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DBBC Development Status

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Abstract. More DBBC units of version 1 have been built. DBBC version 2 has reached an advanced stage of development and realization. The detailed status of the project is presented including: the existing hardware versions and their layout, the main differences between DBBC.1 and DBBC.2, the new elements which are under development, the implementation timing for DBBC version 2, and observational tests. Moreover possible uses of the DBBC hardware as a general purpose backend for VLBI and radio astronomy are presented.

1. Hardware

A new class of boards has been developed for the DBBC in the version 2. This new implementation greatly improves performance and reduces the number of elements to realize the entire functionality of a Mark4 equivalent rack. A description of the main element is reported below.

The first ADB2 board prototype has been completed and initial testing has commenced. The board offers several operation modes with demultiplexing in two or four buses. Maximum sampling clock is 2.2 GHz, maximum signal frequency to be sampled is 3.5 GHz, 10-bit representation. A board ADB2 can feed as piggy-back element a FiLa10G, giving the possibility to place the sampling element at the receiver site, connecting the DBBC through optical fibers.

The new processing unit Core2 board, in the V5 version, was delivered and now is under test. The board is compatible with ADB1 and ADB2 and supports a minimal equivalent of four Core1 functionality. The PCB has a number of 40 equivalent layers and all the connections for signal transfer are differential, twisted, and matched in delay and impedance between the pads of the dice and the pins of the bus connectors. A piggy-back element can be adopted for additional functionality, like memory bank for pulsar de-dispersion, memory corner or other needs where a significant memory addition is to be adopted. The memory piggy-back is under the final stage of development.

The CaT boards (Clock and Timing) are ready and under test: the Clock board is able to generate a highly flexible number of synthesized sampling clock values (e.g., 2048 MHz, 1024 MHz), phase locked with an external 10 MHz. Low phase-noise and very small sensitivity to temperature are the main performance. The Timing board is producing 1PPS synchronization signals for all the ADB boards and the entire digital chain. Frequency selection with the use of different VCOs for large range selection is programmed by using the DBBC internal PC Set.

The FiLa10G boards realization is under way and the first prototype of the board is expected in summer 2008. It can be used as piggy-back board for any ADB2 sampler, giving the possibility to transmit and receive at the same time a high data rate of 20 Gbps + 20 Gbps. The bidirectional functionality could be required for instance when an RFI mitigation is needed to be realised in a remote location with respect to the sampling and processing site. With the typical sampling frequency of 2.048 MHz and the full 10-bit data representation, a double optical fibre set meets the full data handling requirements. Moreover the board is equipped with two additional transceivers able to operate at 1-2-4 Gbps for slower connections. The full number of transceivers is four and all or a subset can be used, with the possibility to populate the board with any number of them, depending on the needed functionality. The board indeed can even support the data tx-rx of 2×2 VSI connections and in such a case can still be used as p-b element of an ADB2 or as stand-alone element. The configuration files can be also loaded by the on board stand alone flash memory. The entire triangle connectivity HSI/HSIR–VSI-in/VSI-out–Optical-Fibers is supported. The board can support the connection with the Mark 5C recorder and its ancillary in a DBBC system as long as MK5C is not in the field. The FiLa10G is at an excellent level of development, and a test bench is progressing in MPI in parallel with the final board preparation. On the test bench it is possible to hardware-verify the entire data flow from the data input (as coming from samplers or from a down-converted data stream) up to the optical physical layer. The final board, after verification with the test bench will be finalized for a complete prototype. The first complete FiLa10G prototype is expected in June, final delivery time is September. FiLa10G is necessary only for MK5C connection through 10G, while DBBC.2 will in any case be usable with 2 VSI connection even at 4 Gbps.

2. Firmware

Some elements of the already developed configurations still need to be improved, mainly the xxx.99 MHz tuning setting, now achievable with a fractional difference of about 9 mHz, and a high sensitivity in the correlation amplitudes with the IF levels. Several approaches are taken into consideration and an iterative process of observations-correlation-configuration modification is followed. The same method is going to be realized for testing other features. In order to accelerate this process, EVN members, that will be willing to contribute to the development, could dispose of a small DBBC kit to verify their implementation. The same kit can be used for developing different functionalities of the backend system. Several groups are already working on different kinds of functionalities with the DBBC programmable kit; the products are expected to be shared among the system users. Related to the VLBI functionality it can be cited, for instance, a multiband fixed tuning configuration that is in development and shortly expected, to be used as an alternative to the standard base band converter configurations. This configuration is what the IVS2010 is suggesting as back-end method for the wide band observations.

3. Observation

The Europe89 was observed for 12 hours in September using 8 BBC equivalent in X band and 3 BBC equivalent in S band: fringes have been detected in all the sub-bands. Euro90 observed 24 hours at Wettzell with all the standard number of sub-channels (8 BBC equivalent in X band and 6 in S band).

