THEORETICAL AND PRACTICAL RADIO FREQUENCY INTERFERENCE MITIGATION DEVELOPMENTS AT NANÇAY OBSERVATORY

Rodolphe Weber[(1)], Stéphanie Bretteil[(1)], Andrée Coffre[(2)], Pierre Colom[(3)], Cédric Dumez-Viou[(1,2)], Pierre Couratier[(1)], Laurent Denis[(2)], Eric Gerard[(3)], Guy Kenfack[(2)], Philippe Picard[(2)], Alain Kerdraon[(3)], Alain Lecacheux[(3)] , Philippe Ravier[(1)], Ivan Thomas[(2)], Philippe Zarka[(3)],

(1) LESI/Polytech'Orleans, BP 6744,Orléans, Cedex 2 F-45067, France, E-mail : forename.name@univ-orleans.fr
(2) Station de radioastronomie de Nançay, 18330 Nançay, France Email :forename.name@obs-nancay.fr
(3) Observatoire de Paris-Meudon, 5, Place Jules Janssen,92195 Meudon cedex, France,
Email :forename.name@obspm.fr

INTRODUCTION

Radio frequency interference (RFI) mitigation has become a significant issue for current and future radio telescopes. To some extent, the final power spectral estimation can be preserved by blanking polluted time frequency slots in real time. With this aim in view, several real time systems have been designed at Nançay observatory. In this paper, the following developments will be described: Multipurpose "Reconquête" receiver, FASR (Frequency Agile Solar Radio telescope) prototype receiver, Radar Pulse Blanker. Finally, results of real time RFI detection algorithm implemented in these systems and applied on actual observations will be shown. Moreover, different uses of cyclostationarity will be also considered.

MULTIPURPOSE "RECONQUÊTE" RECEIVER

Fig. 1 describes the global architecture of the robust radio receiver (R^3), see also [1]. It can drive simultaneously 8 signals (RF) coming from the different radio telescopes. Each RF signal is independently down converted to an intermediate frequency (IF) of 70 MHz, providing a final usable bandwidth of 14 MHz. These 8 IF signals are simultaneously digitized and processed by 8 banks consisting of digital modules plugged on PCI boards. To increase the observational flexibilities of the receiver, a switch matrix has been included in the analogue down converter process. Depending on its configuration, any of the 8 RF inputs can be redirected to one or more of the 8 IF bands. In particular, several sub-bands (contiguous or not) from the same RF input can be processed in several digital banks running the same or different algorithms. The primary function of the R^3 is to provide high resolution spectral analysis. This functionality has been implemented (see low part of the Fig. 1) in the two Field Programmable Gate Arrays (FPGA), leaving Digital Signal Processors (DSP) and part of a FPGA still available for post detection RFI mitigation technique. This receiver is connected to three Nançay observatory's radio telescopes: the decimeter radio telescope, the decameter radio telescope and the surveillance antenna.
Another receiver (Robin 2) is based on the previous one but it is specifically designed to decameter observations in Kharkov Observatory (Ukraine, INTAS 03-51-5727).

FASR PROTOTYPE RECEIVER

The Frequency-Agile Solar Radiotelescope is a groundbased spectro-imaging radio telescope designed specifically for observing the Sun. It will process large instantaneous bandwidths, possibly outside protected radio astronomy bands. As a result, it must face the problem of RFI mitigation.
Nançay is working on a concept based on quasi-perfect reconstruction digital filter banks (see Fig. 2). An analysis filter bank based on cosine-modulated filter bank is applied on the broadband input signal. By the use of a priori information on RFI, channels identified as polluted are discarded. Then, a synthesis cosine-modulated filter bank is applied on the RFI-free channels to reconstruct a clean broadband signal. A demonstrator of this receiver is under development at Nançay.

RADAR PULSE BLANKER

A Radar Pulse Blanker is presently in operation at the Nancay radiotelescope in two 50 MHz channels. The blanking signal which triggers the spectral autocorrelator is generated by a power level threshold video detector and interface circuit which includes a reference voltage and signal shaping.

