The Nançay Radio Observatory

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Abstract

The Decimetric Radio Telescope, the Radioheliograph and the Decametric Array are operational with renovated instrumentations. The french LOFAR station is installed and connected to the ILT. The CODALEMA experiment of cosmic shower radio detection has deployed 60 new autonomous antennae and the EMBRACE SKA-demonstrator is in its final phase of calibration and testing. R&D activity is growing rapidly with new developments in integrated receivers, focal plane array design and RFI mitigation techniques for SKA. The concept of an extended LOFAR station at 15-80 MHz is under study, for an area 20 times that of a single station.

1. Introduction

The Nançay Radio Astronomy Facility is jointly operated by the Paris Observatory (Observatoire de Paris), by the National Research Council for Scientific Research (Centre national de recherche scientifique - CNRS), and by the Université d'Orléans. In 2009, Nançay was one of the three founding laboratories of a new research institute called the Observatoire des sciences de l'Univers de la région centre (OSUC).
The Nançay facility specialises in low frequency radio astronomy, with the development and use of instruments which detect electromagnetic radiation in the frequency range from 30MHz to 10GHz. It is home to a number of large instruments for astronomical research. A number of scientific observations at Nançay are done in support of space programmes operated by ESA or NASA.

Fig 1. General view of the Nançay site. The Nançay decimetric large radio telescope (NRT), the Nançay Radio Heliograph interferometer (NRH) and the french E-LOFAR station FR606.

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2. Radio Telescopes

The large Nançay Radio Telescope (NRT) operates in the frequency band 1.1GHz to 3.5GHz.The NRT is the fourth largest single dish radio telescope in the world. It has a collecting surface of 7000 m^2, i.e. the equivalent of that of a 94 m diameter antenna. It is able to cover 83% of the entire sky, and with ample observing time available for scientific programmes (7000 hours of telescope time per year !). The NRT is used for a number of scientific projects from the chemical composition analysis of comets up to the dynamics of the large scale structures of the local Universe. At Galactic scale, this includes in particular the analysis of the mass-loss history and interaction with the interstellar medium of evolved stars and the precise timing of pulsars for both neutron star emission mecanisms studies and gravitational wave background detection. Concerning this latter point, the NRT is part of two large international collaboration, for the multi-wavelength support of FERMI observations and for the Pulsar Timing Array building effort. At extragalactic scales, the NRT is widely use for dwarf galaxies studies and large scale surveys of spiral galaxies at 21 cm within. Several thousands of galaxies have thus been measured in HI in the last decade.

Solar physics remains a principle interest at Nançay since the foundation of the facility. Two instruments currently make routine observations of the solar corona. The Nançay Radio Heliograph (NRT) makes thousands of interferometric images each day of the solar corona in the frequency range 150 MHz – 450 MHz, and the Decametric Array (NDA) collects high resolution dynamical spectra of the Sun at very low frequency between 10 MHz and 80 MHz. The Nançay Decametric Array is also used for observations of the planet Jupiter magnetosphere and as a test bed for cosmic shower radio detection. This set of solar instruments is being complemented with a new spectrograph (ORPHEES) in the band 100MHz – 1GHz, which should have its first light in autumn 2011.

In 2010, the E-LOFAR station FR606 was installed at Nançay. It is now fully operational and has joint the full network as part of the International LOFAR Telescope (ILT). A french consortium is also currently studying a concept of extended LOFAR Station, where each of the 96 antennae connected to the RCU could be replaced by a phased array of typically 20 antennae sensitive in the range 15-80MHz, thus creating either a second LOFAR core at low frequencies, adding sensitivity for long baselines, or providing us with a powerfulll stand alone instrument for a science case complementary to that of the ILT. This new instrument, if funded by our national agencies, could be installed at the Nançay site within 2014.

