Next-Generation DAS for the Russian VLBI-Network

E. Nosov

Abstract The Data Acquisition System (DAS) R1002M was developed by Institute of Applied Astronomy for upgrading radio interferometric network "Quasar" (Grenkov et al., 2010). The new DAS uses digital signal processing on video frequencies and provides enhanced performance. It is compatible with existing analog DASs and is intended for their replacement. The system consists of 16 Base Band Converters (BBC), IF-distributor, Clock Generator, Data Stream Combining Board (DSCB) and auxiliary units (Fig. 1). It has four IF-inputs which can be electronically connected to the BBCs in required way by IF-distributor unit. The BBCs' output data streams are combined in DSCB and available on its output in VSI-H format with up to 2048 Mbps data rate. The DAS is well suited to work with Mark 5B+ recording system but it can also work with Mark 5B in case of 1024 Mbps and lower data rate. For properly synchronizing the DAS is required for 1 PPS and 5 or 10 MHz signals. The clock generator automatically determines which input reference frequency (5 or 10 MHz) is used.

Keywords DAS, DBBC, Quasar network, FPGA

1 Base Band Converter

The main purpose of the BBCs is to cut a part of the input IF-signal in required frequency range and translate it to a baseband, separate side bands, form desired bandwidth and execute 2-bits quantizing in compliance with VSI-H format (Grenkov et al., 2009). In R1002M the translation to baseband is performed by high quality analog mixer and local oscillator (LO). The output signals of the mixer are then digitized and all subsequent processing is implemented by an FPGA (Fig. 2). The digitizing is performed by 2-channels analog-to-digital converter (ADC) with sample rate of 64 Msps. To separate the side bands it is necessary to inject phase shifting of 90° between digitized input signals. A special multirate filter bank with complex-valued coefficients was developed and realized in FPGA for this purpose. It contributes precise phase shift of 90° in the whole bandpass started from as low as 10 kHz (−6 dB level achieved at 5 kHz). It gives an opportunity to use the usual phase calibration signal of 10 kHz for correlation processing and makes the R1002M DAS fully compatible with existing analog DASs. At the same time the use of this technique allows achieving relatively high image rejection rate. Its typical value for the digital BBC is $-40 \div -45$ dB (at frequencies below 16 MHz) while for existing analog BBCs the typical value is about $-20 \div -25$ dB.

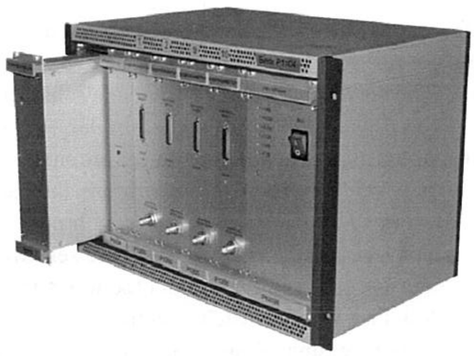

Fig. 1 Block1 of R1002M DAS.

E. Nosov
Institute of Applied Astronomy of RAS, 10, Kutuzova emb., 191187 Saint Petersburg, Russia

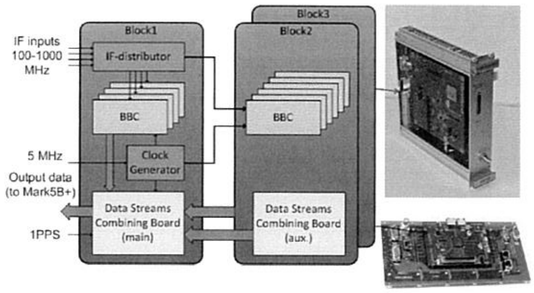

Fig. 2 Simplified structure of R1002M DAS and pictures of the BBC and DSCB.

A few additional switchable FIR-filters are used for forming six possible bandwidths: 0.5, 2, 4, 8, 16 and 32 MHz. The resulting amplitude-frequency characteristics of the digital BBCs are made similar to those of BBCs of existing analog DASs for improving compatibility between the systems. Furthermore, the bandwidths of 4 and 16 MHz have variants with close-to-square characteristics. It could improve the sensitivity of radio interferometer a bit more in case it is only the digital DASs that work on each station. The using of digital signal processing allows to achieve almost complete identity over the channels and thus it allows to avoid associated sensitivity loss of the interferometer.

2 Control

There are three possible ways to connect the R1002M DAS to control computer of radiotelescope. RS-232, RS-485 and 100/10 Ethernet interfaces could be used for this purpose. Normally, the DAS is controlled by Field System software, but the special control software under Windows OS is also available. Besides regular functions of control and monitoring it provides a few additional useful futures mainly intended for testing and service goals. First, it allows on the fly computing of 128-points 2×2-bits correlation function between any channels of the DAS. The computing itself realized in the FPGA of DSCB and the software just does some post-processing and graphic representation of the result. Second, the software could find the power spectrum density or cross-spectrum by using an FFT of received correlation function. Finally, the program displays counted by DSCB 2-bits distribution of quantized output signals.

