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A Design of Data Acquisition System for Korean VLBI Network

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Abstract

Korean VLBI Network is under construction and will be capable to observe several frequency bands simultaneously. We are developing the KVN data acquisition system for our multi-channel receiver system. To cover 1 GHz bandwidth, we employ four high speed samplers, which can be operated at 2 Gsps and 4 bits per sample. These four data streams of 8 Gbps each will be transported via optical fibers to the operation building, and then distributed among sixteen FIR digital filters. With these filters, we can choose one of predefined passbands whose center frequency is arbitrarily programmable in the 1 GHz-wide input bandwidth, and then resample the filtered data at 2 bits per sample. These resampled data streams are then formatted and sent to the recorder. We plan to use the new Mark 5 recorder. KVN is involved in the development consortium for Mark 5, which is led by Haystack Observatory of MIT.

1. Introduction

Most of current VLBI systems in the world are based on the narrow-bandwidth multi-channel data acquisition systems because of the historical reasons on samplers and recorder characteristics. With the progress of the techniques on digital signal processing, it becomes possible to sample a wider bandwidth signal directly, and to record them up to 1 Gbps recording speed. Thus new type of VLBI systems that are based on the wide-bandwidth single-channel data acquisition system has shown up. However these progresses make that more and more VLBI stations are not compatible to each other since the different data acquisition systems.

Korean VLBI System (KVN) is under construction [1], and we are designing our data acquisition system in these circumstances. We are willing to build a unique data acquisition system which takes many benefits of the digital data processing, but which is compatible to existing VLBI observation modes. We will employ the high speed sampler and FIR digital filters.

With minimizing the analog IF processing, we can get more stable frequency and phase characteristics. Since there is one set of bandpass filter and baseband converter in analog IF stage, the single whole passband is digitized by a high speed sampler at once, there are no phase offsets between each channel. And also it becomes possible to change the passband characteristics by controlling the programmable filter coefficients. It can be used for both of the narrow-bandwidth multi-channel observation and the wide-bandwidth single-channel observation with the same equipment. It is possible to build several equipments with same characteristics, and is easy for maintenance and upgrade.

In this paper, a design of the KVN Data Acquisition System is proposed. Figure 1 is the conceptional block diagram of KVN data acquisition system.

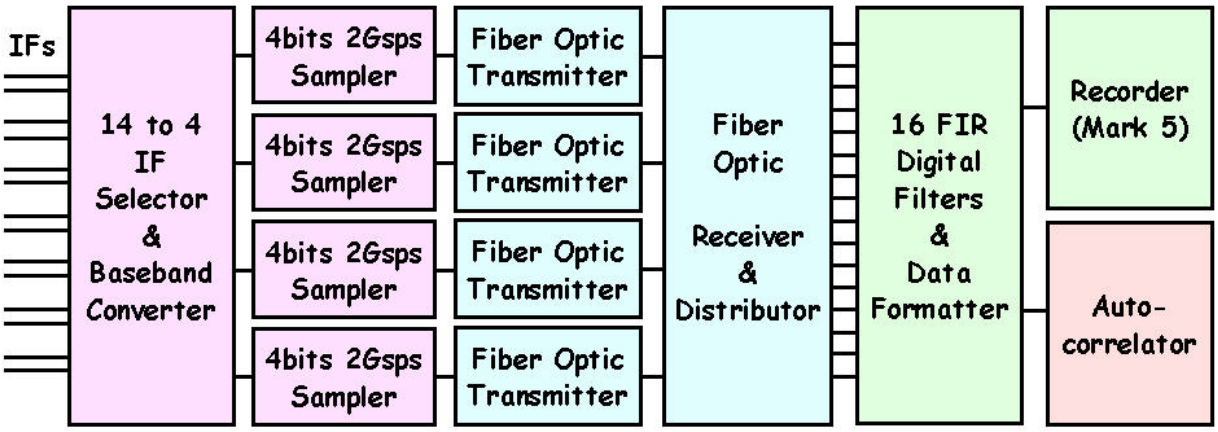

Figure 1. Block diagram of KVN Data Acquisition System

2. IF Processing Unit

KVN data acquisition system is designed to be suitable for the simultaneous multi frequency observation, such as phase compensation of the millimeter VLBI observation. Our multi-channel receiver system [2] will have two setups, which are the 2 and 8 GHz configuration mainly for geodetic observation and 22, 43, 86 and 129 GHz configuration for astronomical observation. Each of the receivers will provide both the left hand and right hand polarization IFs.

