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An active dipole for cosmic ray radiodetection with CODALEMA

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Abstract

The CODALEMA experiment detects the electromagnetic pulses radiated during the development of Extensive Air Showers (EAS). Since 2005, in addition to spiral log-periodic antennas, ultra broad bandwidth active dipoles have been designed to detect the full electric pulse shape of these signals. A few performances of these new detectors are presented.

Since its installation in 2003, the CODALEMA set-up has used the antennas of the decametric array of the Nançay radio-observatory (1) allowing to highlight without ambiguity the existence of radio-frequencies pulses associated to EAS (2) (3). In order to extend the detection array, a more flexible and cheaper antenna was designed based on a short active dipole allowing a large bandwidth (0.1-100 MHz), a high sensitivity and a large reception pattern.

Fig. 1 shows the electromagnetic signals filtered in the 37-70 MHz frequency bandwidth due to a cosmic shower detected with CODALEMA. Cosmic ray pulses, appearing in time coincidence as oscillating structures due to the filtering, are clearly visible. The time delay between the various pulses allows to reconstruct the direction of the air shower by triangulation. Moreover, differences in amplitude of the pulses give the shower core location and the electromagnetic spread.

One easy way to achieve a wide bandwidth antenna is to design a short dipole associated with a high input impedance amplifier. The electrical model of this apparatus is a voltage source in serial with the antenna impedance, composed of a capacitance, an inductance, together with radiation and loss resistances. For frequencies well below resonance (up to 1/4 of the resonance frequency), the antenna impedance becomes equivalent to a capacitance due to a drop of the radiation resistance when decreasing the frequency. Loaded with an amplifier whose input impedance is a capacitance, a capacitive attenuator is obtained. The relationship between the amplifier input voltage and the voltage induced on the antenna becomes independent of the frequency. In this scheme, the larger the antenna capacitance is, the smaller the capacitive

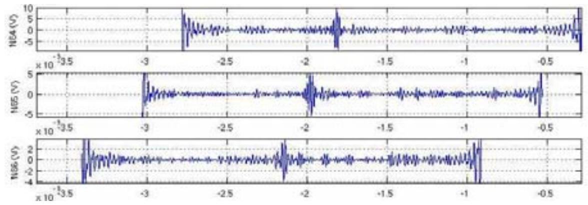

Fig. 1. Filtered transients induced by a cosmic ray detected in coincidences by 3 dipoles of CODALEMA (voltage in V vs. time in μs). Oscillating structures seen on the edges are artifacts due to the numerical offline filtering.

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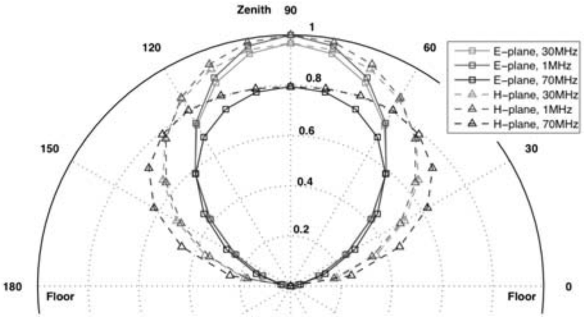

Fig. 2. EZNEC simulation of the dipole normalized gain (because the dipole is loaded by a high input impedance, the gain corresponds to a normalized voltage). The half maximum beam width is 120° for the H-plane and 90° in the E-plane.

attenuation is. One way to increase the antenna capacitance without decreasing the resonant frequency is to enlarge the antenna wire (fat dipole). In this configuration, the decrease of the antenna inductance lowers the Q-factor; the antenna can be used up to its resonance frequency and the Ohmic loss drops when compared to a thin dipole. The gain (*i.e.* directivity) of the dipole, placed horizontally above the ground, is constant as long as the antenna height is much below the detected wavelength and the ground characteristics stay constant. Fig. 2 represents the gain pattern of such a dipole (1.2 m length, 1.20 m height, 0.1 m wide) for frequencies ranging from 1 MHz to 70 MHz and for the E-plane and H-plane. At high frequencies (100 MHz), destructive interferences progressively appear due to the delay between the direct and ground reflected waves. Nevertheless the 100 MHz zenith gain is still one half of the 1 MHz one.

