DBBC3 - A full digital implementation of the VLBI2010 backend

Gino Tuccari

INAF, Istituto di Radioastronomia
e-mail: `g.tuccari@ira.inaf.it`

Abstract

The project of the third version for the DBBC backend system implementation is presented. This system is able to fully implement in digital the functionalities required by a complete VLBI2010 backend, including the sky frequency conversion in the entire range 2-14 GHz, so avoiding any need of an analogue down-conversion to be used as pre-processor of a polyphase digital filter bank. The architecture and adopted methods are described.

1. Background

The DBBC development started in 2004. During the previous few years ad-hoc experiments in laboratory and with real signals from the sky indeed had demonstrated as it could have been achieved the possibility to emulate in the numerical domain the entire functionality included in the MK4 VLBI analogue terminal, converting immediately the signal available as IF from the receiver. This process was not anyway straightforward to be fully included at a reasonable cost and moreover at that time it was a challenge for the wide band and the high frequencies involved. During the first decade of 2000 with progressive improvements the DBBC project generated an evolution in the input bandwidth up to 8 x 1 GHz, and output data rate up to 32 Gbps. The first version (DBBC1) was a replacement one to one of the existing VLBI terminal, while with the DBBC2 in addiction to such possibility included more observing modes, not existing in the analogue backend. This has been still enhanced within the VLBI2010 that is a backend able to accomplish the VLBI2010 observing mode, the coming next generation of geodetic VLBI backend system. The VLBI2010 mode operates in a single wide band ranging between 2 and 14 GHz. Inside this range four 512 or 1024 MHz wide pieces are selected, in both polarizations, to realise a band synthesis translated in a much wider portion of spectrum with the respect to the present one. Such wide portion of input band is also of great interest for astronomy because of the significant increase of sensitivity. Having the chance to process an entire piece of band wide 14 GHz could then represent an actual quantum leap in the digital radioastronomy data acquisition. The goal is very ambitious and represent the first time we are aware of, for such an implementation in the radio technology. This is the goal for the DBBC3.

2. DBBC3 Structure

The DBBC3 system needs to meet some mandatory requirements: to be compatible with the existing backends of the previous generations and to be able to realise the new functionality in the very wide band. In order to be compatible with the existing systems, the new hardware needs to be 'mechanical and level-compatible'. This aspect is useful because existing DBBC terminals on the field can just be upgraded to meet the new performance. Moreover elements proper of the DBBC3 can be adopted in the existing DBBC2 and DBBC2010 to improve the capability with additional functionalities. The much higher performance requires new hardware parts, to be accompanied by new firmware development. The main features of the new system are:

Number of Wide Input IF: 4 Instantaneous bandwidth in each IF : 14 GHz Sampling representation: 8 bit Processing capability N x 5 TMACS (multiplication-accumulation per second), with N number of processing nodes Output data rate: max 1 TBps Compatibility with existing DBBC environment.

In the figures are represented the main schematic components of the DBBC3: overall architecture, the ADB3 structure, the Core3 structure, FILA40G concept.

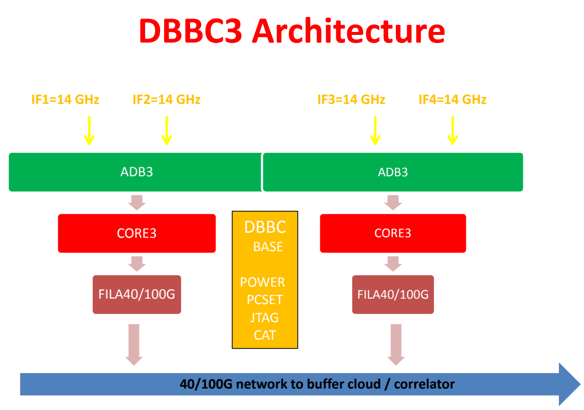

Figure 1. DBBC3 Architecture

The structure of the system is straightforward. Four IFs 14 GHz wide are sampled with 8-bit representation. Such data is then transferred to one or more dedicated processing nodes, with their own single element identity and functionality. Such processors are then extracting in digital format portions of band (tunable or fixed) and producing in output VDIF packets. The last logic element of the chain is the FILA40G whose functionality is to condense in single optical fibres at 40Gbps data rate and to enable functionalities at network packet level.