The IF selector consists of eight 2-to-1 IF switches and four 8-to-1 IF switches, to select four IFs among sixteen IF input ports. Each of the IF signals has the center frequency 8.5 GHz and the bandwidth 2GHz, and is converted to the baseband of center frequency 1.5 GHz and 1 GHz bandwidth. Finally these four baseband signals are fed into four high speed samplers respectively for digitization.

With this IF processing unit we can configure our receiver system as simultaneous four frequency band observation, simultaneous two frequency band observation with dual polarizations, and so on. For single dish operation, it has not only the IF blanking capability, but also the Doppler tracking capability via fine control of LO while baseband conversion.

3. High Speed Sampler and Optical Transmission

Each of baseband signals is sampled with the high speed sampler that is operated at 2 GHz for 1 GHz bandwidth. The sampler is under developing by combining two 1 GHz base samplers with a special clock-shifted clocking unit. Figure 2 is the schematic of the high speed sampler, model CXS-2048. The sampler has several modes of quantization, and we will use the 4 bits quantization as system default, in order to reduce the signal losses in the second sampling at the final stage of digital filtering. The sampler is controlled via 10/100 based Ethernet, and has self-diagnostics within itself.

The four data streams of 8 Gbps for each IF are serialized and transmitted to digital filter in the operation building apart about 100 meters, using the 10 Gbps optical transmitter and single mode optical fiber. We are considering to include the analog optical links for test and maintenance purpose, if possible.

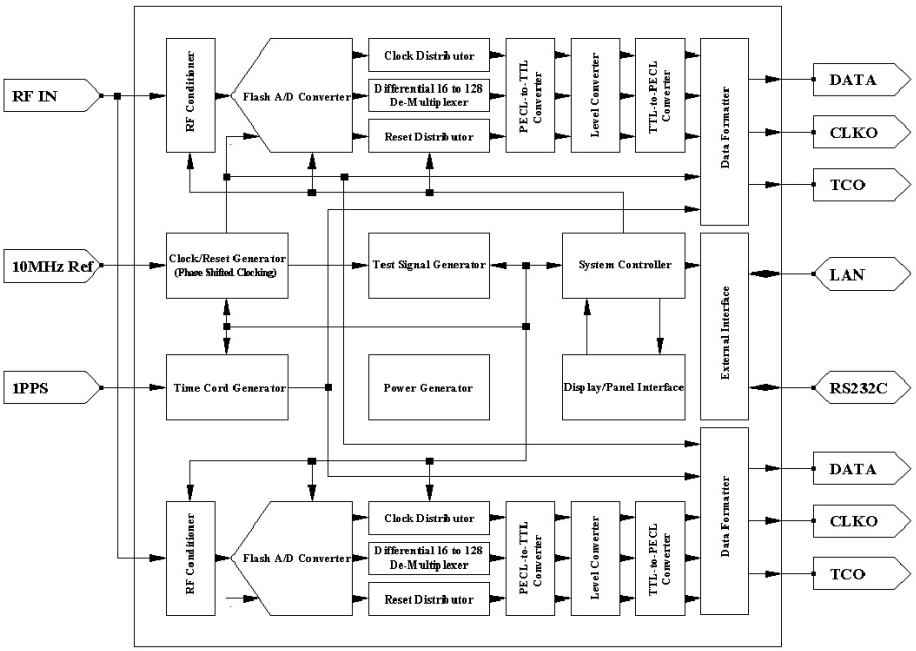

Figure 2. Schematic of High Speed Sampler CXS-2048

At the operation building, these data streams are divided into sixteen streams each as in optical form, and are distributed into every input module of digital filters. With this original idea in data distribution, we can reduce the complexity and difficulty of data feeding in electrical form.

