DBBC4 - A 256 GHz bandwidth flexible VLBI environment

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Overview

The development of the newer version of the VLBI digital front- and back-end system belonging to the DBBC systems' family is under way as a work-package of the RadioBlocks Project. This instrument dedicated to increase the VLBI observation capabilities in terms of bandwidth and output data rate involves a number of relevant novelties ranging from the full 32 GHz digitized input band in a number of up to 8 RF/ IFs per system, to a fast recording system, and is including for the first time in a VLBI system the introduction of a hardware AI processor.

The DBBC4 can be implemented as a distributed system of elements to be positioned in different parts of the radio-telescope site, or in a more traditional way in a single box.

Distributed elements which can operate also as stand-alone are: DiFrEnd28 with full 28 GHz bandwidth, DiFrEnd4T with 6 GHz bandwidth in the range 0-33 GHz, DiFrEndVGOS covering the entire VGOS range 2-14 GHz. This last one can also be used in conjunction with the DBBC3 to digitize the full VGOS band and replace any analogue frequency conversion.

All the distributed elements can have backend functionality being able to produce channelized VDIF output packets to be recorded or sent through the correlator.

The progress of the DBBC4 development is reported together with a comprehensive description.

DBBC4 – What it is capable of

The DBBC4 is the latest in the successful family of DBBC backends (DBBC, DBBC2, DBBC3) developed in a long-lasting collaboration between the MPIfR and INAF (Istituto Nazionale di Astrofisica, Italy). The DBBC4 key technologies are based on and extend the developments of the EVN BRAND (BRoad-bAND) digital receiver project covering the 1.5 - 15.5 GHz band, including the IVS VGOS bands. Fig. 1 shows in logarithmic scale the evolution path of the performance of the various backend systems.

DBBC Family Evolution (Table)

	DBBC1 (2004)	DBBC2 (2009)	DBBC2010 (2010)	DBBC3 (2014)	BRAND (2020)	DBBC4 (2024)
Max Input Bandwidth (MHz)	512	4096	8192	32168	57600	256000
Max Output Data rate (Mbps)	1024	8192	16384	131072	460800	4000000