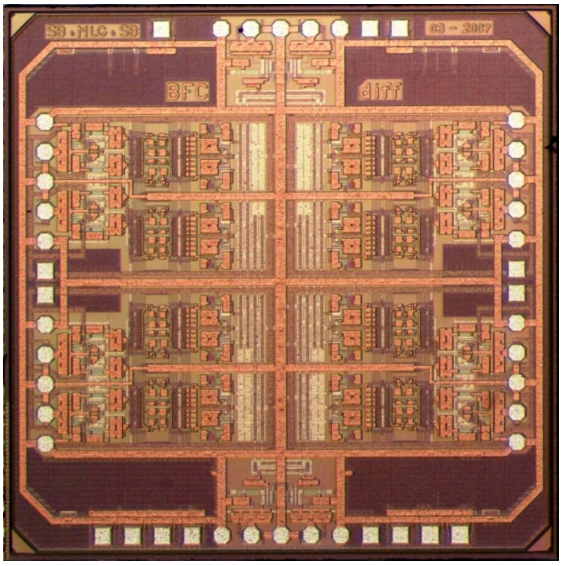

Fig 2 . The EMBRACE Beamformer chip (2,5x2,5 mm²) designed by Nançay engineers

3. Research and developments

Nançay is also the main site of development in France for technology leading to the next generation of radio astronomical facilities. This is done in partnership with European (ASTRON, University of Manchester) and the whole international radioastronomy community within the SKA common effort. Much of the research and development at Nançay is in the areas of microelectronics and signal processing. Integrated microchips are developed by Nançay engineers to perform multiple tasks such as amplification, signal digitisation, and signal processing. One of the application under study is the integration of components in an analog integrated circuit, ultimately combining a filter with Low Noise Amplifier in a single chip, and Analog to Digital Converters with Serialiser in a single chip. This technology is developped in the framework of the Apperture Array Verification Programme within PrepSKA/FP7. In terms of signal processing, Nançay engineers and researchers develop state-of-the-art pulsar coherent dedispersor backends (currently : 512 MHz bandwidth, 128 channels, 8 bits, dual complex polarisation), they design RFI mitigation algorithms for real time applications and implement them both in GPUs and FPGAs.

In addition to these instrumental developments, the Nancay site hosts several demonstrators.

The first one is the SKA demonstrator EMBRACE, a dense network of aperture arrays covering the frequency range 500 – 1500 MHz, and installed both at ASTRON (Netherlands) and Nançay. It provides two independent analogue beams of approximately 16 degrees beam width at 1 GHz. Both beams are capable to scan electronically more than 45 degrees from zenith using a combination of phase shifters and time delay lines. It is made up of 5000 single vivaldi elements phased together. Nançay engineers designed the analog beamformer chip used in the two demonstrators, one in France, one in the Netherlands.

The second one is FAN, a focal plane array developped for the NRT and based on phased array technology.

The third one is a new test instrument to characterize the radio emissions from atmospheric particle showers caused by very high energy cosmic rays. This instrument is called CODALEMA. It is made up of a network of low frequency antennae mixed with a set of scintillators. It is designed and built in collaboration with the SUBATECH sentence.

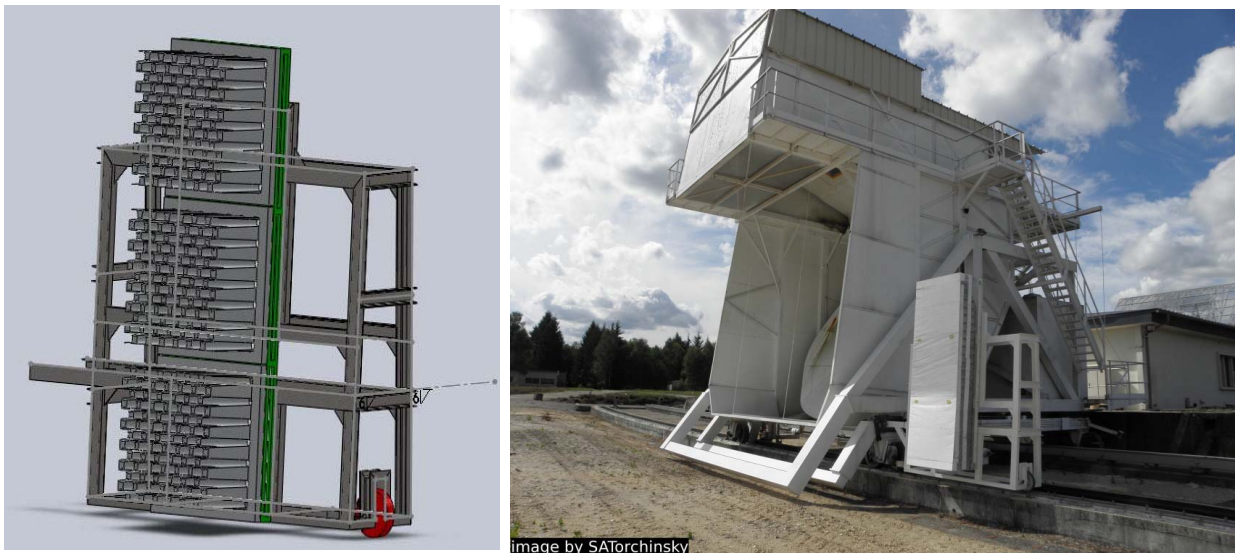

Fig 3 . The FAN focal plane array demonstrator design (left) and its first installation for testing, next to the NRT focal chariot (right).