4. Digital Filters

Digital filter is one of the most highlighted parts of KVN data acquisition system with the high speed sampler. The structure of digital filter for KVN data acquisition system is shown in figure 3. It consists of sixteen identical FIR filter cards with associated optical input modules and the station cards, which is used to build up the output data stream to the recorder and the autocorrelator. At the input module, one data stream is selected among the four data streams, and is converted back to electrical signal.

Each FIR digital filter card is used to calculate tap weighted multiplying with configurable tap size from 64 to 2,048 in maximum to generate the 2-bits wide output data streams from 1 to 16 in 32 MHz data rate. It can be operated in the data rate of maximum 2,048 Msps. Final data output is conformed to VSI-H specification, and is sent to the recorder. We will use the hard disc type data recorder Mark 5. KVN is involved in the development consortium for Mark 5, which is led by Haystack Observatory of MIT.

This digital filter is programmable to support the variety of observational needs from the narrow-bandwidth multi-channel observation to the wide-bandwidth single-channel observation. One can choose one of the predefined passbands whose center frequency is arbitrarily programmable in the 1 GHz-wide input bandwidth, and then resample the filtered data at 2 bits per sample for recording. The most common operation modes are shown in the Table 1. The fundamental 1/4

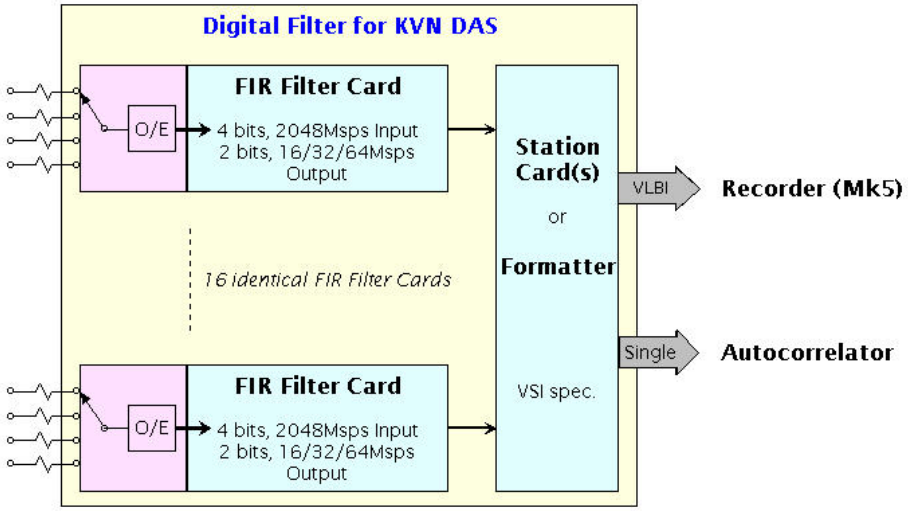

Figure 3. Structure of Digital Filter for KVN Data Acquisition System

band mode is the wide-bandwidth single-channel configuration, which is for mainly astronomical continuum observation. With these 1/64 band mode and 1/128 band mode, we can setup the digital filters to be compatible to the currently existing narrow-bandwidth multi-channel data acquisition systems. The most common operation mode is 1/64 band for 16 MHz bandwidth. The 1/128 band mode for 8 MHz bandwidth is a degraded operation mode for geodetic observation. Part of the output data will be used to keep the compatibility to the current existing recording format of the geodetic observation. One of the simulation results is shown in figure 4, which is for basic 1/64 band mode of this digital filter card.

