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A Scalable Muti-Rate Digital Signal Processing for Radio Astronomy

Engineering

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ABSTRACT

Challenges in designing digital signal processing systems for radio astronomy needs to process very large amounts of data with very high rates for more than one telescope. It is also required for shorter development and faster development of Digital Signal Processing System Design. Traditional design approaches a lack of high level -platform independent application specifications that can be experimented with and later ported to and optimizable for various target platforms.

We try to pack a large amount of information into a finite allocation of frequency and filter specifications. Multi-rate filters are also able to change the input data rate at various intermediate points within the filter itself while an output rate is identical to the input rate. At a minimum level of design multi-rate system requires filter with high orders i.e. larger lengths, which implies more storage for coefficients and much higher execution rates for the processor. These filters can achieve both greatly reduced filter lengths and computational rates as compared to single rate filters.

I. Introduction

Below 100 Mega-Hz, ground-based high fidelity, high-angular-resolution (i.e. arc-second) aging of all but the simplest and brightest astronomical sources has historically impossible due to the presence of the Earth's ionosphere. Multi-rate signal dispensation techniques are extensively used in several areas of contemporary engineering such as interactions, image processing, digital audio, and multimedia. The major benefit of a Multi-rate system is the considerable decrease of computational density, and consequently, the inferior power utilization in real-time operations, slighter chip area pursue by the cost diminution. Multi-rate systems are structure blocks frequently used in digital signal processing.

II. Design of sampling rate converters

I. Interpolators and decimators:

Interpolator or a decimator is implemented with up-samplers ↑M and down-samplers ↓M respectively. We begin by defining the up-sampler and the down-sampler. For discrete-time signal define the up-sampler ↑M and the downsampler ↓M by

$$\uparrow M:\ \{x[t]\}_{t=0}^{\infty} \rightarrow \{x[0], 0,0,0 \ldots\ldots\ldots 0, x[1], 0, \ldots\}$$
$$\downarrow M:\ \{x[t]\}_{t=0}^{\infty} \rightarrow \{x[0], x[M], x[2M], \ldots\}$$

The up-sampling operation is implemented by inserting M−1 equidistant zero-valued samples between two consecutive samples of x[t], before the sampling rate is multiplied by the factor M. On the other hand, the down-sampling operation is implemented by keeping every M^{th} sample of x[t] and removing in-between samples to generate x[t], then the sampling rate becomes multiplied by 1/M.

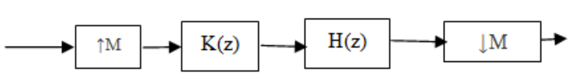

Figure 1: Block Diagram of Sampling rate converter with Interpolator and Decimator

II. Tunable Digital Downconverter

In this paper, a decimator refers as a blockwhich decimates or down-samples the input signal without processing of signals, The factor which is defined as the ratio of the sampling rate at the input of a decimator to that at its output is called decimation. In a multi-phase implementation of a decimation filter. An anti-aliasing filter generally proceeds the decimator. The baseband channels are highly oversampled and thus decimation is required to bring the sampling rate down in accordance with the bandwidth of signal. The same process is also used in the implementation of a structure as a single computing block.

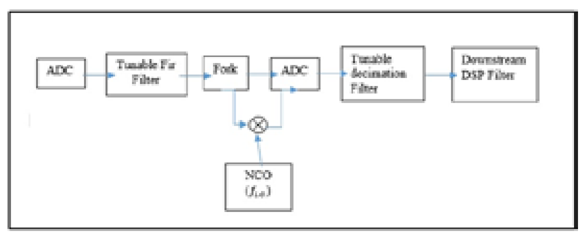

Figure 2. Tunable digital down-converter

An eight-bit A/D converter (ADC) receives a baseband input Intermediate Frequency signal of bandwidth 800 Mega Hz and has the sampling rate of 1.6giga-samples/second.Correspondingly, also all the decimation blocks have 8 input and output ports. Thus, they are connected with any two blocks with 8 connections as shown in Fig. 3 and their output is directly connected with the output block diagram. The observations with narrow band filtering , the Nyquist sampled and the output of the Tunable digital down-convertor will be analyzed by an existing spectrometer. The greater spectral resolution is provide by the number of spectral channels as compared to analyzing the entire input bandwidth. We have to use Tunable Digital Design supports integer decimation factors between five and 12.

