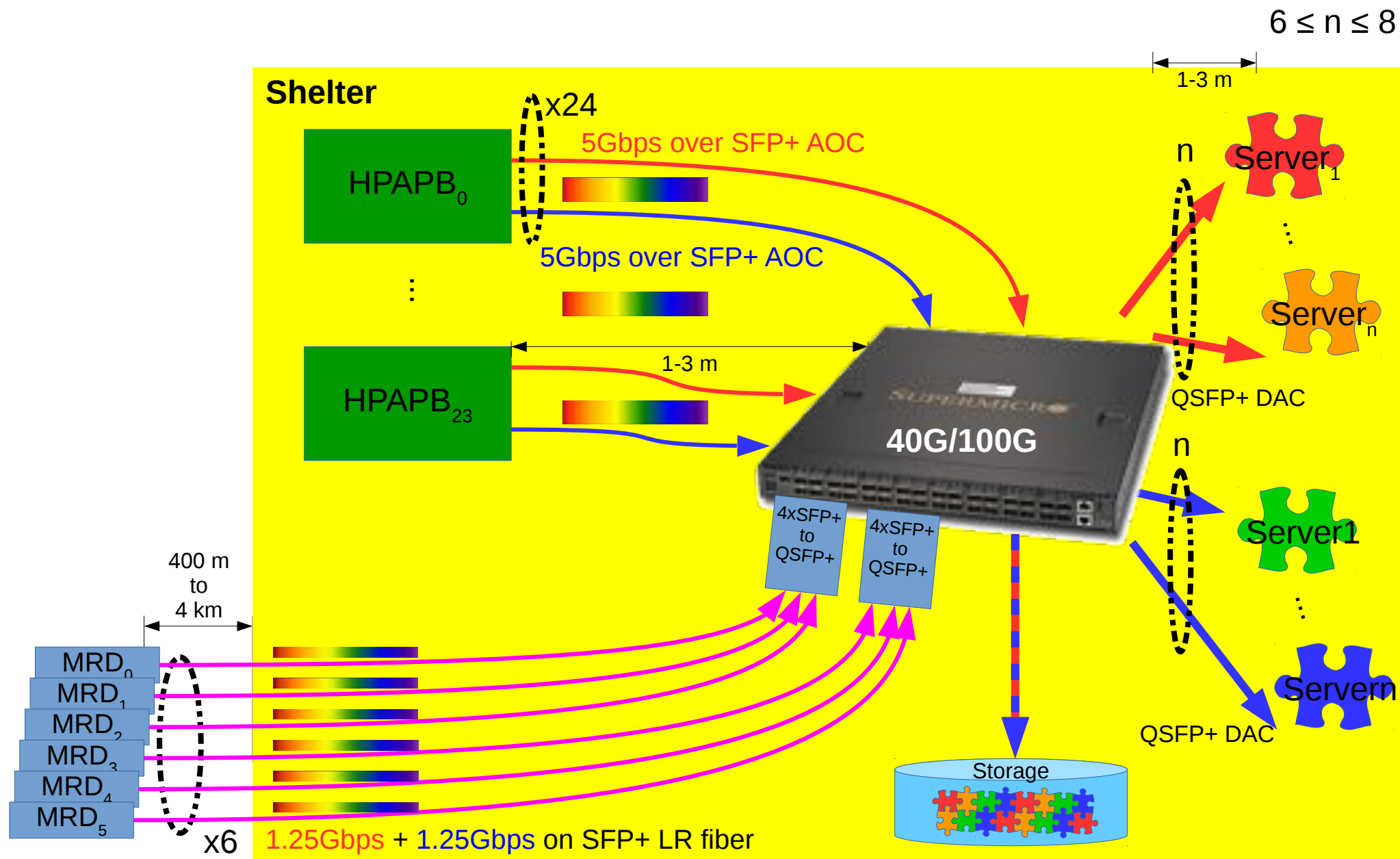




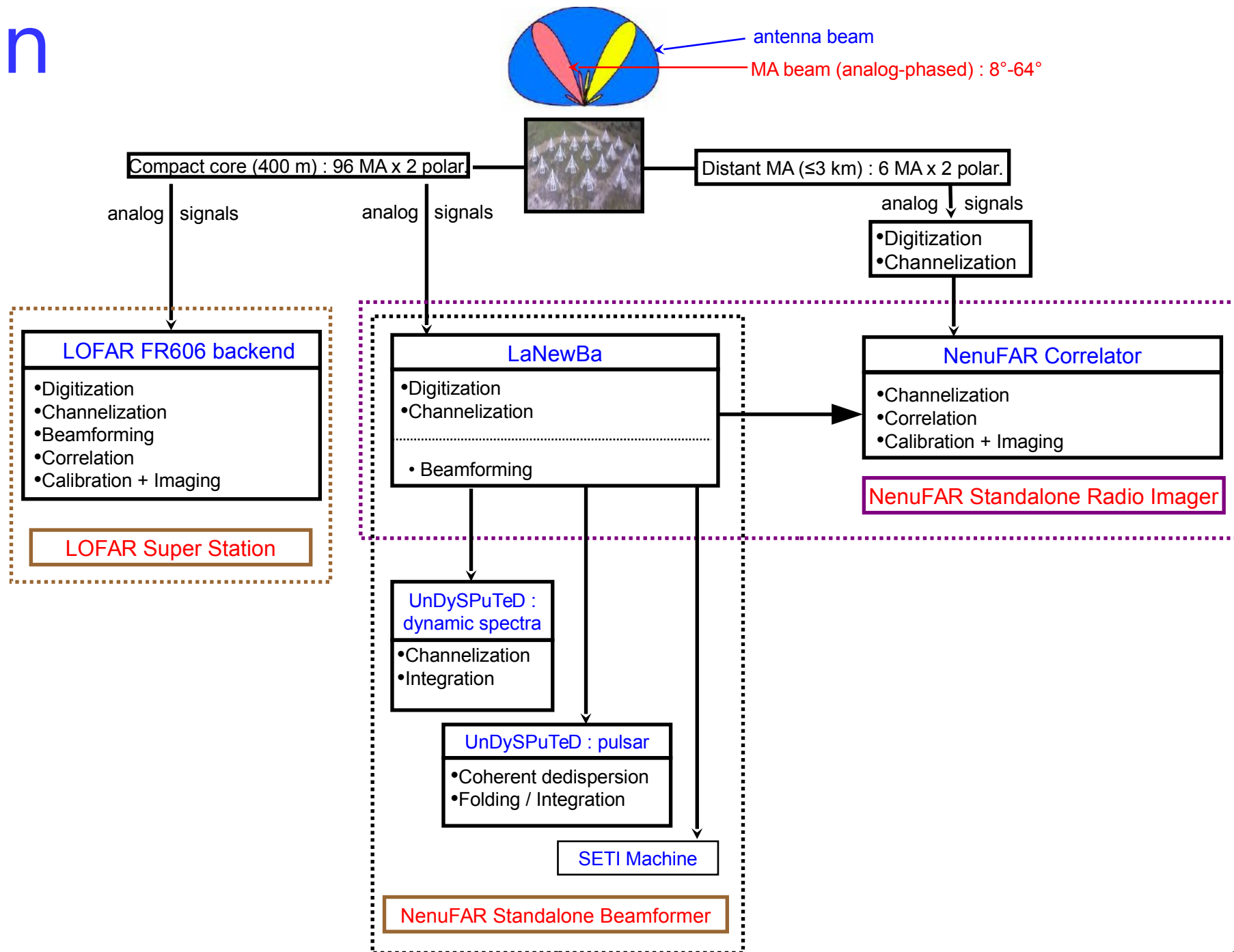
2 beams full-band ($\sim 10\text{-}85$ MHz), full-polar.



