Digital sideband separating downconversion for the Green Bank Telescope phased array feed

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A digital sideband separating downconverter consists of splitting the signal into its I and Q components in the analog domain and reconstruction of the upper and lower sidebands in the digital domain. The focus of this work is the digital signal processing required for the digital sideband separating downconverter and the time to frequency domain transformation, which is implemented on field programmable gate arrays (FPGAs).

For a high speed serial data link the DC balance, clock recovery, clock synchronization, and word-alignment needs to be addressed. Radio astronomy signals are white noise signals with a Gaussian distribution which ensures that the aforementioned serial link requirements are met. The sample codes of both two's complement and straight binary are symmetrical thereby ensuring DC balance and the high transition density of a white noise signal ensures a successful clock recovery. Furthermore, the XOR of the most significant bit with the second most significant bit of the more probable middle range in the sample codes is one. This allows for the use of unformatted digital data transmission and word alignment at the receiving end can be achieved by using this statistical property of the signal.

After initial signal conditioning within the cryogenic dewar the RF signal is downconverted to an IF by mixing the signal with two phase-quadrature LO producing the I and Q components. The I and Q components are digitized at the feed and the data is serialized before being sent over a high speed optic fibre serial link. On the receiving end, the clock and data recovery is implemented using the gigabit transceivers on-board the FPGA. The data streams are then synchronized by crossing clock domains from individual recovered clocks to the system clock. In order to obtain the location of the most significant bit in a word, the XOR of each bit with the next bit is computed and the result is accumulated. The highest total will indicate the location of the most significant bit and the data can be aligned accordingly. By following a similar procedure the I and Q components can be identified. In order to reduce signal leakage and scalloping loss, a polyphase filter bank is implemented to complete the Fourier transform of the data. Reconstruction of the upper and lower side bands of the spectrum is completed by multiplying the I and Q components with their corresponding calibration coefficients. This completes the digital sideband separating downconversion and frequency transformation process.