IonTV: Using Timing Reference Signals to Observe Ionospheric Variation

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This work presents a statistical analysis of the variation in timing signals, broadcasted by the National Institute of Standards and Technology's (NIST), as a result of ionospheric propagation effects. In addition, the design of a software defined receiver (SDR) for processing the amplitude modulated dual sideband (AM-DSB) timing signal is outlined. Specifically, by observing the time shift between consecutive seconds of the 10MHz WWV timing signal, reflected from the ionosphere, the change in the effective height of the ionosphere can be estimated. If simultaneous measurements are taken from different observation angles a more accurate image of the ionosphere, and how it changes moment to moment, can be formed - the ideal scenario being real-time tracking of the effective height. As such, the primary goal of this project is to impart a straightforward, reliable, way for hobbyists, and citizen scientists to demodulate and process their own NIST timing data. Roughly 16 minutes of WWV data sampled at 32kHz was analyzed. To process the timing data a heterodyne SDR with a digital phase-locked-loop (PLL) was built in Python. The advantage of implementing a PLL is that the carrier offset can be used to track the doppler shift associated with wave propagation through the ionosphere, in addition to correcting for carrier offset in the local oscillator (LO). Once the LO is tuned to the carrier offset frequency, timing information is extracted from the 100Hz subcarriers by passing each through a high pass filter. The change in angle between in-phase and quadrature (I and Q) components of the sidebands reveals the doppler shift undergone by each as it propagated through the ionosphere. The signal power plus some noise is then used to set the threshold for edge detection. Finally the detected edges are passed through a matched filter to distinguish clock pulses from other information on the subcarriers. Results from processing a single sideband, in an arbitrary ten second window, suggest that the variation between consecutive second markers is a uniformly distributed Gaussian random variable.