The Millstone UHF Radar Timing System Modernization

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We are currently implementing a significant upgrade to the Millstone Hill UHF Radar's timing system with the goal of greatly improving reliability, performance, and ease of use. A modern radar timing system is responsible for precise sequencing and control of the radar transmitter, waveform generators, receivers, and secondary electronics. Such systems form the basis of modern radar control and are one key component in determining the capabilities of a radar system. When complete the upgrade will allow the use of fiber optic lines which were previously installed between major locations within the radar system. This will provide a much higher degree of protection against lightning damage. Lightning events are a common cause of failures in the existing Millstone timing system which can cause significant damage to subsystems in the radar which are expensive and time consuming to repair. The new timing system implementation will also be far more capable and it will be possible to implement redundant control if additional reliability is required. We will describe the concepts, components, and architecture of the timing system and describe the status of the overall implementation.

The design of such systems is often lost in the noise (i.e. 'just implement it with an FPGA') which overlooks the larger design issues associated with such systems. The reliability, functionality, and easy of use of such systems is governed by the interface choices made and the divisions between signaling hardware, realtime sequencing, and high level software control. The sequencing of complicated timing patterns, the generation of coded waveforms, and the alignment of outgoing signals in universal time also determine the overall flexibility possible for implementing new measurement approaches and applications in the context of multi-static systems.

The new fiber optic timing control system used by the radar in based on binary image patterns which are transmitted by the timing hardware. The binary image patterns are defined at a higher level using an XML description which is then translated to the lower level binary image. A given operational state of the radar is made up of sweeps, codes, and modes. A mode is a logical definition and exists at the experiment control, signal processing, and analysis level. A "sweep" is the low level block of binary timing information and is associated with a single radar pulse repetition period . A "code" is the unit of timing information which defines a collection of "sweeps" each of which has a unique aspect but shares a common length, baud length, and pulse length. A code provide a common definition point for sweeps that will need to be combined in a common signal processing decoding steps (e.g. for an alternating code).

We have defined an XML specification for timing related "modes" and "codes" and implemented sequencing software which translates these specifications into sweeps consisting of binary images. Different radar systems have different requirements for timing control lines and the translator implements the particular lines needed for a given radar system. This isolates the definition of the radar waveforms from the underlying radar hardware details. The primary commonality becomes a parallel binary sequence that will be sequenced at a known rate. These XML definitions are also used directly by our Software Radar system to automate the processing of common radar waveform types.

At the hardware level we are using COTS digital pattern generation cards produced by National Instruments in a PXI form factor and controlled by a computer running a hard realtime operating system. The realtime control and sequencing system is implemented using RT Labview and provides a responsive and highly reliable platform for the generation and tracking of the outgoing and feedback radar timing signals. Global coherence is maintained using a GPS time source and the PXI clock/trigger distribution capability. Realtime feedback analysis is supported in the FPGA but is currently limited to feedback timing and sweep alignment to UTC. The output of this system is interfaced through several custom hardware components that allow the distribution, fanout, signal standard conversion, and selective redundancy for critical control lines. The components are implemented in standard cPCI form factors and use off the shelf SFP fiber modules for optical signaling and HSSDC2 infiniband connectors for use over MEMS isolated differential copper lines. Radar mode changes are controlled over ethernet or via external triggers and occur with low latency at the sweep level. Such changes may also be triggered by GPS UTC time boundaries. Full interleaving of sweeps in arbitrary orders is supported. The result is a highly configurable and reliable radar control system that is easy to program for typical ionospheric radar applications.