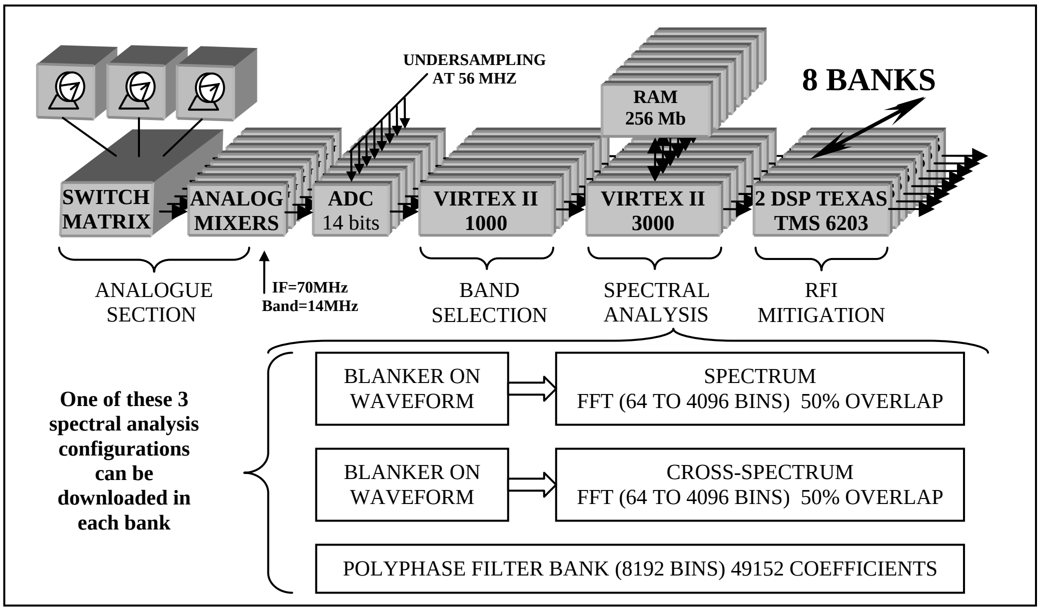

Fig. 1. Overview of the robust receiver. The flow can be reconfigured to share the calculation power between all the banks.