A technique to compensate for fractional frequency offset is under evaluation. Indeed a frequency correction is needed at the internal DDS frequency resolution, as geo observation needs to detect cal at 10 kHz from the integer MHz. More options are possible and observational tests are underway to determine the best solution. An ad-hoc DDS based on binary-decimal phase counters can be adopted. It could be applied a firmware millisecond phase adjustment using the available frequency setting in a dedicated sequence to achieve the avarage exact frequency. The method has been demonstrated at the Bonn correlator with 24+1 sequence in a 25 seconds long scan correlation with the Europe90 experiment.

The digital system use requires to optimize or to equalize the IF flatness in band: a new version of Conditioning Module is under development to optimize this aspect, but a good equalized band is expected from the receiver. Additional observational tests will be realized with the Wz unit. Testing will be accelerated with the introduction of a DBBC.2 system even in Effelsberg for a fast evaluation time with the correlator.

A further improvement is also expected by the introduction of better in/out band filter rejection, achievable with the additional resources available in the Core2 boards.

Dedicated Web pages have been added to the Noto Internet server with information about the DBBC system. A document series is in preparation and it started to be available in these pages, so as a page with News.

The integration with the FS is now almost ready. It is realised in a first time as a collection of station commands, as the software structure the DBBC is able to recognize. The system gain information in the different part of the instrument are recorded in a log that can be available under a specific FS command request for calibration purposes.

4. Production

INAF is going to support a spin-off company creation for the DBBC production. This process started about one year ago and will be completed in the first semester 2008, as soon as all the bureaucracy will be completed. A final documentation will be ready in the end of Apr. and the final approval is expected in summer.

The company will have an agreement with IRA-Noto Section, where laboratories will be placed for a part of the production. Its under evaluation the possibility to take an other part of the production in MPI, for an initial setting phase.

The production phases have been carefully defined and a certain number of operations will be realised by external companies. The full process time for a complete system, tested in laboratory, will be three months, and in parallel more systems (1–6) could be built, with the initial manpower and logistic capability.

5. System Deployment

On Nov. 5, 2007 a geodetic version of DBBC arrived in Wettzell. The Wettzell DBBC system comprises 4 IFs and 14 equivalent base band converters. In the same month it was installed and integrated with the other VLBI equipment. Recording of its output is realized with a Mark 5B+ system. Europe90 observation has been done for testing the equipment. Fringes have been found on all channels and data analysis in underway. Some elements require to be revised, mainly related to the calibration tones exact tuning and the sensitivity of the correlation amplitude to the IF amplitude. The second and third system for Wettzell are ready in all the other parts and waiting for completion of the final delivery of the new Core2 boards. Indeed even if the three units have been ordered in the 256 MHz IF version, without synthesizer, equipped with Core1 boards, the new version will be delivered, and also the first unit will be upgraded as DBBC.2.

The DBBC system for Irbene (Latvia) has been completed and in the first days of February it was transferred by Latvian colleagues to their station. The Irbene DBBC is a reduced version having two IFs and 2 Core1 boards. As soon as Irbene will be able to upgrade the system, few Core boards will be added to achieve a complete architecture. At present the system will allow to perform the first observations and tests of the antenna and the 6 cm receiver.

A system similar to the Irbene one has been delivered to the Arcetri Observatory. The main purpose is to use it as a development system for FPGA configurations devoted to the realization of spectrometer, pulsar, total power, polarimetry back-end. The Arcetri team is part of an FPGA team established to support firmware development on the DBBC platform.

Other complete DBBC.2 systems are under construction for Yebes, Effelsberg, Noto, Medicina; and in particular the Medicina unit is expected to support the multibeam 22 GHz receiver (7 feeds $\times$ 2 polarization $\times$ 2 GHz bwd/ea) for VLBI and single dish applications.

6. Linear to Circular and Stokes Conversion

Different projects are under development within the DBBC hardware. One is described in this section. The main goals are the conversion from linear polarization to circular polarization and the formation of Stokes parameters in the DBBC for single-dish broad-band polarimeter. The reason for requiring this is that Effelsberg and geodetic antennas are moving to broad-band feeds and extremely-broad bands are possible only with linear polarization.

It looks as VLBI is simplest with circular polarization, and existing analog polarizers are narrow band due to imperfect 90 phase shift. A possible solution is envisaged by making perfect 90 phase shift across broad bandwidth digitally (e.g., Hilbert transform).

Processing Steps in this process:

1) receive time series from ADC at 1 Gbps,
2) measure gain and phase difference between X and Y polarizations,
3) fourier transform time series to frequency domain,
4) equalize the gain using result from 1),
5) shift phase of one polarization by 90 in each frequency channel,
6) D-term correction (idea by Koyel Das):
    6.1)correct for leakage between X and Y,
    6.2)form X Dxy Y and Y Dyx X outputs using an adaptive filter,
    6.3)filter to adjust D to minimize the output power.
7) fourier transform back to time domain.
8) form circular polarization by summing X and phase-shifted Y.
9) send result from 8) on to existing DBBC processing stages.
10) take result from 6) and form Stokes parameters and integrate in time.

The expected result would be excellent circular polarization over wide bandwidth, zero D-terms, Stokes parameters in many channels over wide bandwidth.