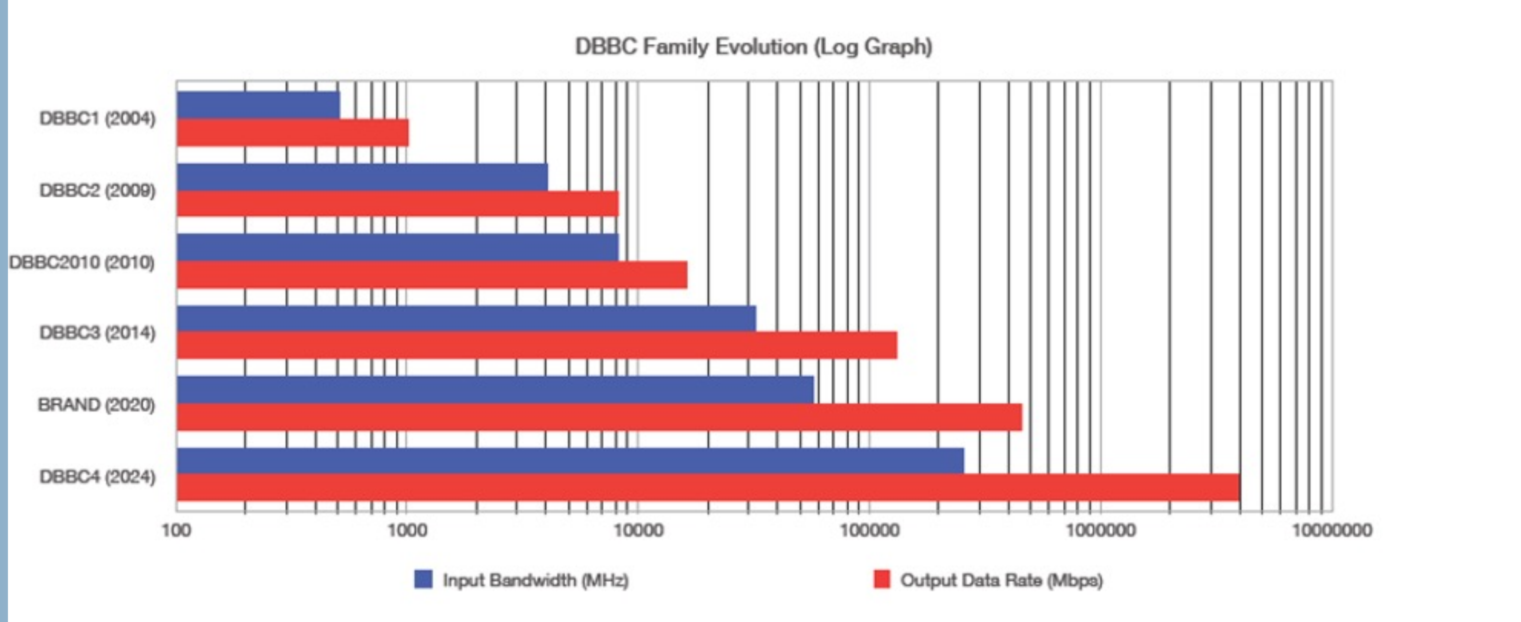

Fig. 1: Development in the time of the max. input bandwidth and output data rates provided by the various models of the DBBC family of backends. The DBBC4 will increase the IF-bandwidth that can be processed by a factor of 8 in comparison with the current DBBC3 model.

The DBBC4 will be a key technical component in enabling new scientific applications in the rapidly evolving field of wide-band, multi-frequency astronomical and geodetic VLBI and will set a new standard in the area of VLBI backends. Technically the DBBC4 will incorporate the latest state-of-the-art sampling technology enabling an increase of the processed bandwidth by a factor of eight compared to the DBBC3, the predecessor system and current de-facto standard for astronomical and geodetic VLBI. The use of artificial intelligence algorithms will allow mitigation of radio frequency interference (RFI) in near real-time; one of the most severe issues to be addressed when increasing the observing bandwidth.

The DBBC4 backend is intended to offer the following capabilities and features:

- **Input bandwidth:** 274.4 GHz maximum full aggregate bandwidth realized by 8 x 28.8 GHz in digital front- or backend plus 8 x 5.5 GHz in ancillary digital front-end.
- **Output data rate:** up to: 1 Tbps@2-bit, 2 Tbps @4-bit, 4 Tbps @ 8-bit
- **Processing modes:** DSC (full band for data transfer), OCT (wide bands defined in the input band), DDC (narrow band tunable down-conversion)
- **New functionalities:** Burst-mode, AI-mode for RFI-mitigation and transient detection, net-to memory/ disk capability

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DBBC4 – How it is done

The DBBC4 contains several functional entities already present in previous backend models, but introduces a number of new elements:

- **100GCoMo**, analogue conditioning for 40 GHz bandwidh
- **ADBCore4**, digital dual polarization 28 GHz sampler and digital processor
- **FILA100G_Mem**, data storage and network interface
- **A-EYE**, AI deep neural network controller for RFI mitigation and others
- **DiFrEnd28,** digital 28 GHz front-end (sampler and processor)
- **DiFrEndVGOS**, dedicated to the VGOS observations to be used even with the DBBC3
- **DiFrEnd4T,** digital 6 GHz sampler and processor in the 40 GHz range