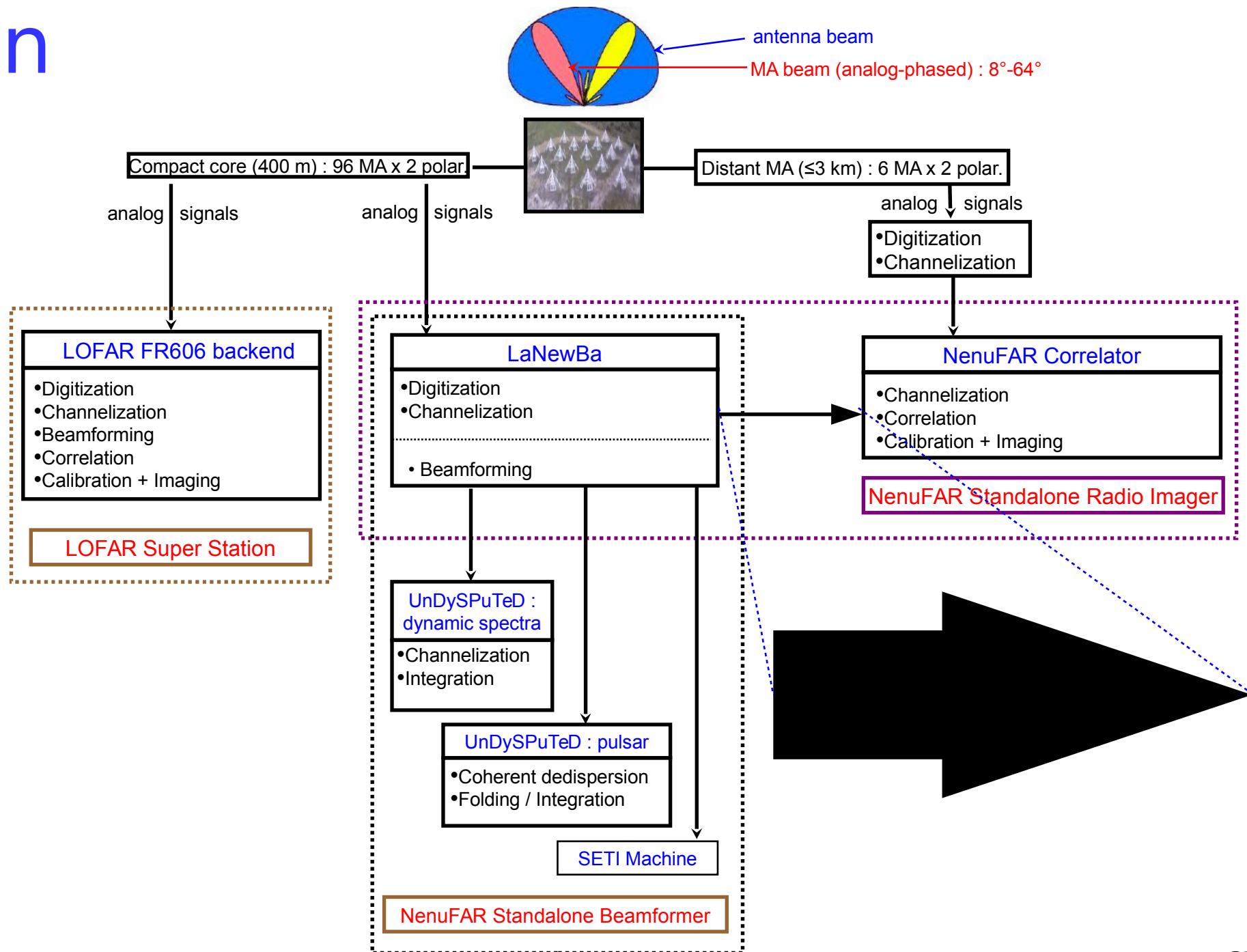
Distribution de données (en cours de déploiement)



Plan



Plan



Questions ?