Table 1. Operational Modes of Digital Filter Card

Mode / Bandwidth	# of Taps	Input Format	Output Format	# of 32 MHz Outputs
1/4 Band / 256 MHz	128	4 bits × 64 @ 32 MHz	2 bits, 512 Msps	16
1/8 Band / 128 MHz	256	4 bits × 64 @ 32 MHz	2 bits, 256 Msps	8
1/16 Band / 64 MHz	512	4 bits × 64 @ 32 MHz	2 bits, 128 Msps	4
1/32 Band / 32 MHz	1,024	4 bits × 64 @ 32 MHz	2 bits, 64 Msps	2
1/64 Band / 16 MHz	2,048	4 bits × 64 @ 32 MHz	2 bits, 32 Msps	1
1/128 Band / 8 MHz	2,048	4 bits × 64 @ 32 MHz	2 bits, 16 Msps	1

5. Summary

We present a design of the KVN Data Acquisition System, which consists of the high speed samplers, optical data transmission, and FIR digital filters. It is suitable to observe up to four independent IFs simultaneously for the cases of phase referencing observation which is critical for mm-VLBI, multi-transition study, dual polarization study etc. It covers 1 GHz bandwidth each

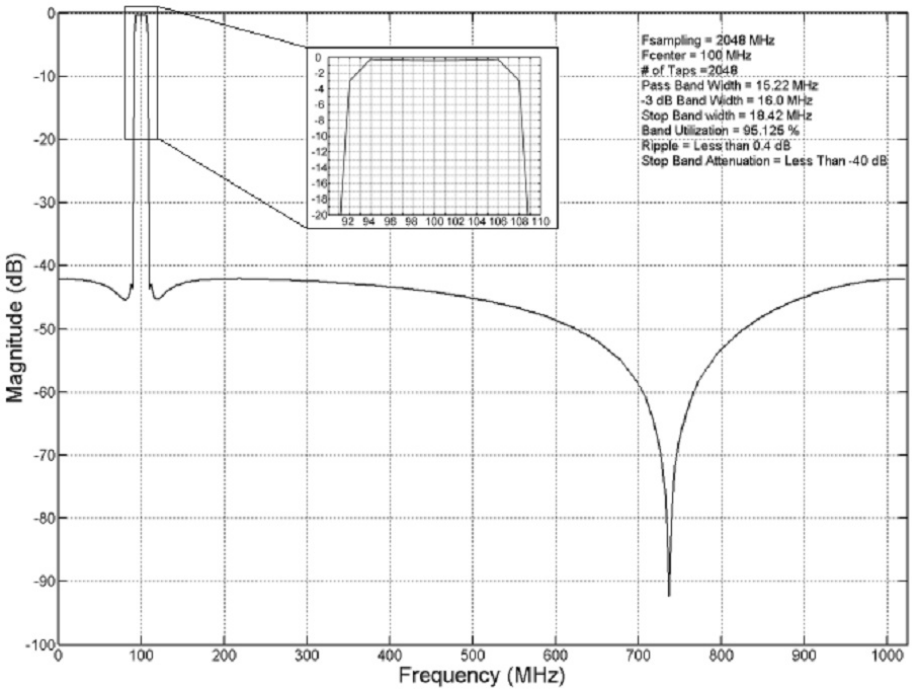

Figure 4. A simulation result of 16MHz bandpass characteristics

for four IFs. With the current limitation of data recording speed, it can be used to record a 256 MHz bandwidth in 2 bits per sample. But we can hopefully observe more than 1 GHz bandwidth in near future.

The KVN Data Acquisition System is very flexible to be used in variety of observational modes, and is capable of operations in the narrow-bandwidth multi-channel observation and the wide-bandwidth single-channel observation. It includes many original ideas for the high speed data streams and for the flexible mode configuration. With a wideband multi-channel receiver system of KVN, this unique high-speed and flexible data acquisition system is ideal for the phase compensation technique of the multi-frequency observation, which is essential for the mm-wave VLBI.

References

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[2] Han, S.-T. et al., IVS 2004 General Meeting Proceedings, edited by N. R. Vandenberg and K. D. Baver, NASA/CP-2004-212255