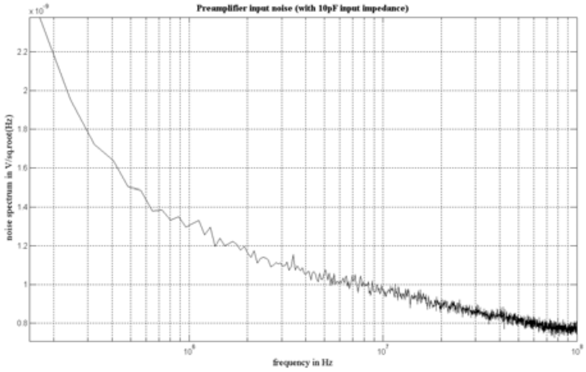

Fig. 3. ASIC measured input noise in $\mathrm{nV}/\sqrt{Hz}$ vs. frequency in Hz

To fulfill the noise and bandwidth constraints, an ASIC amplifier was designed at SUBATECH. The chip is based on 3 fully differential amplifiers. The input amplifier is low noise with a gain of 45 and a capacitive input impedance of 10 pF. The gain of the middle amplifier is programmable from 3 to 6.9. The power output amplifier is designed to drive a 100 Ω load. Because a low noise is required from the lowest frequencies and the antenna impedance is inversely proportional to frequency, a MOS transistor was chosen due to its absence of current noise. The flicker noise is reduced choosing a P channel whereas the thermal noise is lowered by sizing a wide PMOS transistor. A measurement of the ASIC input noise density is shown in Fig. 3. The middle range gain of the amplifier board is 34 dB with a high cut-off frequency of 240 MHz and a low cut-off adjustable above 10 kHz. The input dynamics is 24 mV and the consumption is 1/4 W.

Fig. 4 shows the frequency spectra measured in the range 1-150 MHz. The bottom plot corresponds to the analyser noise, the middle one shows the amplifier noise and the top one exhibits the performances of the whole device when detecting the sky. Since 2005, 8 such dipoles have been used in the CODALEMA experiment.

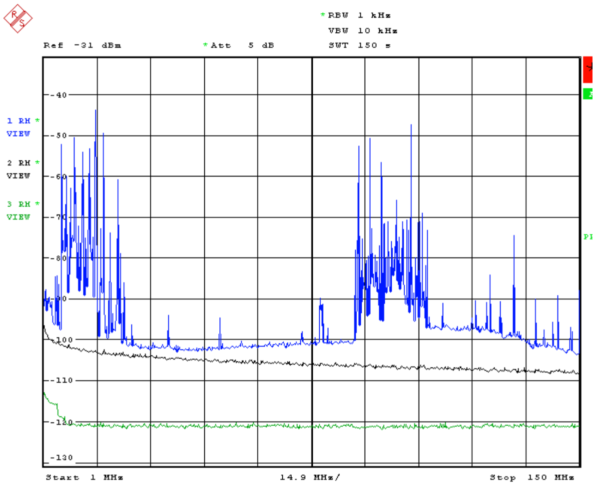

Fig. 4. Frequency spectrum measured with the apparatus (from bottom to top: analyser noise, amplifier noise, dipole signal). Gain are given in dBm/kHz.

References

[1] http://obs-nancay.fr

[2] D. Ardouin *et al.*, Nucl. Instrum. Meth. A 555 (2005), p.148 - astro-ph/0504297.

[3] D. Ardouin *et al.*, Proceedings of the 29th ICRC, Pune, India (2005) - astro-ph/0507160.