Chip set for autocorrelation spectrometer applications

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INTRODUCTION

Three integrated circuits for autocorrelation spectrometer applications have been designed and manufactured. The first circuit is an IQ-converter that provides down conversion to baseband and quadrature. The second circuit is a digitizer that transforms analog information to digital information. The last circuit is a digital signal processing circuit that calculates the autocorrelation function for digital input data. The IQ-converter and the digitizer have been manufactured using a bipolar silicon process and the autocorrelator has been manufactured in a 0.25 µm CMOS process. This paper will first describe the autocorrelator system and then describe the three integrated circuits and a multi chip module that has been used. At last, future projects will be described.

AN AUTOCORRELATION SPECTROMETER SYSTEM

The autocorrelation function of a discrete sequence, $x(n)$, of length N is defined as:

$$R_{xx}(l) = \sum_{l=0}^{N-1} x(n)x(n-l), l, n \in Z$$

By applying the discrete Fourier transform to the autocorrelation function the power spectrum is obtained. The resolution of the spectrum is improved by increasing the length, l, of the function. The autocorrelation function can be realized using a digital integrated circuit.

The input to the spectrometer is some analog frequency band that is being observed. This band is down converted and split into subbands. The subbands are individually down converted to baseband with the IQ-converter. The baseband information is quantized by the digitizer and then fed to the autocorrelation circuit.

THE IQ-CONVERTER

The IQ-converter is used to convert the subbands to the baseband. It also provides quadrature meaning that two identical signals shifted in phase by 90° is produced. The quadrature is used to analyze the upper and lower sidebands at the same time.

The IQ-converter was manufactured using a 0.6 µm silicon bipolar process. The circuit consists of two doubly balanced mixers and buffer amplifiers to amplify the IF-signals at the output.

Experimental results showed that the IQ-converter could be used up to 10 GHz input frequency and up to 1 GHz output frequency. However, the performance of the IQ-converter was not satisfactory due to badly balanced output buffers. This means that commercial circuits are used in this version of the autocorrelation spectrometer system.

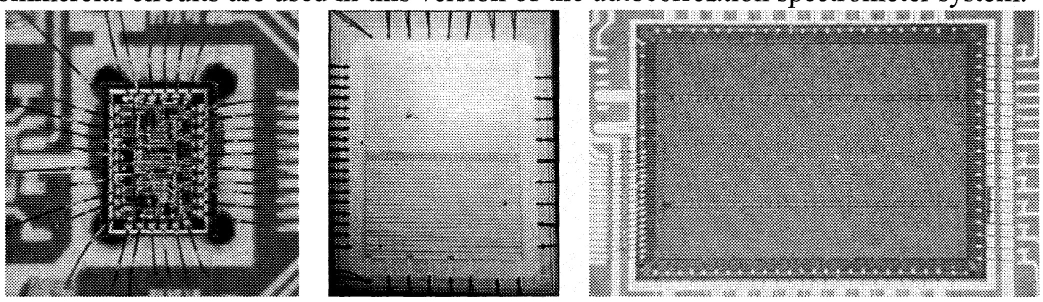

Figure 1. The digitizer (left), the low resolution chip (middle) and the high resolution chip (right)

THE DIGITIZER

The signals produced by the IQ-converter are analog and need to be converted to digital data in order to be manageable by the digital autocorrelator. For this, a digitizer is used. Time multiplexing may be used since the quantization is possible to achieve at higher frequencies than the following digital signal processing.

The digitizer was manufactured using the same 0.6 μm silicon bipolar process mentioned in the previous paragraph. A bipolar process was chosen due to the possibility to design high speed high precision comparators. This circuit was designed to be used in parallel with the correlator, meaning that I/O and functionality is matched. In order to reduce the influence of noise on the data and reference ports, a differential interface was chosen. The chip consumes 200 mW and its size is 1.175×0.775 mm^2.

THE AUTOCORRELATOR

The serial output data from the digitizer is fed to the autocorrelator. This data is then split in two identical parts and fed to a multiplier that calculates the autocorrelation function for zero delay, l=0. One of the serial data paths is then delayed one clock cycle and multiplied with the initial data to produce the function for l=1. This procedure is then repeated until the desired resolution is obtained.

Two autocorrelation chips have been manufactured using a 0.25 μm CMOS process from STMicroelectronics, one low resolution correlator with 128 channels and one high resolution correlator with 1024 channels. The number of channels corresponds to the number of delay blocks described in the previous paragraph. The autocorrelation circuits can analyze a maximum bandwidth of 1.5 GHz. Synchronization blocks have been introduced each sixteen channels in order to synchronize the data and the clock. The low resolution correlator has a DC-power consumption of 300 mW and its size is 2.5×3 mm^2. The high resolution correlator has a DC-power consumption of 1.5 W and its size is 7×5 mm^2. A possibility to switch off channels to reduce the power consumption has been implemented on both versions. When the high resolution correlator works at its maximum frequency it performs 3×10^{12} operations per second.

THE MULTI CHIP MODULE

Digitizer and correlator were together with mixers bias circuits and digital control circuits implemented on a PCB. The naked chips were mounted and bonded to a ceramic carrier. In order to protect the chips and bond wires from the environment, a glob of epoxy was placed on this carrier. By placing the chips in module the test possibilities are improved since the module is possible to move between different PCBs.

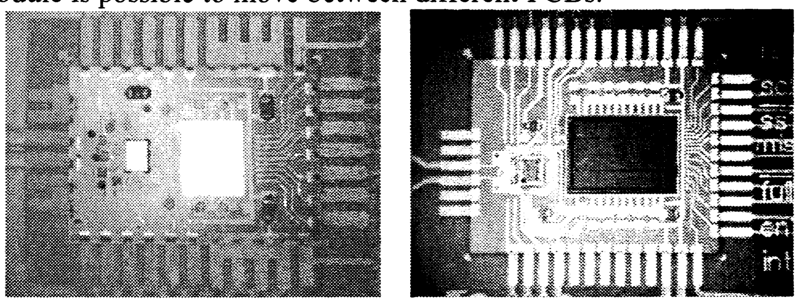

Figure 2. The multi chip modules for the low resolution correlator (left) and for the high resolution correlator (right)

FUTURE WORK

Some efforts have been made to implement bipolar and CMOS functions on the same chip using a SiGe BiCMOS process. Some improvements are expected when using this technology since the bipolar transistors have a higher frequency of operation.

CONCLUSIONS

The digitizer and correlator chips described in this paper show good performance and they will be used in future spectrometer applications. Quadrature, time multiplex and sampling methodology have improved the performance of the spectrometers. The multi chip module provides easy handling and testing of the circuits. The power consumption is exceptional and an order of magnitude better than comparable solutions. A future implementation on SiGe BiCMOS looks promising.

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