3. ADB3 Sampler

The impressive sampling functionality is performed by a state of the art device at present available in some prototype units. An extensive analysis is under way to determine the phase performance of such device, due to the interferometric use it is called to perform. An alternative general method to improve the bandwidth is to make use of complex samples. Two channels in quadrature are used sampling at a clock frequency equal to the full instantaneous bandwidth. The device under evaluation to be used for the ADB3 doesn't require such solution because is able to process the entire band in the real domain.

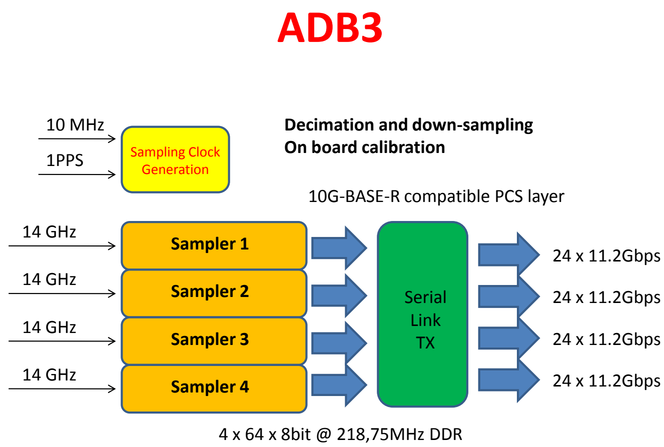

Figure 2. The Sampler ADB3

Sampled data have to be transferred to the next processing stage, and due to the very high data rate (224 Gbps) parallel bus are not convenient or just possible, for the very wide bus required operating at high speed, with all the problems arising for the physical connection and the data alignment. Serial connections are then required linked with dedicated alogorithms.

4. CORE3 Processing Node

Data coming from the samplers board ADB3 are routed using the high speed input lanes (HSIL) bus to the processing node CORE3. Such board is able to process data in order to realise DDC (Direct Digital Converter) and PFB (Polyphase Filter Bank) functionalities. From such pool of channels the selection is performed in order to accomplish the actual output data rate, through the high speed output lanes (HSOL) bus, allowed by the recording or network media. Additional input and output connections are available to maintain the compatibility with the DBBC stack. The large DSP resources available in the FPGA adopted in the CORE3 gives access to digital filters in the class of 100dB in/out band rejection. This feature is required for the large presence of RFI signals in the very wide input band. Such discrimination should be appropriate to obtain useful down-converted and clean (due to the tuning ability) pieces of observed band.

5. FILA40G Network Node

Data from the converted bands are finally transferred to the network controller FILA40G as multiple 10G-like connections. The number of connections is then cumulated in 40GE fashion (maybe 100G if the technology will be available) to be transferred to the final destination points. Such final points could be more nodes of VLBI correlators so as a buffer cloud. In addition to the 40G network capability the FILA40G unit will be able to manipulate the data packets in order

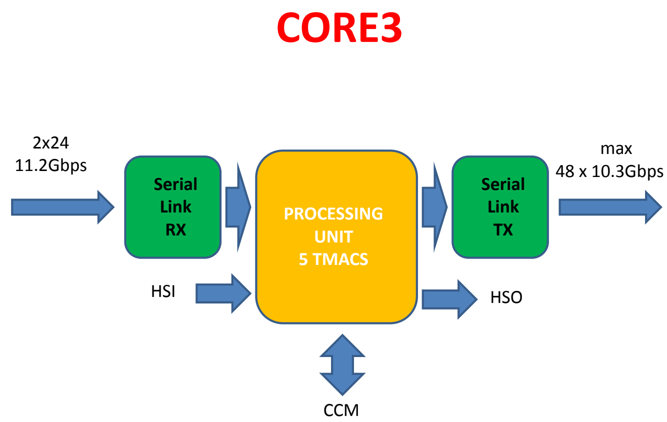

Figure 3. The Processing Node CORE3

to perform functionalities like corner-turning, pulsar-gating, packet filtering and routing, burst mode accumulation, and any other functionality that could be required at packets level as soon as the VLBI methods evolve. Additionally it will be possible to include storage elements for data buffering.