III. Advancements of multirate signal processing

The major benefit of multi-rate is considerable decrease of computational density, the inferior power utilization of real – time operation. The multi-rate based algorithms are worn to solve a few of composite signal processing errands that could not be resolve otherwise, such as illustration rate conversions, signal disintegration and reconstruction, totaling of DSP transforms. A number of Multi-rate comprehension help to merge pulse shaping and interruption at a fraction of the charge compared to the difficulty of traditional interpolation procedure. The use of polyphase DFT strain banks in wideband satellite infrastructure systems has been description in the past.

III. Complex baseband signal representation

In digital signal processing, signals are usually represented by their low pass equivalents, which is a suitable representation for narrowbandsignals in a digital communication system, and also applicable in the radio astronomy context.A real valued band-pass signal with center frequency may be written

$$\tilde{s}(t) = Re\{s(t)e^{j2\pi f_c t}\} = x(t)\cos 2\pi f_c t - y(t)\sin 2\pi f_c t$$

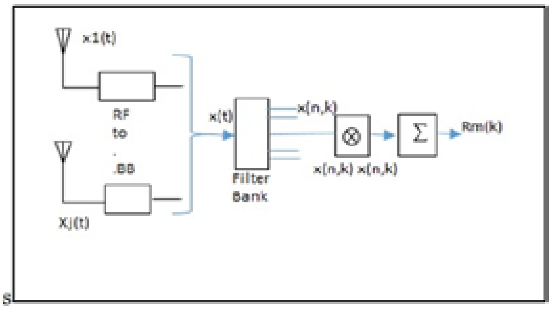

Figure 3: Baseband Signal Processing Model

Suppose that the bandpass signal is dselayed by a time τ. This can be written as Under this condition, we have for the complex envelope of the delayed band-pass signal that The conclusion is that, for narrowband signals, time delays smaller than the inverse bandwidth may be represented as phase shifts of the complex envelope. Phased array processing heavily depends on this step. For radio astronomy, the maximal delay τ is equal to the maximal geometric delay, which can be related to the diameter of the array.

IV. Ployphase filter bank

The multi-phase filter bank is a very effective implementation for uniform multirate filter bank design using a FFT. Array of digital baseband down convertors with equally sprayed and spaced center frequencies and bandwidth combine together to form a classical uniform multirate filter bank. A filtering with low pass filter is used for selecting the sub band and down-sample technique is using for reducing the sampling frequency but, it has to be made sure that the Nyquist-Shannon theorem must be satisfied. A factor in the sampling theorem is reduced to the number of channels of the multi-rate filter bank. In figure 4, the block diagram of a standard 64-channel multiphase filter bank is shown. The input signal is first de-multiplexed by a factor of 64, represented by commutator. The output is followed by an array of digital filters, which is down sampled by by-64 decimation factor. This implies that the original Finite ImpulseResponse of low-pass filter of N coefficients is divided into 64 all-pass Finite Impulse Response poly-phase filters of N/64 coefficients. Since these filters present different linear phase responsestherefore they are known as poly-phase filters.

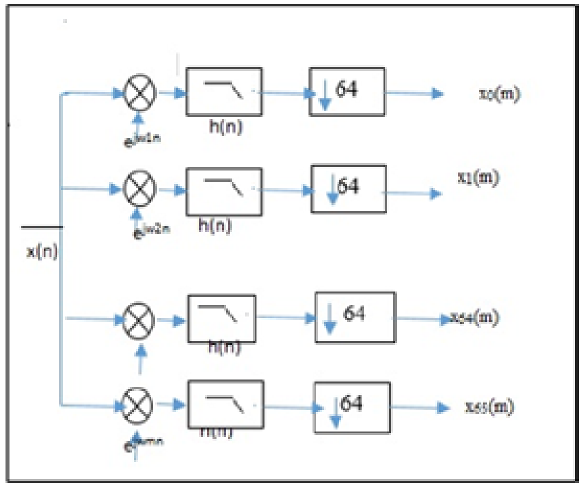

Figure 4. 64-channel classical uniform multirate filter bank

Conclusion

In this paper, we have proposed a multi-rate signal processing approach for radio astronomy Digital Signal Processing System. Platform-independent specification has been used in this case, and assistance in functional verification, is provided by high-level application model and important resource estimation tasks. The implementation and design of such multi-rate filter banks are a subject of future research. Currently faster development of DSP system across various target platforms can prove effective reducing the development cycle.

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