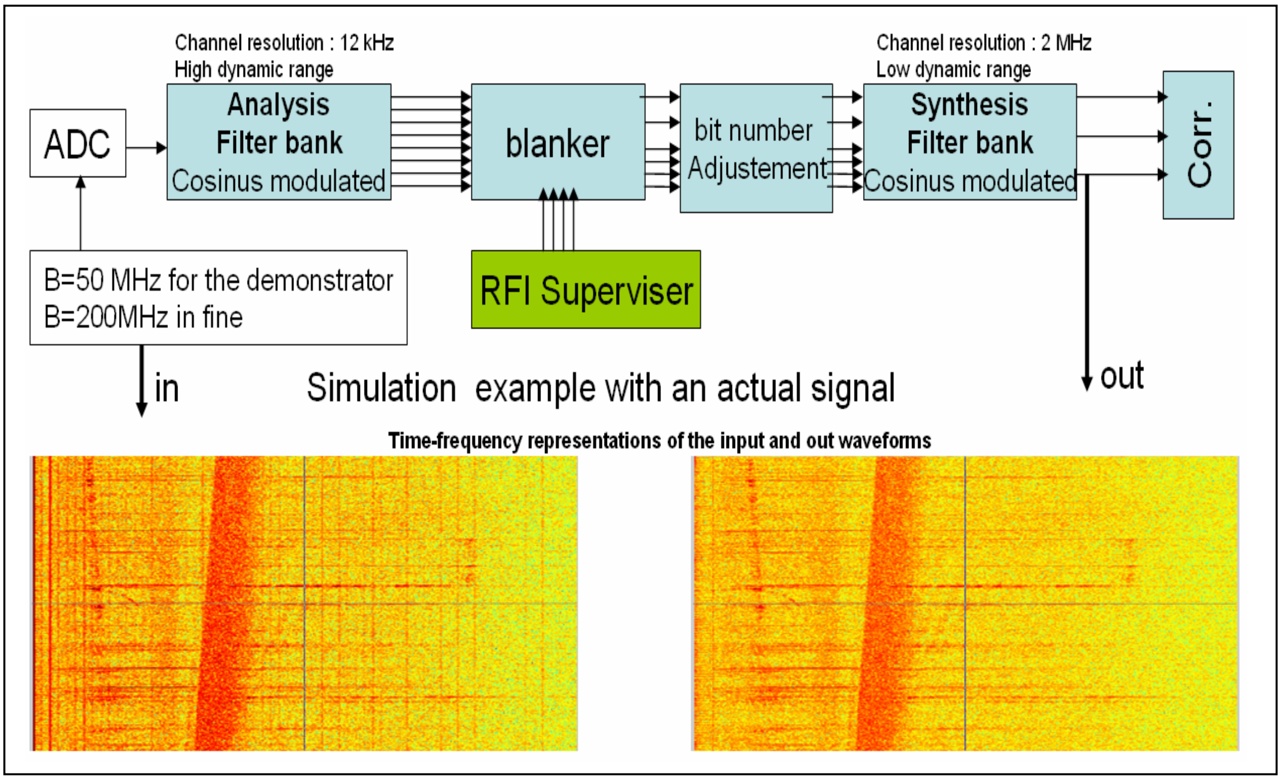

Fig. 2. : Architecture of the analysis/synthesis filter bank for the FASR receiver. A simulation with a signal polluted by spectral lines is shown at the bottom of the figure. The demonstrator will process a 4096 channel filter bank on a 50 MHz bandwidth input signal (the blue line in the middle of the time-frequency representations is just a superposed cursor).

For short pulse blanking the detection time is set lower than a few microseconds. To take into account the pulse falltime to the reference voltage (Vref) and pulse falltime from Vref, the duration of blanking signal is increased by 6 microseconds. A 3.2 microseconds delay line on the incoming correlator samples allows the time synchronization in the correlator array between the polluted samples and the blanking signal. An example is shown on Fig. 3.

ALGORITHMS IMPLEMENTED IN R^3

RFI-robust algorithms are designed and implemented at Nançay Observatory. RFI-blanking threshold by power detector is applied to Time and Frequency Division multiple Access (T-FDMA) modulations and ground based radar (GBR) interferences. Robust mean estimators have been developed to satisfy real-time constraints [2]. It increases blanking efficiency in the time-frequency domain and allows us the observation of both 1667 MHz and 1665 MHz OH frequency lines in the Iridium band (T-FDMA modulation) [1]. GBR pulse blanking is also performed digitally on 14 MHz bands (see Fig. 4). Statistical inconsistencies of the noise probability distribution function within a sliding window over the signal waveform leads to the detection of radar pulses as low as 0.8 times the standard deviation while keeping a low false alarm rate (2-4%).
Detection of brief events in the decameter band that is heavily corrupted with narrow band modulations and wideband interferences (lightings, ignition coils, ...) is under study at Nançay [3].

CYCLOSTATIONARITY

The present study focuses on mono dimensional signals coming from a single dish antenna. In the case of digital modulated RFI, we propose to use their cyclostationary properties with a view to detecting/blanking [4] when they are intermittent or estimating/canceling [5] when they are continuous. Fig. 5 shows simulations on the cyclic cancellation algorithm. The principle is to compute the synchronized averaging autocorrelation of the input signal. For specific values of the RFI carrier parameters, part of the synchronized averaging autocorrelation is free of RFI and it can be used to estimate the astronomical source. In Fig. 5, the simulated RFI is a spread spectrum emission. The modulation can be seen as a BPSK modulation with a symbol rate 8 times the sample rate. A raised cosine shaping pulse (193 coefficients and roll-off equal to 0.5) has been added to show the robustness of the method to any filtering. The astronomical source is a band-limited Gaussian noise emitting in the same frequency band as the RFI. The spectrum measured without blanking is shown in Fig. 5.a. Assuming that the synchronization with the carrier frequency has been done, Figure 5.b shows the result after cancellation. The RFI has been completely removed. The drawback is that the correlator configuration has to be driven by the RFI specifications. The sensitivity of the method will depend only on the precision of synchronization with the carrier frequency. The next step will be the implementation of such algorithms on real time hardware architecture.