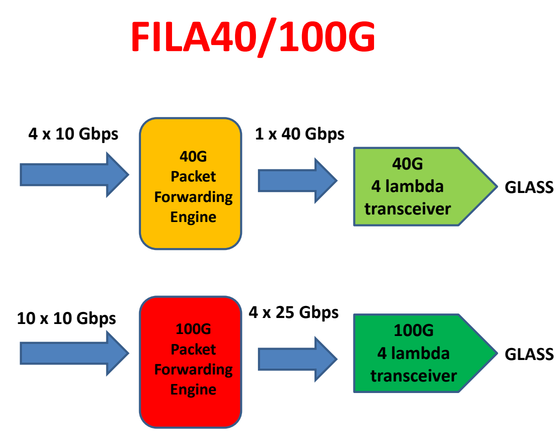

Figure 4. The Network Node FILA40G

6. Preliminary results

Test and experiments performed with the ADB3 prototypes already available, showed as a direct data conversion is possible in the digital domain for the full 14 GHz band, without a need for a preliminary analogue conversion. This represents a very challenging and interesting step ahead in the simplification and in the improvement of the VLBI2010 electronics so as a significant reduction in the system cost. The same term backend will not be anymore adequate due to the typical functionality of a front-end this system would cover. It was possible to perform measurements in different campaigns in 2011 and 2012 adopting the direct acquisitions with a full input bandwidth of 14 GHz. Zero baseline cross-correlations have been realized with samples at the entire 8-bit data representation, coming from two completely independent samplers having only a common low frequency reference clock, both fed with the same signal coming from a noise generator. Results are shown. It can be seen as the amplitude and phase behave pretty well. Phase variations are due only to the wide band splitter used to generate the copy of the input signals, as it was determined by separate measurements.

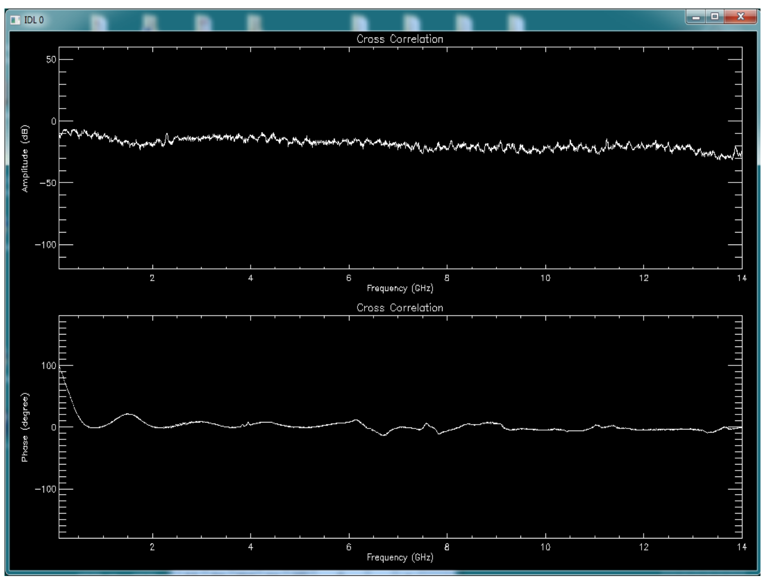

Figure 5. ADB3 Preliminary correlation results in zero baseline cross-correlation

References

[1] Tuccari, G., Development of a Digital Base Band Converter (DBBC): Basic Elements and Preliminary Results In: New Technologies in VLBI, Astronomical Society of the Pacific Conference Series ISSN 1050-3390, Vol. 306, 177–252, 2004.

[2] Tuccari, G., DBBC - a Wide Band Digital Base Band Converter International VLBI Service for Geodesy and Astrometry 2004 General Meeting Proceedings. Ottawa, Canada, NASA/CP-2004-212255, N. R. Vandenberg and K. D. Baver (eds.), 46–50, 2004.