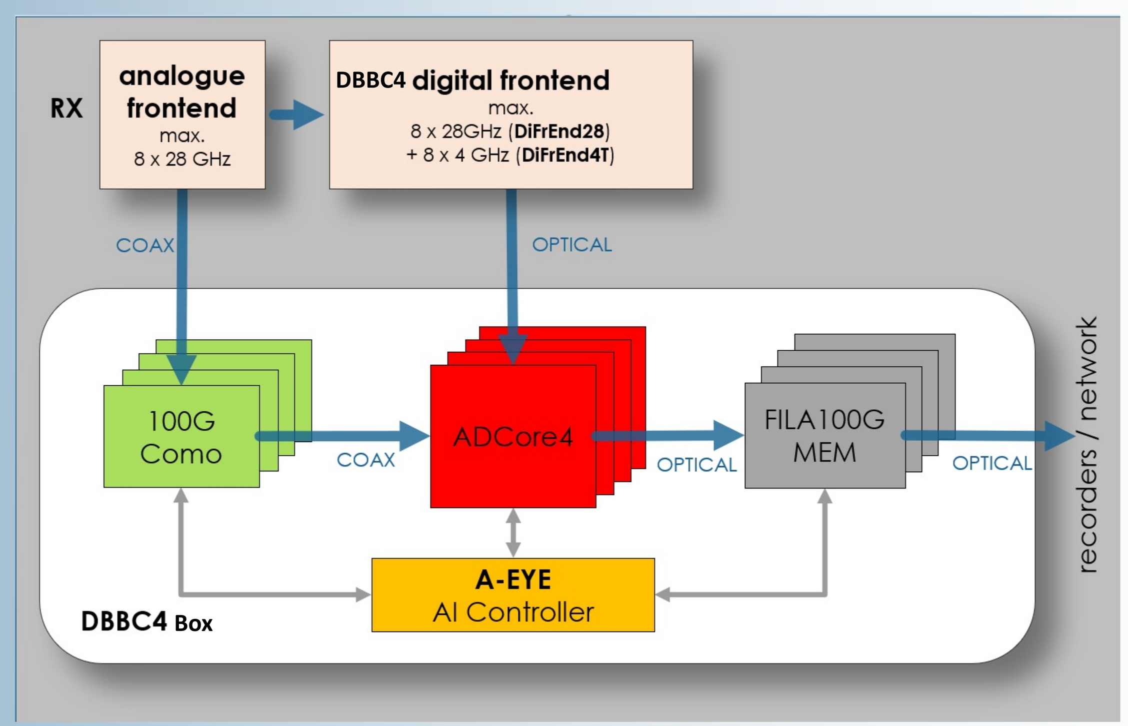

Fig. 2: Schematics of the DBBC4 VLBI System. The architecture is modular and can be adapted to the requirements of the individual telescope. The DBBC4 will allow one to process analogue IF signals as well as digital inputs. A novel AI controller can identify and mitigate RFI signals and can mark non-statistical noise signals for offline transient searches.

DBBC4 – Development Status

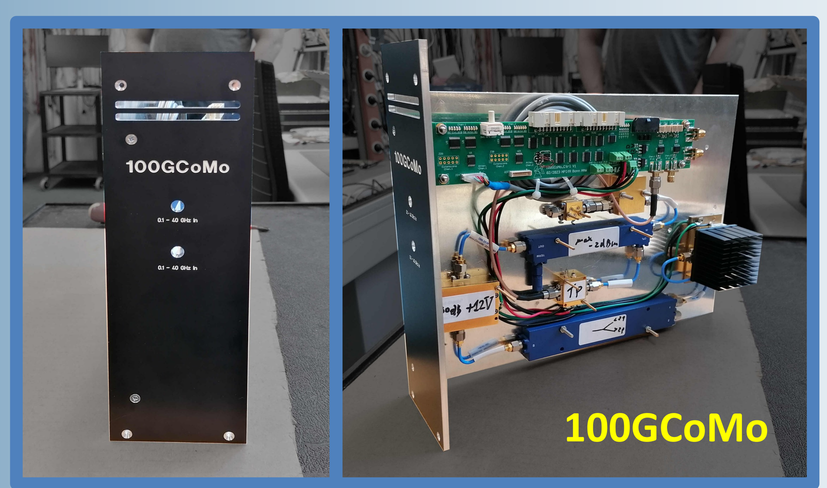

Fig. 3: The **100GCoMo** is the analogue conditioning module responsible for coupling the analogue input signal (0-40 GHz) to the digital conversion step. A DBBC4 system can contain up to 4 dual polarization 100GCoMo

