Overview of a Software Radio Beacon Receiver Project

Frank D. Lind[1]
Damian Ancukiewicz[2], Harendra Guturu[3], William Harmon[4]
Anthea J. Coster[1], Philip J. Erickson[1], Jim Marchese[1], William J. Rideout[1]

(1) MIT Haystack Observatory, Westford MA, USA
(2) Columbia University, New York NY, USA
(3) University of California, Berkeley CA, USA
(4) Rochester Institute of Technology, Rochester NY, USA

A recent REU student project at MIT Haystack Observatory attempted to implement an end to end software radio beacon reception capability for the ISIS Array (Intercepted Signals for Ionospheric Science). The Software Radio Beacon project was a team effort involving three students for several months along with five advisors. I will discuss our substantial progress towards implementing this capability given the limited time available for this project.

The ISIS Array is a coherent software radio network capable of operating as a flexible multi-role distributed radio science instrument. The system is composed of a series of MIDAS-Mobile data systems (MIllstone Data Acquisition System) which can coherently capture wide bandwidths of RF signals from a variety of antennas. The ISIS Array is a pathfinder project to evaluate a variety of configurations and techniques for ionospheric science applications as one precursor to the much larger DASI effort (distributed arrays of small instruments).

The Software Radio Beacon Receiver project goal was to implement a flexible satellite beacon receiver using the MIDAS-M data system and software radio techniques. The intent of this effort was to measure the S4 index, Sigma Phi, and TEC using satellite beacons at 150, 244, 400, and 1067 MHz. The data will be collected, processed, and delivered to the Madrigal database for management and visualization. This end to end approach is intended to provide a robust software radio chain for delivering beacon receiver data to end users. A key aspect of the effort was the identification and tracking of all relevant meta-data to allow the context of the measurements to be understood in detail.

The project was divided into three sections with the first devoted to a wideband RF tuner design, the second to software radio signal processing of beacon signals, and the third to analysis of the beacon data combined with visualization and storage using the realtime Madrigal database.

The wideband tuner effort focused on the RF signal path for the satellite signals. A tuner was designed and simulated using appropriate RF analysis tools. A set of printed circuit board were fabricated and the firmware necessary to control the tuner has been completed. Testing of the down converter is currently underway. The tuner design has a wide range of applicability beyond beacon reception due to its design.

The software radio signal processing effort involved the development of the software necessary for acquisition and processing of beacon signals using the ISIS software radio platform. The software development involved prediction of satellite over-flights, planning of the tuning frequencies and observation intervals, operation of the ISIS software radio platform, and processing of the signals to extract and compute scintillation and the relative total electron content (TEC) measurements.

The final portion of the effort was the analysis of beacon receiver data and delivery of the resulting science data to the Madrigal database. Software to perform standard analysis of beacon data was created and tested. A data format for storing beacon receiver data in Madrigal and tools for interpretation of scintillation information in a broader scientific context were also developed.

As a student project the effort was very successful and provided a very complete team development experience for everyone involved. The limited time available for the project prevented us from achieving full end to end integration. The effort was well documented and structured and it will be possible for us to continue the work when additional resources and time become available.