PROSPECTS

In the framework of the European Ska Design Study, the Nançay RFI mitigation group (see web site at http://www.obs-nancay.fr/) will pursue these developments and will start new one on spatial filtering.

REFERENCES

[1] R.Weber, C.Viou, A.Coffre L. Denis, P.Zarka and A. Lecacheux, DSP-enabled radio astronomy : towards IIIZW35 reconquest, in press, *Journal of Applied Signal Processing*, 2005.

[2] P. Ravier and C. Dumez-Viou, Robust Mean Estimation For Real-Time Blanking in Radioastronomy, *EUSIPCO'05*, Antalia, Turkey, septembre 2005

[3] C. Dumez-Viou, P. Ravier and P. Zarka, Real-Time detection of natural brief events in a corrupted environment, *AG URSI*, New Dehli, 2005.

[4] S.Bretteil and R.Weber, Comparison between two cyclostationary detectors for RFI mitigation in radio astronomy, in press, *Radio Science*, 2005

[5] S. Bretteil, R. Weber and N. Bouguerriou, Spectral estimator of radio astronomial sources corrupted by digital modulated radio frequency interferences, *EUSIPCO'05*, Antalia, Turkey, septembre 2005

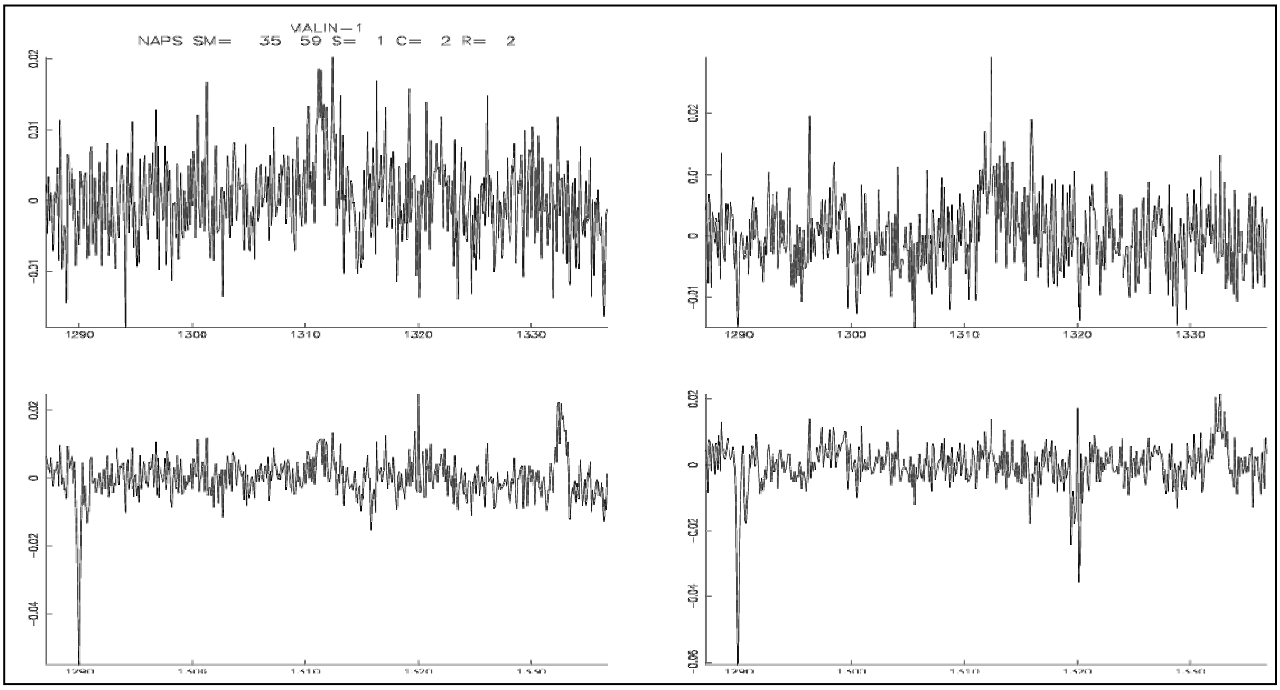