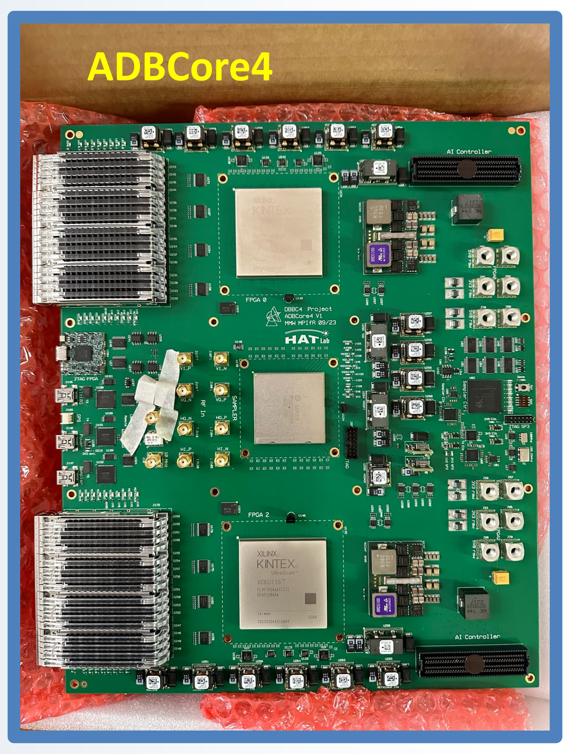

Fig. 4: The **ADBCore4** is a key element sampling the signal conditioned by the 100GCoMo and then the digital format of it transferred to the CORE4 FPGA using an aggregate number of serial lines. The required functionality between DSC, OCT, DDC is then processed and kept available to the output channels in order to be sent out to the correlator/recorder or to the FILA100GMEM module

Fig. 5: The **DiFrEnd28** is a standalone module expected to be allocated in the receiver area in order to minimize the connections between the analogue part and this section where the sampling with a 28.8 GHz bandwidth is performed and the output bands are generated.
For VGOS observations, a dedicated unit has been developed making use of the same hardware, but running a specialized firmware version. The so-called **DiFrEndVGOS** component can be connected to a DBBC3 backend in order to perform the full VGOS band sampling in dual-polarization

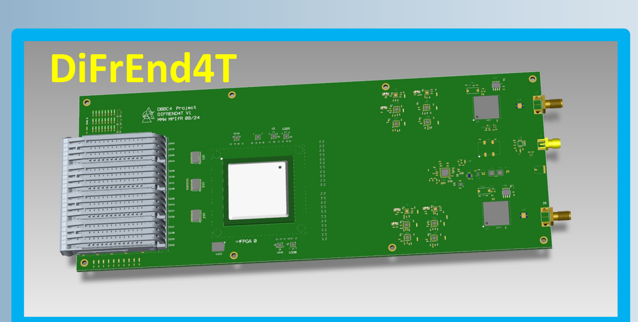

Fig. 6: DiFrEnd4T is a standalone sampling unit which provides 6 GHz of sampled bandwidth in a range of 0-40 GHz. The desired portion of the band can be selected by an appropriate filter. In the case of the DBBC4 the DiFrEnd4T is planned to cover the frequency range 27.5-33.0 GHz

Fig. 7: This controller is a multi-CPU FPGA device optimized will make use of pre-trained neural networks. RFI recognition and mitigation, extraction of non-statistical-noise signals, recognition of human-like extraterrestrial emissions, etc. are the expected applications

Fig. 8: The FILA100G_MEM is an optional component that provides fast buffered memory for bust-mode operations and direct writing of the received packets on SSD NVMe (PCIe mode) disk modules