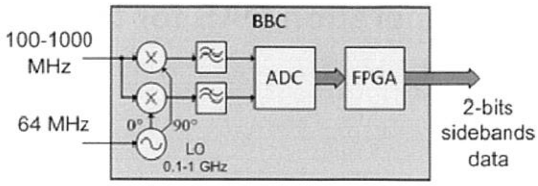

Fig. 3 Simplified structure of the BBC.

3 Field tests

The DASs R1002M have been installed in Svetloe and Zelenchukskaya observatories and have been used in the following observations: Ru-E090, Ru-E096 and Ru-U133. The systems operated in parallel with regular DASs (Mark IV in Svetloe and VLBA4 in Zelenchukskaya). Correlation processing of these observations proves compatibility between the digital and the analog DASs. Furthermore, using R1002M on both stations gave appreciable increase of SNR on the correlator output. Ratio of SNRs in case of digital-to-digital and analog-to-analog channels correlation is counted and averaged over 215 scans (Fig. 3). In average over the session the digital DASs gave an improving of about 36on each station of radio interferometer. The Multi-band delay (MBD) error was decreased as well (Fig. 4).

4 Summary

The channels of R1002M DAS have high repeatability, high rate of image noise rejection, low LO phase noise, low ripple of amplitude-frequency response and linear phase-frequency response. It allows minimizing degradation of radio interferometer sensitivity contributed by DAS. Wide control and monitoring futures makes it handy for using. Due to reprogrammable FPGAs the DAS functionality could be easy upgraded and new futures could be added. The tested observations prove advantages of created DAS and its compatibility with existing analog DASs. The third R1002M DAS is ready for installing in Badary observatory and after additional testing the R1002M DASs will be accepted as a regular DAS for all telescopes of "Quasar" network.

Input frequency range	$100 \div 1000$ MHz
Number of IF-inputs	4
Number of channels (BBCs)	16
Selectable bandwidths	0.5, 2, 4, 8, 16, 32 MHz
Separated sidebands	Both lower and upper
Image rejection rate (typ.)	$-40 \div -45$ dB
Commutation of input and output signals	Electronically
Local oscillators phase noise (rms)	$\leq 0.7°$ (measured from 30 Hz to 30 MHz)
Ripple of amplitude-frequency response of the BBCs	≤ 0.3 dB
Output data format	VSI-H
Output data rate	Up to 2 Gbps
Available control interfaces	RS-232, RS-485, 100/10 Ethernet
Total dimension (three 19″ subracks)	$445 \times 950 \times 315$ mm

Table 1 R1002M DAS specification

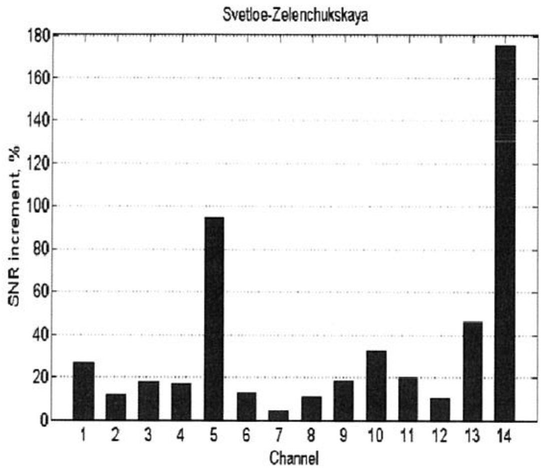

Fig. 4 SNR increment in the digital system in compare to the analog systems. Average over 215 scans. Base: Svetloe–Zelenchukskaya.

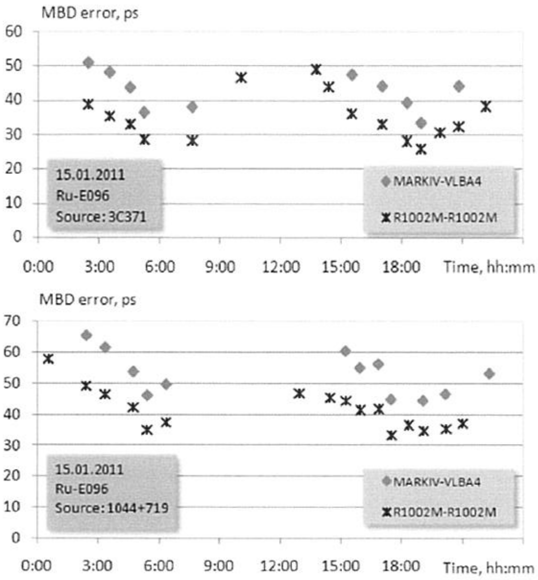

Fig. 5 MBD error for MarkIV-VLBA4 and R1002M-R1002M cases during RU-E096 observation session for 1044+719 and 3C371 sources. Base: Svetloe-Zelenchukskaya.

References

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