Radio-detection performances of CODALEMA using astronomical phenomena

La sensibilité de détection et les performances de l'expérience CODALEMA ont été évaluées en utilisant deux phénomènes naturels : l'observation d'une éruption solaire permet d'estimer la résolution angulaire inhérente à la méthode de triangulation, et l'observation du signal de fond radio galactique permet d'estimer la sensibilité des antennes en termes de champ électrique détecté.

During an initial phase of studies of the CODALEMA experiment at Nançay, conical helix log-periodic antennas from the Nançay Decameter Array [1] have been associated to 4 particle detectors, allowing to provide firm evidences for a radio emission counterpart of EAS [2, 3]. A good understanding of this detection method has been achieved taking advantage of two natural phenomena: the accuracy in the reconstruction of the arrival directions has been estimated using a radio emission from the sun; the calibration of gains and sensitivities of the antennas have been deduced from the analysis of the galactic signal modulation [4].

Solar flare radio observation: on January the 15th 2005, the mean squared signal seen by our antennas as a function of time was about 20 times higher than a typical day.

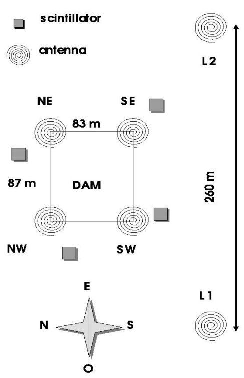

Fig. 1: CODALEMA set-up on Jan 15th 2005 during the sun emission..

In parallel, the Nançay Decameter Array detected a particularly intense solar activity during almost the whole day. Since the duration of the transient signals corresponding to EAS don't exceed a few tenths of nanoseconds, we have suspected that our 10 µs recorded signals mainly come from the sun emissions. To confirm this hypothesis, the arrival directions of the waveforms were calculated using the triangulation method developed for the shower detection with the current sep-up at that time (Fig. 1).

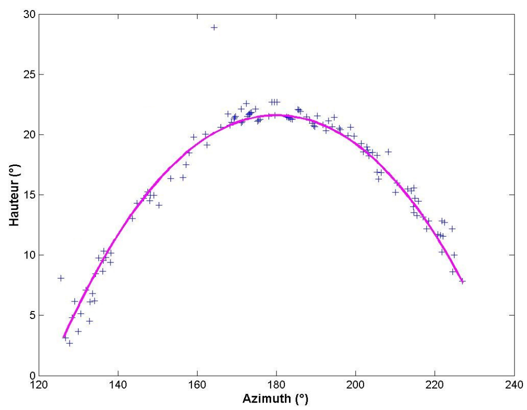

Fig. 2: Reconstructed directions (crosses) obtained using 3 (left circular polarized) of the 6 log-periodic antennas, compared to the Sun trajectory from ephemeredes (solid line).

The result of triangulation is plotted on Fig. 2 and compared to the exact trajectory of the Sun from ephemeredes. The angular distance distribution, after correction for systematic errors, fitted by the expected function (a Gaussian centred on zero multiplied by a sine function coming from the solid angle factor) was then calculated. A standard deviation of about 0.7°, which is the angular resolution related to point-like source detection by three log-periodic antennas, was obtained.

Galactic radio signal: as the distance between the source and the receiver must be higher than several wavelengths, the antenna calibration in the 1-100 MHz band is tricky. One way to perform it is to use the galactic background radio signal, provided that electronic noise and local emitters are not dominant. This is the case in the 37-70 MHz band at Nançay. Indeed, the signal standard deviation, averaged over all antennas, for each local sidereal hour has been calculated over a six months period (Fig. 3).

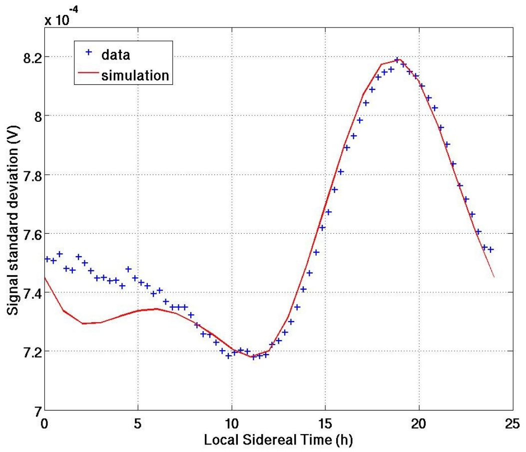

Fig. 3: Averaged signal as a function of the local sidereal time over 6 months. Red solid line represents the expected galactic background signal.

The signal dependence as a function of the local sidereal time (LST) demonstrates that our antenna setup is sensitive to a galactic signal (otherwise it would have been constant). Simulation of the radio signal intensity along the galactic plane was deduced using data from [5]. Using the formula discussed in [2] to convert voltage into electric field, the measured galactic signal corresponds to a field E = 7.7 µV/m. Assuming the galactic frequency spectrum in the 37-70 MHz band to be flat, the Fourier coefficient in this band is $(\varepsilon_{\nu})_{Meas}$ = 0.23 µV/m/MHz which is of the same order of magnitude as the theoretical expectation ($(\varepsilon_{\nu})_{Th}$ = 0.14 µV/m/MHz). This indicates that the response of our antennas for the galactic noise can be used for voltage conversion into electric field. In addition, the galactic radio signal can be used to make a more precise relative calibration between all antennas requesting that LST signal variations must be the same for each antenna. This relative calibration has indicated that the fluctuations between antennas are lower than 15%. Finally, the galactic signal is also a way to test the antenna directivity, as the antenna lobe is included in the simulation.

L'un des atouts de la technique de détection radio des gerbes cosmiques est de pouvoir mesurer de manière directe la performance en détection du système. Ceci a été réalisé en mettant à profit 2 phénomènes naturels détectés par le réseau d'antennes de CODALEMA : l'émission radio d'origine solaire qui permet d'estimer la résolution angulaire de notre méthode de détection, et l'émission galactique qui permet d'estimer la sensibilité des antennes en termes d'amplitude du champ électrique détecté. La résolution angulaire dans le cas d'une source ponctuelle non transitoire et pour un réseau de 3 antennes a été estimée à 0.7°. La valeur du champ électrique produit par l'émission de fond de la Galaxie dans la bande d'observation est quant à elle en très bon accord avec les mesures. La calibration relative qui en découle (entre les différentes antennes du réseau) a permis de montrer que les fluctuations de sensibilité d'antenne à antenne sont inférieures à 15 %.

[1] http://www.obs-nancay.fr/
[2] D. Ardouin et al., 2005, NIM A 555, 148-163.
[3] D. Ardouin et al., 2006, Astrop. Phys. 26, 341-350.
[4] J. Lamblin and the CODALEMA collaboration, 2007, Proceedings of the XXXth ICRC, Merida, Mexico.
[5] C.W. Allen, 1973, Astrophysical Quantities, Third edition, p. 269-272, The Athlone Press.