P5.5 DIGITAL WAVEFORM GENERATOR FOR WEATHER RADARS

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1. INTRODUCTION

Modern digital signal processing technology now provides advanced weather-radar features such as second-trip echo recovery, Doppler-tolerant pulse compression for klystron and solid-state transmitter systems, optimization of the occupied bandwidth, and pre-distortion of exciter signals in order to improve the sub-clutter visibility of the radar. An important requirement for these developments is a programmable signal source capable of synthesizing flexible, low phase noise IF waveforms.

This paper describes the architecture, performance, and applications of a dual-channel IF waveform generator developed at Lassen Research for use with the Lassen-Gematronik digital receiver Aspen DRX.

2. WAVEFORM GENERATOR ARCHITECTURE

The waveform generator (WGen_R2) is designed to be used with one or two Lassen Research digital receivers/signal processors. This requires that the generator be easily controlled by the signal processor, and that provision be made for low-jitter synchronization of the generator and the receivers.

The first goal is achieved by controlling the generator using a Sharc DSP communicating directly with the Sharcs on the digital receiver cards via linkports, with alternate control via a serial port (which also serves as a console serial port for on-board diagnostics). Control consists of downloading waveforms, controlling pulse-to-pulse waveform parameters, and receiving status information from the generator BITE.

Synchronization is achieved using differential PECL clocking and timing signals, to preserve the low-jitter performance of the system master clock. A complex system using two receivers and a waveform generator is driven by only one master clock, which may reside on a digital receiver, on the waveform generator, or at a separate master clock source. The absence of other clocks in the system (all DSPs, A/D converters, and D/A converters in the digital receivers and the waveform generator use the same clock) prevents spurious signals from appearing in the generator waveforms or in the digital receiver I/Q data sets.

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The architecture of the waveform channels is straightforward. A separate waveform memory for each channel can hold 262k 14-bit waveform samples, which amounts to 6553 us of waveform data at the D/A rate of 40 MHz. An address generator for each channel is implemented on an EPLD; under the control of a state machine any part of this memory can be output to the D/A at one or many arbitrary points in the range interval. The address generator can modify the locations of the memory data to be sent to the D/A on a pulse-by-pulse basis, to allow arbitrary sequences of waveforms to be generated, either for transmitter driving, receiver calibration, or for weather signal simulation. For example, the architecture allows compressed waveforms to be generated with Doppler shifts.

The 14-bit D/A converter outputs are followed by stable, low-distortion analog IF stages. The nominal bandwidth is 7.5 MHz at –3 dB, 6.0 MHz at –1 dB, and 5 MHz at +/-0.1 dB. The output power is +12 dBm. The IF filtering extends to below 100 dB, eliminating harmonic distortion and spurious signals.

External communications capabilities include three Sharc linkports (20 MBytes/sec each), one high-speed serial port (up to 40 MBaud), one RS232 serial port, front-panel LEDs, and various synchronization and triggering capabilities. Two low-jitter programmable output triggers are provided for testing and utility purposes.

The generator is provided with an extensive BITE capability. A built-in 12-bit high-speed A/D converter can sample either output channel to verify the presence and accuracy of the output waveforms. An environmental system monitors the temperatures of the generator card at four points, and the three supply voltages are monitored to 1 mv.

The presence of the BITE system allows testing of the generator card on a stand-alone basis, using only a terminal attached to the console serial port. An extensive repertory of diagnostic test software is provided in the flash memory to support field maintenance.

Software development and hardware maintenance are also facilitated by the presence of a standard JTAG port, supported by Analog Devices development software.

A 16-MByte flash memory is used to store operational and diagnostic software, as well as D/A waveforms.

The waveform generator is constructed on a single 6Ux160-mm Eurocard, and requires less than 7 watts of power.

3. PERFORMANCE

The wide dynamic range (105 dB) and low phase noise (-73 dB) of the Lassen Research digital receivers set the performance requirements for the waveform generator.

The generator is able to provide any waveform compatible with the 6-MHz (1 dB) bandwidth of the output amplifiers, with a fidelity limited only by phase noise (less than 0.012 deg RMS) and short-term amplitude noise (0.002 dB RMS). The 40-MHz D/A rate over-samples the waveform by a factor of 3. Long-term stability is 0.1 dB over time and temperature.

The IF pass bands of the two generator channels are flat to 0.1 dB and 0.5 deg over about 5 MHz, and matched to within this tolerance. Channel-to-channel isolation is greater than 80 dB, and the on/off ratio of a channel is also greater than 80 dB. The wide-band SNR of the output pulse is 78 dB.

4. APPLICATIONS

The waveform generator can provide a number of advantages for a simple klystron system, when compared with the typical driver using a solid-state switch:

- The klystron drive waveform can have tapered rise and fall edges, to eliminate problems associated with drive signals out of the klystron bandwidth. This also minimizes the bandwidth used by the transmitter, and slightly improves the system efficiency. The tapering is programmable, whereas the band pass filter usually used in inflexible.
- The drive waveform can be pre-distorted to compensate for intra-pulse phase runout, droop, or other problems with the transmitter pulse, usually associated with the modulator, increasing the system improvement factor and further reducing the bandwidth occupied by the transmit pulse. This capability can also reduce the performance requirements placed upon the modulator. When combined with the capabilities of the digital receiver, the process of generating optimum pre-distortion waveforms can be automated and can adapt to changes in transmitter characteristics with time and temperature.
- The generator can provide pulse-to-pulse phase sequencing for simple or compressed pulses to support second-trip echo suppression or recovery.
- One channel of the generator can be used as a receiver calibration signal. Doppler waveforms can be generated at any range, as can Rayleigh distributed signals with spectral widths similar to actual precipitation echoes. It is even possible to generate combined precipitation and clutter echoes for receiver evaluation.

For dual-transmitter systems the generator can provide individual drive waveforms designed to compensate for phase, amplitude, and delay differences between the two transmitters. For example, if the transmitters feed orthogonal polarizations, the waveform generator can create pulse-to-pulse polarization sequences. Again, pre-distortion of the individual drive waveforms can be used to compensate for intra-pulse phase distortion, to keep the transmitted polarization constant during the pulse.

The waveform generator can support virtually any type of pulse compression waveform, including phase coded sequences, non-linear FM sequences, complex Doppler-tolerant waveforms, and frequency-hopping sequences (within the 6-MHz pass band of the generator). Long compression waveforms suitable for solid-state transmitters are supported by the large waveform memory, and it is possible to store many such waveforms to create phase sequences of compressed waveforms, for Doppler simulation or second-trip echo recovery.

Finally, the flexibility of the waveform generator allows realistic simulation of combined precipitation, clutter, and second-trip echoes at the IF level, for evaluation of receiver hardware and software performance.