Fig. 3. This figure shows the 50MHz wide profiles (1311.95 Mhz center frequency) of the MALIN-1 galaxy with (top) and without (bottom) radar pulse blanker activated. The linear vertical (PA= 0) and horizontal (PA= 90) polarizations are shown separately on the left and right side of the figure. The flux density scale is displayed in Jansky and the integration time 25 minutes. The source itself is clearly visible at the center (top).

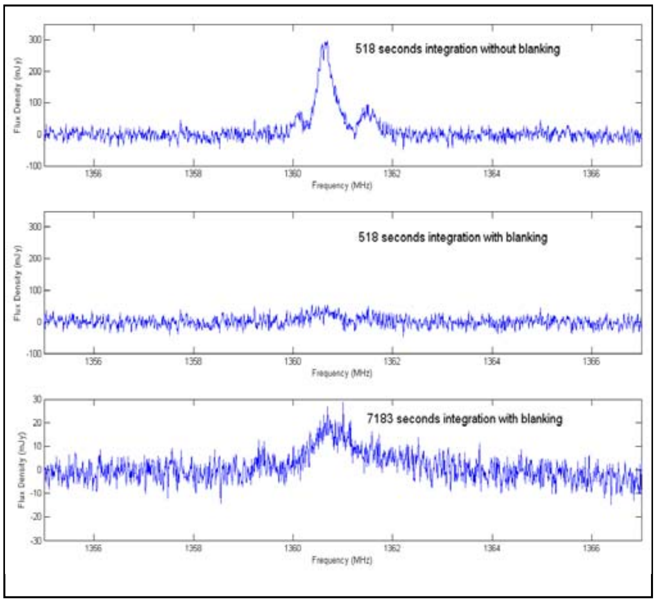

Fig. 4. : Example of real time digital blanking with R^3. The RFI is radar (top). The two others graphs show the averaged spectrum for different integration times. The astronomical source can be now detected.

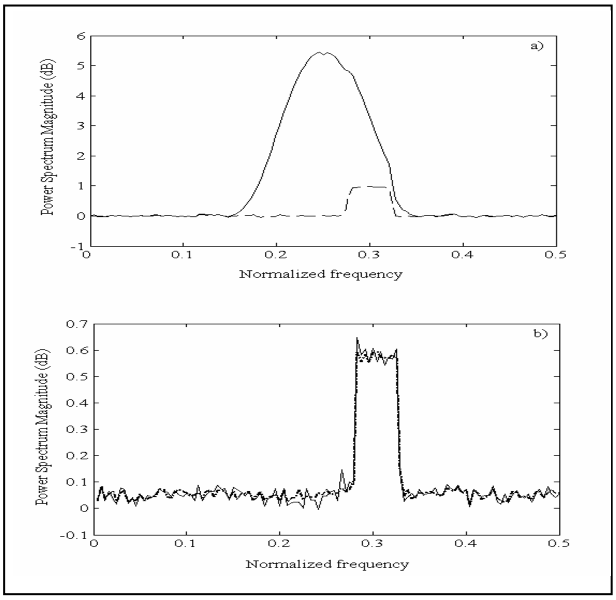

Fig. 5. Simulation of cancellation with a simulated continuous spread spectrum emission. **(a)** Spectrum estimated without cyclic cancellation. The position of the simulated cosmic source is drawn in dashed line. It cannot be detected with a classical spectral analysis. **(b)** Spectrum estimated with cyclic cancellation. The dashed profile is the expected one.